

Study of Excess Sludge Reduction in Conventional Activated Sludge Process by Heating Returned Sludge

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The use of conventional activated sludge as a biological wastewater treatment process has been employed to treat a wide variety of wastewater. The ultimate disposal of excess sludge generated from activated sludge processes has been one of the most challenging problems for waste water treatment utilities in order to solve the problem of excess sludge production. This paper investigated the effect of temperature on excess sludge reduction in activated sludge process, therefore, returned sludge temperature was increased from 30 to 70 °C, stepwise every 10 °C at the time concentrating on each step for 1 h. After reaching steady state in the system, we made use of sampling and testing parameters such as COD, MLSS, MLVSS, SVI, BOD₅ and yield coefficient. Results showed that increasing the temperature from 30 to 40 °C increased the yield coefficient from 0.68 to 0.73. Further increase of the temperature up to 60 °C reduced the yield coefficient to 0.33 and increased residual COD in the effluent from 89 to 195 mg/L, which is less than agricultural reuse standard. Also in this temperature, sludge reduction rate was about 46.8 % and SVI rate was about 44 mg/L. At 70 °C increase in effluent COD and turbidity was noticed. It also did not meet the wastewater disposal standard and the wastewater gave out bad odor and had bad yield coefficient.

Key Words: Activated sludge process, Sludge reduction, Temperature, Yield coefficient, Excess sludge.

INTRODUCTION

Biological wastewater treatment includes the transformation of dissolved and suspended organic contaminants to biomass and evolved gases of (CO₂, CH₄, N₂ and SO₂)¹. Excess sludge treatment and disposal represents a rising challenge for small and mid-scale municipal wastewater treatment plants (WWTPs) due to economic, environmental and regulation factors².

The use of conventional activated sludge as a biological wastewater treatment process has been employed to treat a wide variety of wastewater³. The wide application of activated sludge process in domestic and industrial treatment plants has amplified sludge management problems⁴. However, its primary by-product, excess sludge, has become a large problem; the major drawback in activated sludge processes is high excess sludge production^{3,5}. About 60 % of the total operation cost in a sewage treatment plant is accounted for sludge storage, transport, digestion and disposal³.

Therefore; it is important to develop methods for reducing excess sludge produced during wastewater treatment in a manner, which is practical and also environmentally and economically safe².

Currently, different bio-engineering technologies such as lysis-cryptic growth, uncoupling metabolism, maintenance metabolism and predation on bacteria, are being developed for sludge reduction². Prorot *et al.*⁶ resulted that, a decrease in the number of active cells, subsequent to the thermal treatment had accorded.

Heat-treatment has been used to reduce excess sludge as a simple process⁷. The reduction of excess sludge by heat-treatment is induced by sludge lysis and further cryptic growth (lysis-cryptic growth)⁸. In the lysis-cryptic growth, sludge reduction is achieved because some portions of lysates are consumed by the catabolism and finally emitted as CO₂. Consequently, the microbial community succession in the sludge should occur during heat-treatment. With the development of molecular microbiological techniques, denaturing gradient gel electrophoresis (DGGE) analysis of PCR-amplified 16S rDNA has been used as a useful tool to analyze the diversity of a microbial community⁹.

Heat-treatment is considered to be simple to operate compared to other treatments such as ozonation, chlorination, having the capability of separate or combined application with other methods, such as alkaline or acid treatment⁸.

TABLE-1
EFFECT OF TEMPERATURE ON YIELD COEFFICIENT, COD REMOVAL, SVI, BOD₅, TSS AND SLUDGE REDUCTION

Sludge temperature (°C)	Yield coefficient (mg biomass/mg COD)	COD removal	SVI (mL/g)	BOD ₅	TSS (mg/L)	Sludge reduction (%)
23 (waste water temperature)	0.62	89	92	22	46	-
30	0.68	91	115	18	40	+ 9.7
40	0.73	93	137	14	31	+ 17.7
50	0.39	81	82	81	66	- 37.1
60	0.33	61	44	109	91	- 46.8
70	-	9	-	360	235	-

Sludge reduction is achieved by cryptic growth of microorganisms, *i.e.* microbial growth on its lysates. Therefore, few cell breakage techniques have been developed, of which we could mention; sludge treatment by thermal, alkaline, acid and the combination of thermal treatment with either of above mentioned treatments^{10,11}. It was found that in thermal-chemical hydrolysis, sodium hydroxide was the most efficient for inducing cell lysis¹⁰. Further research showed that the biodegradation of the soluble fraction of the lysates by fresh sludge reached 75 % after 48 and 90 % after 350 h of incubation respectively and a reduction of 37 % of the excess sludge was obtained without altering the purification yield of the process¹¹.

Canals *et al.*,¹² reported that thermal treatment at 90 °C for 3 h led to a 2.5-fold decrease of the observed growth yield and a 3-fold increase of sludge maintenance coefficient¹².

In this work, part of sludge was heated gradually from 30 up to 70 °C for 5 h, every 10° at the time for 1 h in order to reduce biological excess sludge.

EXPERIMENTAL

In this research, one activated sludge reactor used with rectangular cubic shaped Plexiglas tank, including aeration tank with 8 L efficient volume, 30 cm length, 15 cm wide and 18 cm height and settling tank with 3 L efficient volume, 20 cm length, 15 cm wide and 17.5 cm height. Fig. 1 demonstrates schematic diagram of activated sludge reactor.

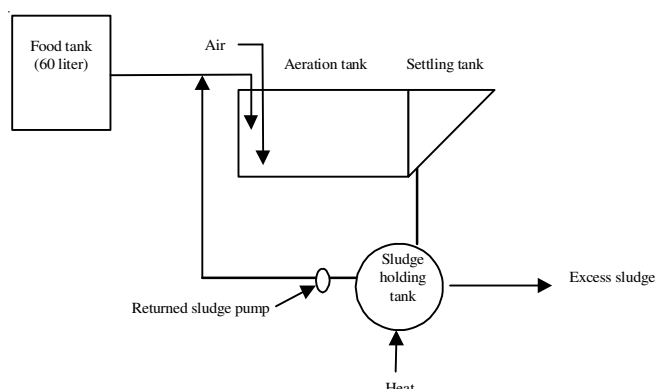


Fig. 1. Schematic diagram of activated sludge process

Synthetic wastewater characteristics: The synthetic wastewater of this pilot scale treatment plant was made by the mixture of 10 mg industrial dry milk with 60 L tap water. The characteristics of wastewater in this experiment were as follows: COD: 500 mg/L; BOD₅: 350 mg/L; Nitrogen (as nitrate): 3.3 mg/L as N; Nitrogen (as organic nitrogen): 21

mg/L as N; Nitrogen (as TKN): 21.4 mg/L as N; Phosphor: 14 mg/L as P.

Pilot start up: As the first step 2 L, from the aforementioned returned activated sludge of the domestic wastewater treatment plant of Ahvaz-Chonaibieh, was mixed with aeration tank (8 L) in order to operate the conventional activated sludge (CAS).

The system was operated for about a month at a flow rate of 30 L/d. During this stage the amount of dissolved oxygen was kept as much as 1.5 to 2 mg/L and the parameters of effluent COD and TSS were tested until the steady state was reached.

After reaching the steady state, within 6 months the parameters COD, BOD₅, MLSS, MLVSS, MLNVSS, SVI and DO were measured yielding kinetics were also calculated. The tests were performed according to standard methods for the examination of water and wastewater¹³.

To calculate the yielding kinetics the following formula was used:

$$dx/dt = Y ds/dt$$

where, dx/dt : The increase rate in biomass concentration or MLSS (mg/L); ds/dt : The removal rate of substrate or COD (mg/L).

On the other hand to calculate Y (yield coefficient) this formula can also be used:

$$Y = \frac{X_t - X_0}{S_0 - S_e}$$

where, X_0 , X_t : Primary and ultimate biomass concentration (mg/L) respectively; S_0 , S_e : Primary and ultimate substrate concentration (mg/L) respectively¹⁴.

Variable situation: After the change in temperature of returned sludge, 6 days were considered for the system to be adapted to the new situation. Within these 6 days effluent COD and TSS, were analyzed until concentration changes of COD and TSS fell below 10 %, which is statistically acceptable. In order to confirm the validity of the experiments, they were repeated 3 times.

RESULTS AND DISCUSSION

After established steady state in room temperature and reached retention time to 10 days, the amount of yield coefficient was 0.62; mg biomass/mg COD, while at temperatures 50 and 60 °C reached to 0.39 and 0.33 respectively (Table-1).

Effect of temperature on yield coefficient: Establishing steady state, room temperature, retention time reached 10 days and yield coefficient was 0.62 mg biomass/mg COD. Available results indicate that increasing the temperature of returned sludge from 30 to 40 °C, increased sludge yield coefficient

0.62 to 0.73. This could be attributed to the increase in bacterial activities which increases the rate of degradation of organic matter consequently the biomass production. Further increase of the temperature of the temperature of returned sludge to 60 °C, reduced the yield coefficient to 0.33 because sludge bacterial cell lysis and many microorganisms die in the reactor (except for limited number of slim microorganisms which can tolerate) (Table-1 and Fig. 2).

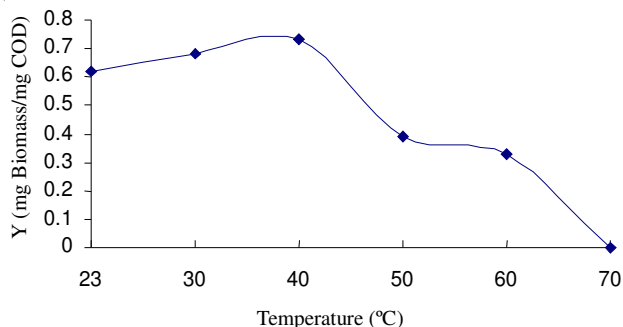


Fig. 2. Effect of temperature on Yield coefficient

Effect of temperature on removal of COD: According to Fig. 3 as the sludge temperature had increased from wastewater temperature to 40 °C, the COD removal percentage did not change, however when the temperature reached 60 °C massive cell lysis occurred, accordingly. The COD removal percentage gradually decreased and reached 60 %. But increasing the temperature over 60 °C would cause cell inactivation and kill a lot of heterotrophic microorganisms. Therefore the soluble COD rate increased appreciably in the effluent and resulted in the massive decrease of COD removal percentage, till falling below 10 %.

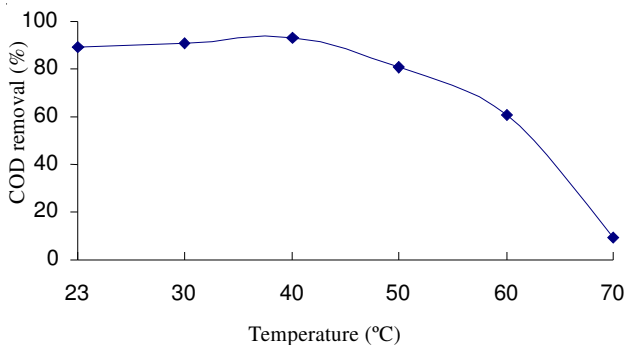


Fig. 3. Effect of temperature on COD removal percentage

Effect of temperature on SVI: Fig. 4 shows experimental results of the SVI with changes of temperature, according to results, SVI value increase from 92 to 137 mL/g with temperature rising from room temperature to 40 °C and further increased to 60 °C reduced the SVI to around 44 (mL/g). On the other hand increasing the temperature would cause MLVSS/MLSS ratio decrease and thus a slight increase in the specific weight of sludge.

Comparison of effluent COD with wastewater disposal and reuse standards: Fig. 5 shows the comparison of effluent wastewater COD with Iran wastewater disposal standards and agriculture reuse standard in different temperatures. Fig. 5

showed that at 40 °C the amount of effluent COD is below wastewater disposal standards, but at temperatures higher than 40 °C, COD values did not match those of wastewater disposal standards. However between 40 to 60 °C it meets the agriculture reuse standard. At temperatures higher than 60 °C effluent COD exceeds the standard level of agricultural reuse.

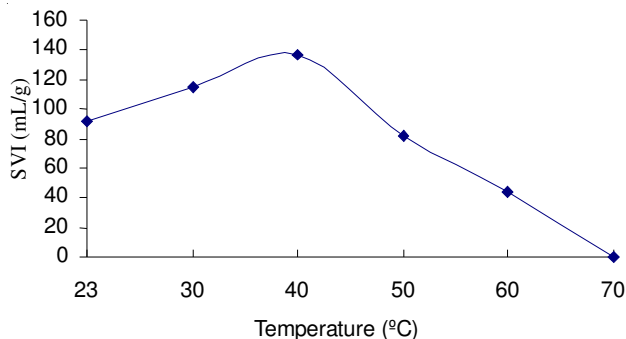


Fig. 4. Effect of temperature on SVI

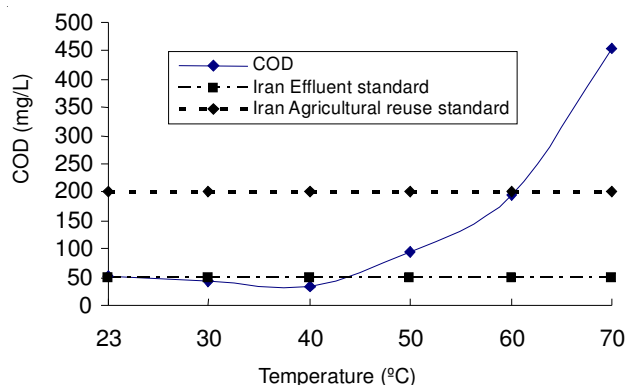


Fig. 5. Comparison of effluent wastewater COD removal with Iran effluent standard and Iran agricultural reuse standard in different temperatures

Comparison with other studies: Table-2 compares the results of this study with other thermal techniques for sludge reduction. Taking the time and amount of heating in this study into the consideration it is clear that the results of this study show a slight improvement compared to the similar studies performed previous to this one.

Operation condition	Sludge reduction (%)	Ref.
1. Urban wastewater (65 °C, 48 h)	80	15
2. Thermal treatment lab scale (90 °C, 3 h)	60	12
3. Membran bioreactor, synthetic waste water, lab scale (60 °C, 20 min, pH = 10)	37	11
4. Pilot plant scale, synthetic waste water, (50 to 70 °C, 1 h) SBR:		
a. 50 °C	39	14
b. 60 °C	47	
c. 70 °C	100	
5. Pilot plant scale, synthetic waste water, (50 to 70 °C 1 h) activated sludge reactor:		
a. 50 °C	37.1	This study
b. 60 °C	46.8	
c. 70 °C	100	

Conclusion

The performance of sludge reduction by heating returned activated sludge was investigated and conclusions were made as follows:

(a) With heating sludge from 23 to 60 °C, the COD removal percentage began to decrease and reached 61 % due to solubilization of extra-cellular polymeric substance (EPS) and microbial lysis.

(b) The amount of SVI after these changes reduced from 92 mL/g to 44 mL/g.

(c) The value of Yield coefficient was 0.62 mg biomass/mg COD at room temperature but with increase of temperature to 40 °C for an hour in returned sludge, yield coefficient increased to 0.73.

(d) Decrease of the yield coefficient occurred after increasing temperature up to 60 °C where the yield coefficient reached 0.33 due to sludge bacterial cell lysis and death of many organisms in the reactor.

(e) Also excess sludge reduced to 46.8 %.

(f) At high temperature (70 °C), biological excess sludge did not produce and the effluent COD increased and did not comply with wastewater reuse standards.

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