ORIGINAL ARTICLE

Removal of Nitrogen and Phosphorous from Wastewater of Seafood Market by Intermittent Cycle Extended Aeration System (ICEAS)

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Abstract

Background: This study aimed to determine the efficiency of the intermittent cycle extended aeration system (ICEAS) and the removal conditions of treating contaminants, especially nitrogen phosphorus from sea shopping center wastewater.

Methods: Experiment was carried out on fish distribution center of Bandar Abbas and 30 samples were collected in a 6 month period from the inlet of the market septic tank. The used pilot study carried out consisted of two zones: pre-react and main react zones. They were divided using a baffle wall. Firstly, wastewater enters a pre-react zone and then through the opening at the bottom of the baffle wall it enters the main react zone. The experiment was carried out with three simultaneous cycles per day.

Results: The results showed that the mean of BOD5, COD, phosphorus, and nitrate and nitrite removal was 91.5, 86.7, 59.5, 49, and 80.8 percent, respectively.

Conclusion: It was shown that the system is able to remove nitrogen and phosphorus almost similar to other proprietary phosphorus removal processes and with lower cost; however, it is not a proprietary process.

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Introduction

Discharge of nutrients, nitrogen and phosphorous (N&P) to receiving waterways increases eutrophication rates in the lakes, ponds and rivers. Long-term accumulation of nutrients will cause eutrophication and influence the quality of water resources.[1,2] Fish processing is one of the pollutant sources that contributes significantly to the overall pollution of the marine ecological system. The wastewater contained large quantities of fish parts and blood, resulting in highly dissolved and suspended organic materials. This results in high biological oxygen demand (BOD) and chemical oxygen demand (COD). Fats, oil and grease are also present abundantly. Often suspended solids and nutrients such as nitrogen and phosphate can be high.[3,4] To avoid this impact, treatment of seafood processing wastewater before discharge has been proposed. Wastewater from fish processing can be treated in different ways: mechanically, chemically or biologically.[5] Chemical treatment is a coagulation process in which the added chemicals (coagulants) form flocks to which dispersed pollutants are easily attached.[6]

Nowadays, biological nutrients removal processes applied to remove N& P from wastewater include conventional activated sludge (CAS) process, anaerobic-anoxic-oxic (A2/O) process, anaerobic/anoxic-oxic (AO) process, oxidation ditch (OD), sequencing batch reactor (SBR), membrane bioreactor (MBR), biofilm reactor and lagoon.[7] One of the successful methods is sequencing batch reactor system. It is possible to achieve nitrification, denitrification and phosphorus removal in a single reactor when a (SBR) is used. Compared with conventional activated sludge systems, the SBR systems have many advantages, such as reduction of operational costs, improvements on nitrogen and phosphorus removal, and less bulking. In addition, its cycle format can be easily modified at any time to offset changes in the processing conditions, influent characteristics or effluent objectives.[8-11] ICEAS could be applied for nutrients removal, high biochemical oxygen demand containing industrial wastewater, wastewater containing toxic materials such as cyanide, copper, chromium, lead and nickel, food industries effluents, landfill leachates and tannery wastewater.[12] Different factors such as entered organics to the system and ration of these matters to entering Phosphorus, Solids Retention Time (SRT), nitrogen nitrate in anaerobic zone, DO concentration in aeration tank, pH, temperature, organic acid concentration and TSS impact Phosphorus removal.[13]

ICEAS reactor is divided by a baffle wall to pre-react and main-react zones. Pre-react zone acts as a biological selector that enhances the growth of desired microorganisms besides limiting filamentous bacteria, an equalization tank and a grease trap.[14]

So far, some studies have been done on the removal of nitrogen and phosphorus from wastewater in fish industry , but about the Fish sales wastewater which is an important problem in southern Iran, there we have not found any study. In a study, denitrifying the phosphorus removal became another research focus because of higher nitrogen andphosphorus removal efficiency.[15-17] Chang and Hao investigated nutrient removal in an SBR to identify process parameters for monitoring and real-time control purposes. COD, total nitrogen and phosphate removal efficiencies of 91, 98 and 98% were obtained at the solid retention time (SRT) of 10 days, with a total cycle time of 6 h.[18]

The specific objectives of this study are:

(i) to examine the ICEAS performance during operations at four flow rates (1.5, 3, 4 and 6 $l.h^{-1}$)

(ii) to investigate the performance of ICEAS in order to remove BOD wastewater combined with nitrogen and phosphorus from seafood wastewater

(iii) to apply a small ICEAS for seafood wastewater to protect the marine environment.

Material and Methods

Fish Wastewater Characteristics

The studied wastewater was characterized by an extremely high organic loading, consisting of fish parts and blood. To treat this wastewater, an intermittent cycle extended aeration system (ICEAS) was used to reduce the organic materials by biological treatment in a pilot waste treatment plant. In Table 1, a typical sewage composition during the study is presented.

Wastewater Samples

In this study, 30 samples in three runs were collected in a 6 month period, from Bandar Abbas fish and shrimp market which consists of 52 booths. Wastewater produced by cutting and washing of fish and shrimps was collected from the inlet of market septic tank.

ICEAS Reactor

The study was carried out using a pilot plant with a capacity of 80 L placed in Bandar Abbas wastewater treatment plant. A pilot tank made of Plexiglass with a thickness of 10 mm was made and installed, using a 100-liter barrel to store the wastewater. Reactor was started up using activated sludge from return line of the settling tank in municipal wastewater treatment plant of Bandar Abbas. The air pump and several diffusers provided required air and mixing in temperature domain between 20-30°C. Wastewater flowed to the pre-react zone using a dosing pump and then entered the main react zone through openings at the bottom of the baffle wall. The system was controlled by automatic five LED timers (Figure 1).

Experiment

After completing the pilot plant construction, the system was operated continuously for 5 days to achieve a steady state in BOD, COD and phosphorus removal. In the present study, the pilot test had three phases, i.e. react, settle and decant, during which influent does not disrupted. Firstly, the wastewater entered the pre-react zone which had a low MLSS concentration. This creates high F/M ratio and prevents filamentous bacteria (cause of bulking sludge) growth. After a short time (about 1.5 hour), the wastewater entered the main-react zone. In the react phase, diffusers supply air and mix MLSS in the aeration tank. In the settling phase, a thick sludge blanket was formed.

Because of this heavy blanket, the entered wastewater did not disrupt. Organics were consumed by microorganisms during passage to this layer. In

Table 1: Statistical parameters for BOD_5 in different flow rates

BOD_5	Q=1.5 ($l.h^{-1}$)		Q=3($l.h^{-1}$)		Q=4.5($l.h^{-1}$)		Q=6($l.h^{-1}$)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
Mean(ppm)	1165.4	73.3	1203.7	97.5	1069.3	96.5	1195.5	128.6
Std (ppm)	131.7	16.0	65.2	11.5	130.1	16.4	154.2	18.2
Max (ppm)	1300	104	1290.0	113.1	1230.0	132.0	1330.0	158.6
Min (ppm)	820	45.1	1090.0	70.0	826.0	70.0	837.5	100.5
Removal (%)	93.7		91.9		90.9		89.2	

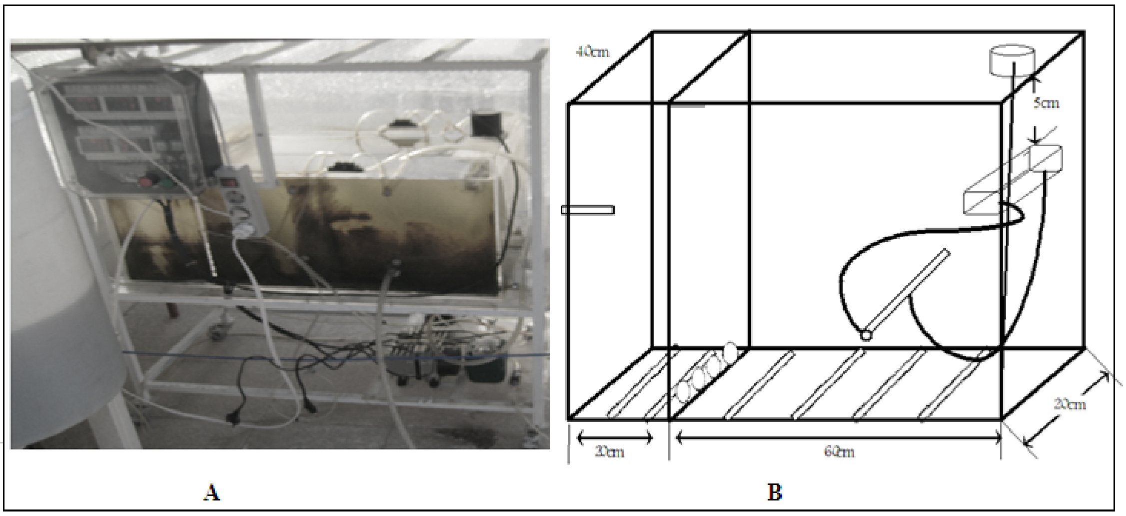

Figure 1: ICEAS pilot plant used in the study; A: real picture and B: schematic view

the decant phase, using decant mechanism a clear supernatant was discharged. Figure 2 shows the flow diagram of the system.

Our samples were from influent and outflow end of the pilot parts. They were analyzed for Dissolved Oxygen (DO), temperature which was both determined in the field. Other measurements were performed from field samples which were immediately transferred to the wastewater treatment plant laboratory. Suspended solids (SS), dissolved solids (TDS), biochemical oxygen demand (BOD_5), nitrate nitrogen (nitrate N,NO^3-N), total nitrogen (TN), total phosphate (TP) and fat- oil and grease (FOG) were analyzed based on standard methods for water and wastewater examination.[19]

The study was carried out lasting 8 hours with various flow rates. Every 8 h cycle includes 6 h aeration (1.5 pre-react and 4.5 main-react), 1 h and 20 min settling and 40 min decanting (20 min for uptake of the weir and 20 min for down), i.e. aeration phase takes 75%, settling and decanting 15 and 10%, respectively.

Firstly, in three stages, wastewater flow (design flow) increased from 1.5 to 3 and then 6($l.h^{-1}$) and lastly remained constant. It was because of HRT increasing for microorganism adapting and sludge forming. Daily sampling and analyzing on effluent was carried out after sludge adapting (system stabilization). After collection of data from experiments, the results were analyzed in SPSS using Central Statistical parameters (mean, standard deviation and t SD test).

Results

During the start-up period, the influent flow rate and subsequently the permeate flow rate were increased gradually from 1.5 $L.h^{-1}$ to 6 $L.h^{-1}$. The mean of BOD_5 in the influent and effluent, removal efficiency, and some of related statistical parameters are shown in Table 1. The means of BOD_5 in the influent and effluent were 1158.5 and 98.97 mg/l, respectively.

Table 2 summarizes the COD variations during the experimental study divided into four different flow rates. As displayed in this table, the mean removal efficiency of COD was 86.7%, regardless of operational conditions.

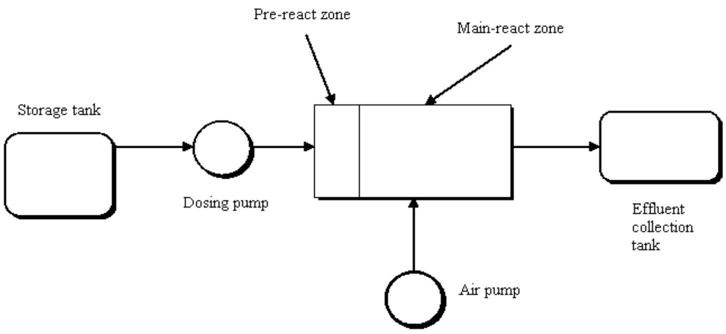

Figure 2: Flow diagram in investigated system

Table 2: Statistical parameters for COD in different flow rates

COD	Q=1.5 ($l.h^{-1}$)		Q=3($l.h^{-1}$)		Q=4.5($l.h^{-1}$)		Q=6($l.h^{-1}$)	
	Influent	effluent	Influent	effluent	Influent	effluent	Influent	effluent
Mean(ppm)	1773.5	168.4	1731.9	218.4	1783.6	264.6	1768.6	288.5
Std (ppm)	1008.9	116.4	116.0	33.8	105.5	24.0	102.9	20.4
Max (ppm)	4450.0	461.4	1895.0	264.9	1950.7	292.2	1914.0	325.4
Min (ppm)	832.0	74.5	1575.0	165.0	1648.0	211.2	1584.0	259.5
Removal (%)	90.5		87.4		85.2		83.7	

Phosphate removal rate changing with effluent NO3 is shown in Table 3. The mean TP removal efficiency was more than 59 percent, which is a good removal rate for this treatment system.

In this study, nitrate and nitrite were measured to evaluate the nitrogen content in the influent and effluent. As shown in Tables 4 and 5, the means of removal rate for nitrate and nitrite were 49.1 and 80.8 percent, respectively.

The total means of the suspended solids for influent and effluent were 235 and 44.5 mg/l, respectively. The total dissolved solids of the studied wastewater were 1276 and 964.5 mg/l, respectively for influent and effluent. Also, the means of MLSS in influent and effluent samples, were 3100 and 640 mg L-1, and the temperature range was 20-30°C.

Discussion

The experimental study indicated that organics removal in ICEAS system is in a satisfactory condition, BOD5 to COD ratio in influent and effluent were 0.66 and 0.42, respectively, which is in a reasonable range. The survey shows that the ICEAS system could be capable of achieving low levels of total nitrogen when adequate conditions for nitrification and denitrification are maintained in the system.

As shown in Table 4, efficiency of phosphorus removal in different flow rates was from51.4% to, 71%, while in the conventional activated sludge system, it is maximum 10-20%. This shows that even in the lowest performance, efficiency is about three times more than other systems.

Table 3: Statistical parameters for PO4 in different flow rates

PO4	Q=1.5 ($l.h^{-1}$)		Q=3($l.h^{-1}$)		Q=4.5($l.h^{-1}$)		Q=6($l.h^{-1}$)	
	Influent	effluent	Influent	effluent	Influent	effluent	Influent	effluent
Mean(ppm)	108.3	32.1	142.9	37.5	146.5	39.1	141.8	33.6
Std (ppm)	9.4	3.9	11.9	6.1	12.5	6.3	11.9	7.1
Max (ppm)	121.1	37.7	162.9	48.8	172.3	49.6	156.6	44.7
Min (ppm)	93.4	23.8	122.2	27.0	125.3	31.2	122.2	24.4
Removal (%)	71.0		60.8		54.5		51.4	

Table 4: Statistical parameters for NO3 in different flow rates

NO3	Q=1.5($l.h^{-1}$)		Q=3($l.h^{-1}$)		Q=4.5($l.h^{-1}$)		Q=6($l.h^{-1}$)	
	Influent	effluent	Influent	effluent	Influent	effluent	Influent	effluent
Mean(ppm)	21.86	9.47	23.04	10.69	21.17	11.78	13.96	8.14
Std (ppm)	5.34	4.50	3.39	3.06	4.52	1.87	5.40	3.11
Max (ppm)	26.34	15.45	26.63	14.51	26.22	13.44	25.09	12.29
Min (ppm)	12.04	3.51	14.38	5.25	12.88	7.23	7.36	4.05
Removal (%)	56.67		53.61		44.32		41.71	

Table 5: Statistical parameters for NO2 in different flow rates

NO2	Q=1.5($l.h^{-1}$)		Q=3($l.h^{-1}$)		Q=4.5($l.h^{-1}$)		Q=6($l.h^{-1}$)	
	Influent	effluent	Influent	effluent	Influent	effluent	Influent	effluent
Mean(ppm)	5.67	0.91	5.98	1.03	5.67	0.91	5.49	1.26
Std (ppm)	1.39	0.43	0.88	0.29	1.39	0.43	1.17	0.20
Max (ppm)	6.84	1.48	6.91	1.40	6.84	1.48	6.81	1.44
Min (ppm)	3.13	0.34	3.73	0.51	3.13	0.34	3.34	0.77
Removal (%)	84.02		82.79		79.37		77.05	

Another important point is cost. As mentioned before, wastewater is received directly from grit chamber and aeration and settling occur in the same tank. So there is no primary and secondary settling tank which is necessary in conventional processes and need high initial investment to construct settling tank, return pumps and also operation and maintenance costs. Also because of absence of primary and secondary settling tanks, the need for land is eliminated.

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Conflict of Interest: None declared

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