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The integration of combined UASB and MBR system to enhanced COD and TSS removal and excess sludge reduction for the treatment of high strength wastewater in various operational temperatures

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Abstract. Combined lab scale system consisting of an up flow anaerobic sludge blanket (UASB) and aerobic membrane bioreactor (MBR) was operated at 20 – 30 ºC and PH 7.6 – 8.4 for the treatment of high-strength enriched municipal wastewater of Ekbatan local treatment plant. The excess sludge from the MBR was recirculated into the UASB. The total volume of each reactor was 5 lit. This reactors was treated fortified municipal wastewater at volumetric COD loading rate of 600, 1200, 1800, 2400 mg/liter At temperature of 30 ºC and 20ºC. The result of present work indicated COD removal efficiency of 73% to 85% in UASB reactor and total combined system has approximately efficiency of 98 % in COD removal and 100 % in TSS removal. Furthermore, nitrate removal efficiency was about 80 %. The results of present work indicated an optimum organic loading (7.2 to 10.8 $kg.m^{-3}d^{-1}$) with COD removal efficiency of about 74% to 85% in both examined temperatures. Moreover, optimum HRT for influent COD concentration 1200 mg/l is shown to be 4 hours. Also excess sludge reduction was over 90%. Upgraded system increases treatment capacity by factor of 5.

Keywords: Enriched municipal wastewater, Temperature, MBR, UASB

1. Introduction

In some cases, domestic wastewater and industrial wastewater such dairy swage discharge into same collector system and then high value of nutrients such COD must be treated in wastewater treatment plants.

To solve these problems, it is thought to install up-flow anaerobic sludge blanket reactor (UASB) prior to ASP to reduce the BOD and COD feed and also admit excess sludge for volume reduction as well as anaerobic digestion. Moreover to eliminate sedimentation basin and have more efficiency in TSS removal and less excess sludge it is thought to install membrane Bio Reactor (MBR) after anaerobic stage.

Submerged MBR system with membrane submerged in the aeration tank treating the effluent of (UASB) was investigated. The integrated system achieves more than 98 % removal for COD_{tot} and 100 % for TSS at wide range of temperature. COD_{tot} removal rate has been left down from 85 % to 70 % by cooling down the operational temperature from 30 ºC to 20 % in UASB reactor.

The aim of the present study is to evaluate the effectiveness of a system consisting of a UASB-MBR system for treating high- strength wastewater in cold and warm weather situation and comprise them. Emphasis will be accorded to the removal efficiency of COD_{tot} , BOD_s and TSS. An important aspect in this study is to assess the ability of the combined system in low temperature comprising to hot weather.

2. Material and methods

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2.1. UASB Reactor

A Plexiglas lab-scale UASB reactor was built for this study (Fig. 1). The total volume of the reactor was 5l and had three sections: 1- feed entrance section with conical shape of 5 cm height, 2- sludge bed and blanket zone with 5 cm diameter and 160 cm effective height and 3- settling zone with 10 cm diameter and 20 cm height. A gas-liquid-solid separator (GLS) device which was inverse conical was installed at the top portion.

2.2. The MBR reactor

The membrane bioreactor was designed and built by dimensions of 65×22×5 [cm^2]. The useful volume in the reactor was 5l, and it was composed of 5 main sections:

1. Sides: The designed MBR was made of two layers: the inner part forms the main reactor basin in which the biological reactions take.

2. Membrane: The membrane used in this study was microfiltration type, with an effective area of 0.1 [m^2], pore nominal diameter of 0.4 [μm], A4 sheet size, and production of the Kuyota Company. The membrane was made of PVDF .

3. Conductor blade: The aeration process in MBR is done for two purposes: to supply the oxygen needed for biological processes, and also to clean the membrane surface and reduce the fouling rate. To achieve the second goal, a polymethylmetacrylate (PMMA) plate was used as a blade to keep the air bubbles near the membrane surface.

4. The height control sensor: The main bar length of the sensor was about 20 [cm], which was installed on the MBR, in a place which indicates the 5 liters volume of the basin.

Fig. 1: Schematic of lab-scale experimental setup

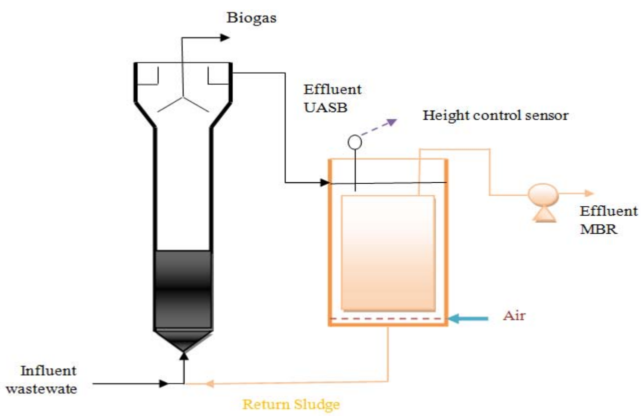

Table 1: Influence wastewater characteristics

parameter	unit	quantity
PH	mg/L	7.6-8.4
COD total	mg/L	600- 2400
BOD5	mg/L	400- 1600
SS	mg/L	190 -250
TKN	mg/L	60-80
alkalinity	mgCaCO$_3$/L	1200-3140
Temperature	º C	20,30

2.3. Operation and start up of reactors.

Influent and effluent wastewater samples analysis daily for COD_{total} and TSS over the hot and cold periods of investigation. After 210 days operating 36 influent and effluent samples were collected and analyzed during a period of 120 days for BOD, TKN, and NH4. The combined system was operated for 210 days of which the first 55 days were considered as a "start up period". The first 120 days operated at 30 ºC and latest 90 days operated at 20 ºC. The MBR sludge retention time was set to be 10 days, so 50 milliliters of aerated sludge was returned to the UASB reactor each day[25,h].

2.4. Characterization of wastewater

For this study, the main source of wastewater was from Ekbatan Wastewater Treatment Plant located in west of Tehran. The COD of this wastewater was enriched by molasses and milk powder. So the total COD could reach to 600, 1200, 1800 and 2400 mg/l. To prevent pH fluctuation of the influent, $NaHCO_3$ and K_2HPO_4 were added to wastewater. Influent wastewater characteristic is presented in Tab. 1

2.5. Anaerobic seed and Aerobic Seed

For startup UASB filled with sludge taken from the Pegah Dairy Company and fed continuously with municipal wastewater from the Ekbatan Wastewater Treatment Plant.The aerobic sludge used in the MBR basin was supplied from the returned activated sludge of the Ekbatan wastewater treatment plant.

3. Results and discussion

3.1. Results of HRT variation

The effect of various RTs of 3,4,5, and 6 hours on COD and TSS RE was investigated in 30ºc to determine the best HRT for set to resume research(results are shown in fig3). As can be seen, the COD RE is the highest in the RTs of 4 and 5 hours.

The reason for this decrease in efficiency while reducing the HRT, in spite of increasing the turbulence in the reactor, is that the contact time of wastewater with sludge granules will be decreased. Therefore, less organic matter is utilized. The efficiency also was lowered by increasing the RT, because of lower amount of mixing because of a reduction in up flow liquid velocity. Rising gas bubbles and the up flow liquid velocity causes mixing in the reactor. The TSS RE in steady state condition for different RTs is also shown in fig.2. As can be seen, the TSS RE is has been risen by increasing RT up to 4 hours, but very smooth reduction(about 1%) was observed for higher HRTs. Therefore, optimum HRT for COD removal (about 80%) can be considered 4 h at 30ºc. As shown in fig .2, increasing the retention time from 5 to 6 hours has almost no effect on COD removal efficiency reduction. This could be because of reduction in SRB bacteria activities, which is a good factor for methanogens bacteria. So the effect of a decrease in mixing is reduced.

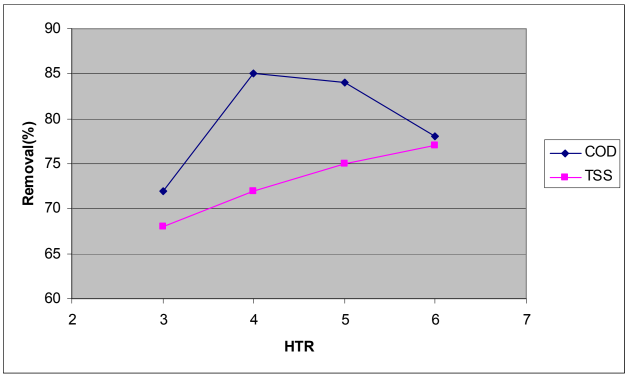

Fig2:COD and TSS removal efficiency with HRT (OLR of 1200 mg/lit, at 30ºc)

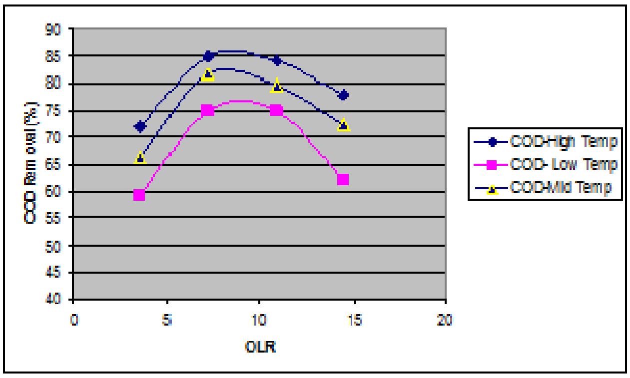

Fig3: The removal efficiency of COD in different OLR

3.2. Results of OLR variation by temperature

The RE of COD and TSS for different organic loading rate of 3.6, 7.2, 10.8 and 14.4 kg COD/m^3 .day (for COD concentration of 600, 1200, 1800 and 2400 mg/L, respectively and HRT=4 hours) in 3 various operational temperature is shown in fig.3 and fig.4.

As it can be seen, the COD RE is the maximum in the organic loading rate of 7.2 to 10.8 kg COD/m^{3}d. The COD RE in this range is about 85%, 81% and 75% in 30, 25 and 20 degree of centigrade, but it reduce to 72%, 66% and 59% while decreasing the OLR to 3.6 kg COD/m^3.d. These values reduce to 78%, 72% and 62% while increasing the organic loading rate to 14.4 kgCOD/m^3.d. These results representing an optimum OLR of 7.2 to 10.8kg COD/m^3.d in 30ºc, 25 ºc and 20 ºc for UASB reactor. By increasing the COD RE from 1800 to 2400mg/L, the COD RE was decreased. The reason for this RE reduction is because of a higher sulfate concentration (from 120 to 200 mg/L) due to the addition of molasses to increase COD from 1800 to 2400). So, SRB and methanogenous bacteria compete to use the substrate.

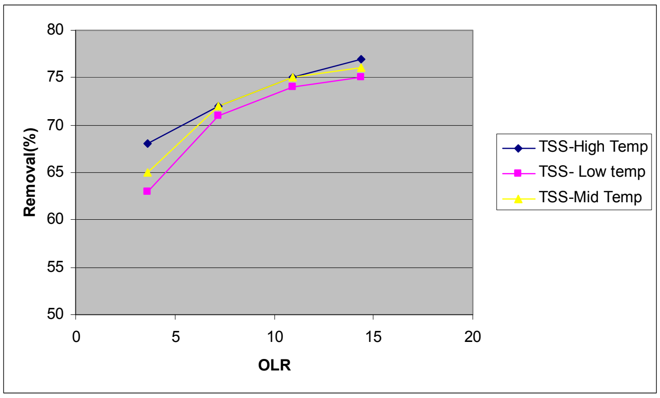

Fig4: The removal efficiency of TSS in different OLR

3.3. Efficiency of COD removal in UASB reactor

The UASB reactor operated at a constant HRT of 4 throughout the study, while OLRs are 3.6, 7.2, 10.8 and 14.4 $kg.m^{-3}.d^{-1}$. UASB reactor operated at two operational temperatures. At First stage reactors efficiency investigated at 30 ºC for various OLR mentioned above. Despite variation and 73 % COD removal for OLR of 3.6 and 14.4 Moreover UASB reactor achieved 85 % COD removal efficiency for OLR 7.2 and 10.8 respectively.

In the second stage, UASB reactor operated at 20 ºC for above OLR and COD removal efficiency decreased approximately 13 % and 16 % for OLR of 14.4 and 3.6. COD removal efficiency had higher performance for OLR rate of 7.2 to 10.8 and only reduced by 10 %.

This relatively good performance could attribute to the long SRT (80 days. results indicated that UASB performance in TSS removal is independent from temperature.

The NH4 and TKN removal in both reactors were low. The results clearly demonstrated that UASB reactors are not sufficient for removing nutrient from wastewater. In the UASB reactors only a change in the chemical forms of nitrogen and phosphorous take place as reported by Bogte et al (1993)

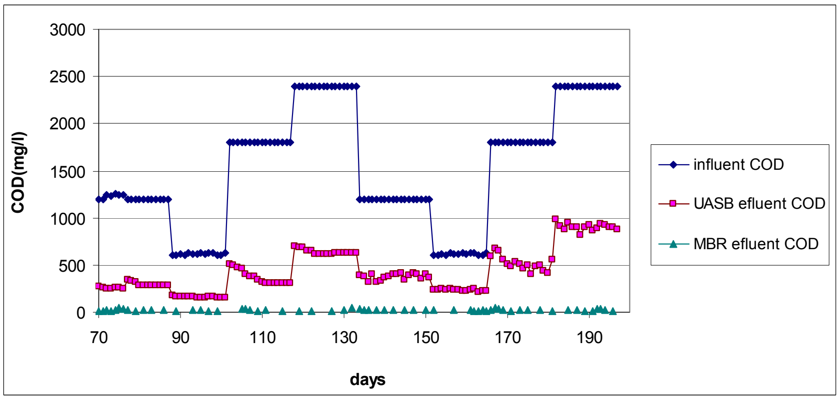

Fig5: COD Removal efficiency in both run time

3.4. Efficiency of COD removal in MBR reactor

The effluent COD in all retention times and temperature in the membrane bioreactor is almost the same. RE of MBR rises above 90% percent and the whole efficiency of the system removal goes to over 98 percent. The TSS removal efficiency in the membrane bioreactor is nearly 100 percent.

3.5. Volume Reduction of system and excess sludge

By using pre-treating UASB reactors and replacing secondary settling tanks with membranes and reducing HRT the activated sludge system's volume can be reduced by up to 5 times. It is necessary to mentioned that the retention time of MBR solids was set to 10 days, and the excess sludge was returned to the UASB reactor. This means that during 210 days of a reactor operation, 105 liters of excess sludge was returned to the UASB reactor, but only about 10 liters of sludge was brought out from the reactor, so the sludge volume reduction factor was near 10.

4. Conclusion

1. The activated sludge systems can be upgraded by UASB as pretreatment and a membrane as substitute for a secondary sedimentation time.

2. Granular sludge appeared after 40 days of startup in UASB reactor. since then, the reactor was in a steady-state condition and the sludge washout stopped. The SVI was also dropped to 12.

3. As was shown, for the UASBR, the optimum HRT is 4 hour and the optimum OLR is 7.2 to 10.8kg COD/m^3.d. In this condition, the reduction efficiency for COD were about 85% in 30ºc , 81% in 25ºc and 74% in 20ºc respectively.

4. Such a system upgrade will increase the treatment capacity by a factor of 5 and will decreased the wasted sludge by 90%.

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