APPLICATION OF THE UASB INOCULATED WITH FLOCCULENT AND GRANULAR SLUDGE IN TREATING SEWAGE AT DIFFERENT HYDRAULIC SHOCK LOADS

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ABSTRACT

In this study the sludge resistant to step and transient hydraulic shock loads have been investigated into two types of sludge, flocculent against granular, in the UASB reactors treating sewage with high solids contents.

In this experiment, decreasing in the HRT (step shock loads) was used to examine how far the HRT can be further reduced without considerable change in COD removal efficiency.

The lowest HRT tested, which is equal to 4 hrs, resulted in only 3-4 % decrease in the COD removal efficiency and the effluent COD contained low VFAs.

Also, different transient hydraulic shock loads at the peak flow hours have been conducted to investigate the impact of the wide gab between the peak and the average sewage flows, which usually happens in a small community (rural area), on both sludge types.

Both reactors were not affected significantly by these shock loads up to 6 times the average flow and the shock loads had only the impact on the reactors during and few hours after the period of the shock loads.

Key Words: Anaerobic treatment, Flocculent sludge; granular sludge; Sewage; UASB; Shock Loads

INTRODUCTION

The function of the UASB reactor depends on the physical parameters and biological processes of the sludge (8). While, Flocculent sludge is characterizes by light, small, and apparently non spherical grains, the granular sludge has grey to black round grain shape and well settling characteristics. Both types of the biomasses are considered as aggregated sludge. However, the most important difference between a granular sludge and flocculent sludge is that flocculent sludge can easily disintegrate under conditions of mild mixing, while granular sludge remains intact even under hydraulic stress (12). These characteristics make granular sludge showed better performance in treating mainly soluble wastewater than the flocculent sludge (3, 7).

Although, granular biomass development and sludge retention without packing media are the main conception in any of UASB reactors, the flotation and washout of the disintegrated granules have been reported in the literature (5) especially at high solids content wastewater.

The organic solids removal inside the reactor passes through many of complex physical-chemical mechanisms which depends on many of the operational parameters such as: reactor operational conditions (temperature, organic and hydraulic loading rates), influent characteristics (concentration, particle size distribution and charges), and sludge bed characteristics (particle size distribution, exopolymeric substances, charges, sludge hold up) (8). In general, solids removal can be attributed to one or more of the following three main mechanisms: entrapment, adsorption, and sedimentation.

The rate of solids conversion to the biogas, in most cases, is limited by the hydrolysis step (10), especially at low temperature.

Although any decreasing in HRT on one hand increases the organic loading rate, which is reported to improve the reactor performance up to a certain limit (8), it is on the another hand increasing the upflow velocity which, above a certain value, can reduce the solids removal due to its effects on the sludge retention (6). Also, HRT is a major parameter which determines the SRT (13).

In this study the sludge resistant to moderate and extreme hydraulic shock loads (low HRT) have been investigated into two types of sludge, flocculent against granular, in the UASB reactors treating sewage with high solids contents.

MATERIAL AND METHODS

Biomass

The flocculent sludge was obtained from the municipal anaerobic digester in Ames, Iowa State, USA and the granular sludge was obtained from the UASB plant treating brewery wastewater in city Brew, Lacrosse, Wisconsin, USA.

The VSS concentrations of the flocculent and granular sludge were 21.6 g/l and 60.4 g/l, respectively. VSS/TSS ratios were 0.61 and 0.82 and SVI values were 28.2 ml/g and 9.15 ml/g in the flocculent and granular sludge, respectively.

Analytical Methods

The total COD, soluble COD, TSS, VSS, VFA and the settleable solids measurements were measured according to the Standard Methods for the Examination of Water and Wastewater (APHA, 1995). The total COD is the sum of the soluble and suspended solids COD. Soluble COD was determined by filtering the samples through 2.5 micron glass micro fiber filter.

Gas composition was analyzed using a Gow-Mac series 350 gas chromatograph with a thermal conductivity detector.

Temperature

The experiment was carried out in an average ambient temperature of 25°C with tolerance of ± 1°C.

Substrate

A representative synthetic domestic wastewater that closely simulates the rural communities wastewater of Egypt was used on the entire experiment. The total COD was in the range of 700-1000 mg/L and COD of SS accounted for about 50-70% of the total COD (1),(2), (9).

This synthetic wastewater was made from a mixer of: dog food (as a source for organic solids), clay (as a source for inorganic solids), sucrose, and peptone. The composition of these materials was chosen to abide by the particles composition required and to maintain the ratio of the organic constituent in the sewage (protein 50%: carbohydrates 40%: fats 10%). The substrate was supplemented with macro and micronutrients that are not originally existed in the substrate as described by Field and Sierra (1990) (4). Alkalinity was provided as sodium bicarbonate to increase the buffering of the sludge.

Experimental Set-Up

The experiment was conducted in two-3.75 l glass UASB reactors, of 0.97 m effective height and an internal diameter of 0.07 m. A schematic diagram of the UASB reactor used in the study is shown in Figure 1. Each reactor was inoculated with 13.5 g VSS/l of different types of the sludge, flocculent versus granular. Both reactors were operated into the same conditions of influent composition and temperature.

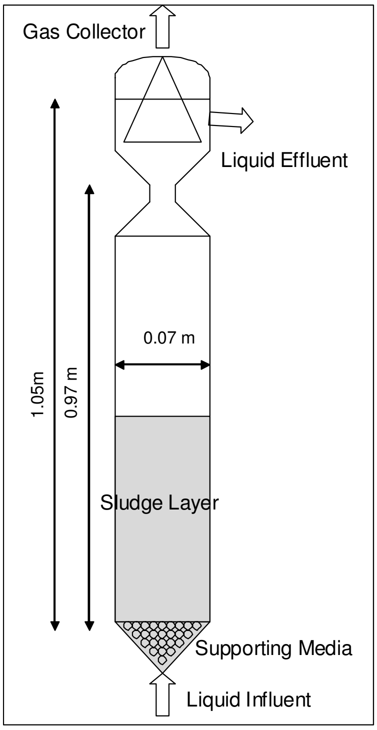

Figure 1: UASB reactor

RESULTS

Step Hydraulic Shock Loads

The average total and soluble COD removals in the steady state condition at different hydraulic retention time (HRT) are determined, figure 2 and 3. At 6 hr HRT both reactors have the optimum removal with almost the same performance result: total COD removals were 92% and 91% for the Flocculent Sludge Reactor (FSR) and Granular Sludge Reactor (GSR), respectively (11). To examine the reactors behavior at rather high hydraulic loading rate, both reactors have been examined at 4 hr HRT. At steady state period of 4 hr HRT, slightly drop in the total COD removal to 87% and 89% was observed in the GSR and FSR reactors, respectively. However, even at this HRT the solids retention time (SRT) was always higher than 30 days and VFA values in the effluent were always less than 30 mg/l and VSS contents in the effluent hardly increase 0.9 g VSS/d in the both reactors which indicates that both reactors are stable at this low HRT. This low VFA in the effluent indicates that the methanogensis was not rate limiting step.

Flocculent sludge had better result at 4 hr HRT than granular sludge. This can be ascribed to that after 7 months of system operation; flocculent sludge had built small granules from the flocculent particles that have better performance than the big granules from the granular sludge. Kripa Shankar et al. (12) in a previous study attributed this improvement to the aggregation of smaller sludge particles into bigger sludge granules. This was observed by the significant decreasing in the sludge volume index (SVI) of the flocculent sludge from 28.2 ml/g at the beginning of the experiment to 15.6 ml/g at the end of 4hr HRT run which indicated improving in the sludge settleability which is considered the main feature at any stable anaerobic sludge. This formation was also confirmed by the digital image analysis of the morphology of the flocculent sludge. Since, the seed sludge particles increased from the initial particles size of 0.15 mm to about 0.26 mm at 4 hr HRT.

Significant increase in the VSS of the sludge in both reactors to 23.6 and 25.9 g/l at the end of the experiment for the flocculent sludge reactor and granular sludge reactor respectively indicates that a major amount of removed COD was due to entrapment of suspended organic solids in the sludge bed rather than COD conversion into methane.

Batch Bioassay Test

To determine the amount of the biological solids (biomass) in the total VSS remain in the sludge at the end of the 4 hr HRT run, a batch bioassay test has been developed. An amount of 150 ml from the both types of sludge was fed to 300 ml-bottles in order to monitor the hydrolsation rate of the organic solids capture in the sludge. Reference bottles were filled with the liquid part of both types of sludge after settling to subtract their biogas yield, which comes from the biodegradation of the soluble organic, from that of the other bottles in order to determine only the biogas yield from the organic solid in the sludge. After the biogas yield ceased, the VSS contents remaining in the bottles were considered the biological solids in addition to part from the very slowly biodegradable organic solids. The difference between the VSS contents before and after the test was estimated to be the concentration of easy and rather slowly organic solids entrapped in the sludge. After more than 4 weeks of the continuous gas monitoring, only 30% and 10% of the total VSS contents of the flocculent sludge and granular sludge respectively, converted to the biogas. 50% of the converted VSS has been found to be easily biodegradable solids, since this portion was converted to methane into the first 4 days in the batch test. Whereas the other 50% of the VSS, which is considered rather slowly biodegradable solids, was converted to methane into the following 4 weeks.

Also it was found that the solid hydrolisation rate is equivalent to the gas yield rate, since no VFA contents have been detected inside the bottles. This indicated that hydrolisation process is the rate limiting step rather than methanogensis process in the anaerobic treatment of such type of wastewater.

Transient Hydraulic Shock Loads

To investigate the impact of the wide gab between the peak and the average sewage flows which usually happens in a small community (rural area) on the both sludge types, hydraulic shock loads at the peak flow hours have been conducted. Diurnal hydraulic shock load from 8 to10 am and from 4 to 6 pm has been used to represent actual sewage generation pattern. Two shock loads runs were used. Each run has a period of 4 days. First one was at 2 hr HRT and the second was at 1 hr HRT and the normal flow was at 6 hr HRT. At the first shock load hit the reactor in the both runs, Samples for total COD, soluble COD, VSS, TSS and VFA determinations were collected every half an hour during the shock load period of the 2 hours and at the first hour, the second hour, and the fourth hour after the shock load period ended. Besides, one sample has been taken every day during the shock load run at 8 am just before the shock load started to see the impact of the shock load on the daily bases.

Enough time between the two shock load runs (11 days) has been left (both reactors have been operated at 6 hr HRT during this time) to return the reactors back to their steady state condition. Samples have been taken during this time to confirm that.

During the shock load run of 2 hr HRT period, the unfavorable performance of both reactors is detected as a result that this low HRT is accompanied with high upflow velocity, which led in washing out of influent solids and viable biomass. However, the flocculent sludge reactor had better result during and after the shock load, Figure 4 and 5. The normal steady state performance has reached again after the HRT was returned back to 6 hr in the two reactors Figure 6. No increasing in the effluent VFA during and after the shock load has been observed in the two reactors and its value hardly increased 30 mg/l. Contradictory, an improving in the performance of the flocculent sludge reactor after the shock load end was observed, Figure 4 and 5. This could be attributed to that during the shock load as a result of granules abrasion most of the dispersed sludge was washout from the reactor and only the good settling characteristics biomass stayed in the reactor. Since in a normal steady state this dispersed solids have a slowly washout and therefore may have a contribution to the amount of effluent COD. This improvement was not observed in the granular sludge reactor due to its low light and dispersed particles contents.

Although at the second run of 1 hr HRT shock loads period (volumetric loading rate equal to 30 kg COD/m^3.d) both reactors had worse performance than that of the first run, both reactors were not affected significantly by these shock loads, Figure 4 and 5. The shock loads had only the impact on the reactors during and few hours after the period of the shock loads. The recovery of the reactors has been accomplished before the following shock load stroke the reactors. FSR was more affected than GSR when the shock load run has changed from 2 hr HRT to 1 hr HRT.

There is no clear difference between both reactors in the amount of effluent total COD in the both reactors at the 1 hr HRT shock loads. However, higher soluble COD friction in the effluent of the flocculent sludge reactor than that of the granular was observed at this period, Figure 5.

This can be interpreted to that the uptake capacity of the flocculent methanogenic bacteria was not enough to convert the soluble substrate as the granular sludge can do at such high loading rate. This can be confirmed too in the dramatically increasing in the effluent VFA of the flocculent sludge reactor compared to that of the granular one during the shock load, Figure 7.

CONCLUSIONS

Both flocculent and granular sludge reactors have good results in treating wastewater with high solids contents in terms of COD and SS removal.

From the batch bioassay test it can be concluded that the hydrolysis of the retained suspended solids in the sludge layer is considered the rate-limiting step in the overall digestion process in both reactors and requires relatively longer retention times.

Both reactors show tolerance to the rather low HRT without causing substantial washout of the biomass. At the lowest HRT (4 hr) tested resulted in only 3-4 % decrease in the total COD removal efficiency and the remaining total COD in the effluent contained low VFAs. This low VFA (less than 30 mg/l) in the effluent indicates that the methanogensis was not rate limiting step.

From the experiment, it can be concluded that the upflow velocity has to be as high as 0.16 m/hr (6 hr HRT) to provide good contact between substrate and biomass and to disturb the gas pockets gathered in the sludge bed, but less than 0.24 m/hr (4 hr HRT) to prevent sludge washout and detachment of the captured solids.

Both reactors were not affected significantly by the shock loads up to flow rate of 1 hr HRT. According to this study, it can be concluded that UASB reactor, inoculated by any types of sludge, is a robust design for communities are expected to grow fast or in small communities where peaks flow are sometimes 5 or 6 times higher than the average.

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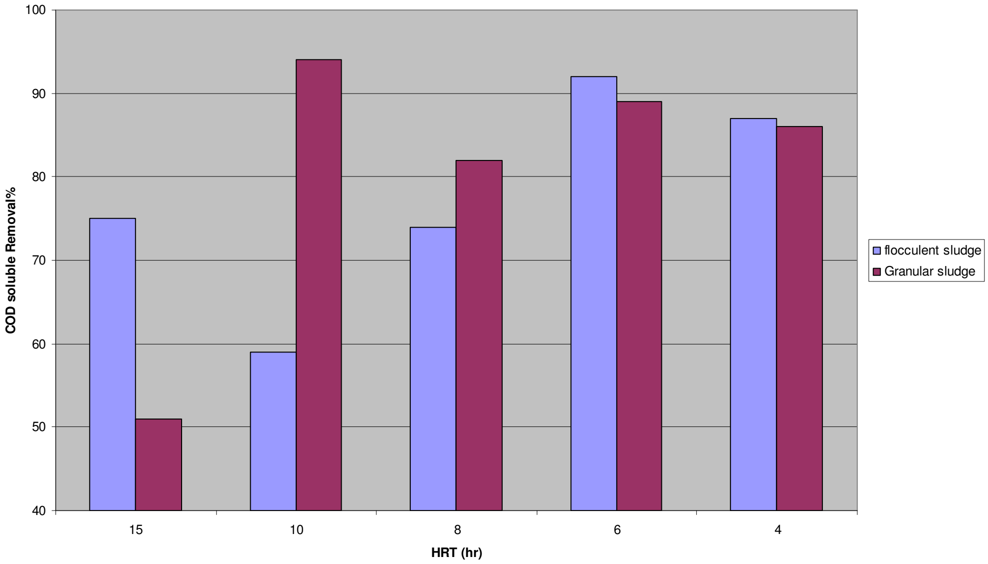

Figure 2: Soluble COD removal efficiencies at different HRT

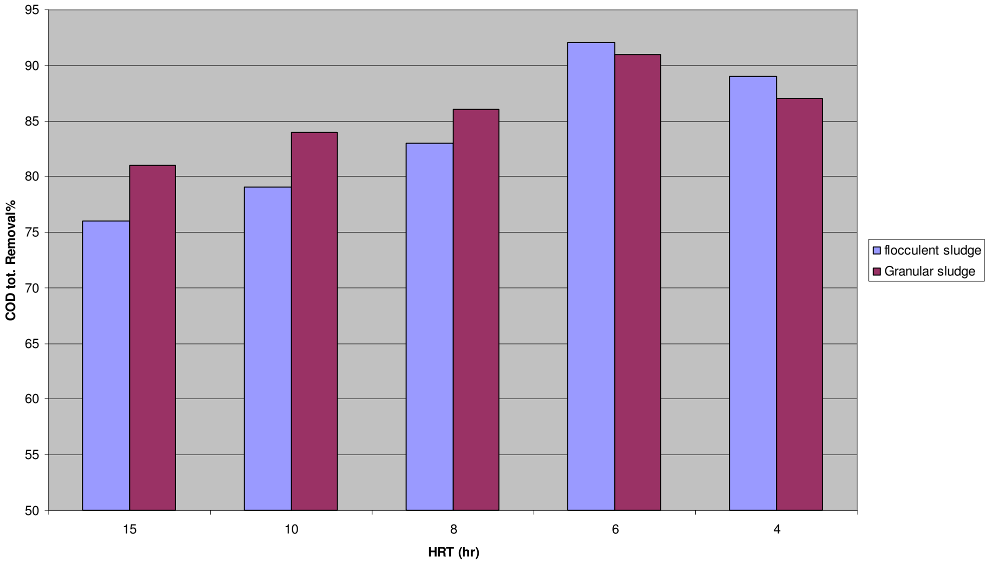

Figure 3: Total COD removal efficiencies at different HRT

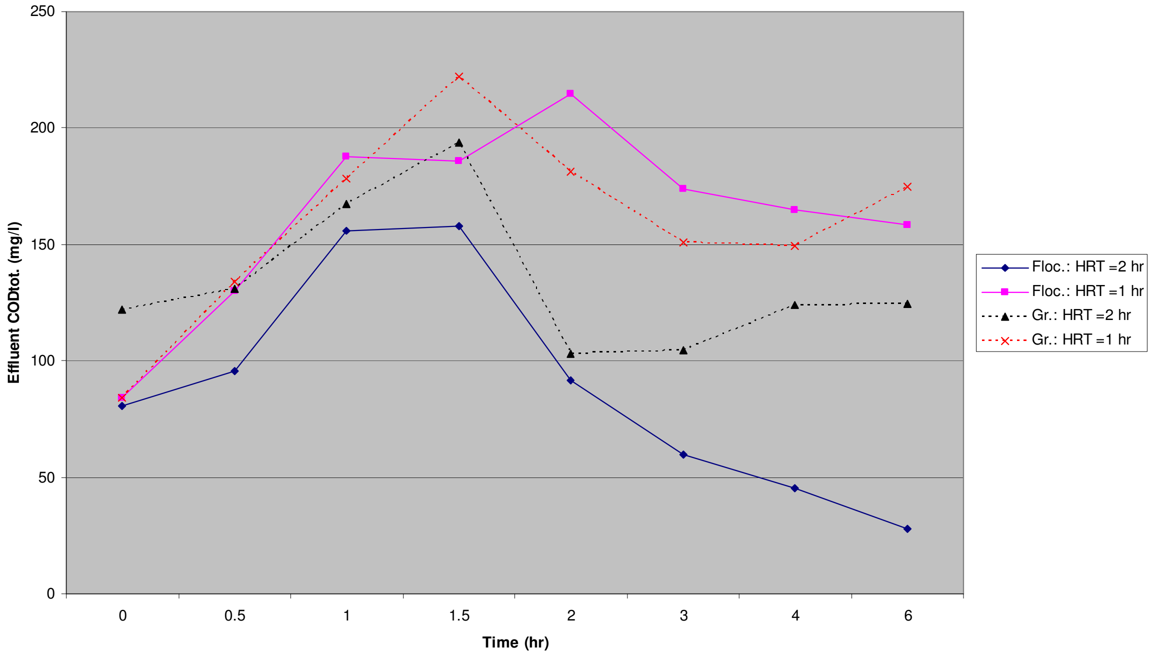

Figure 4: Effluent total COD at 2 hr and 1 hr HRTs

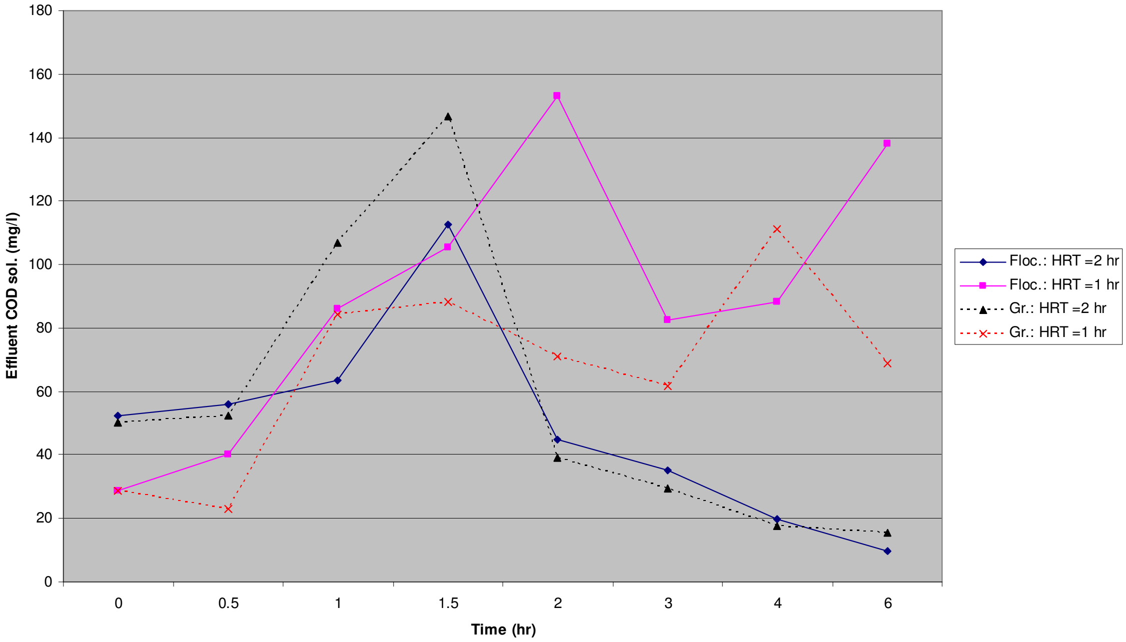

Figure 5: Effluent soluble COD at 2 hr and 1 hr HRTs

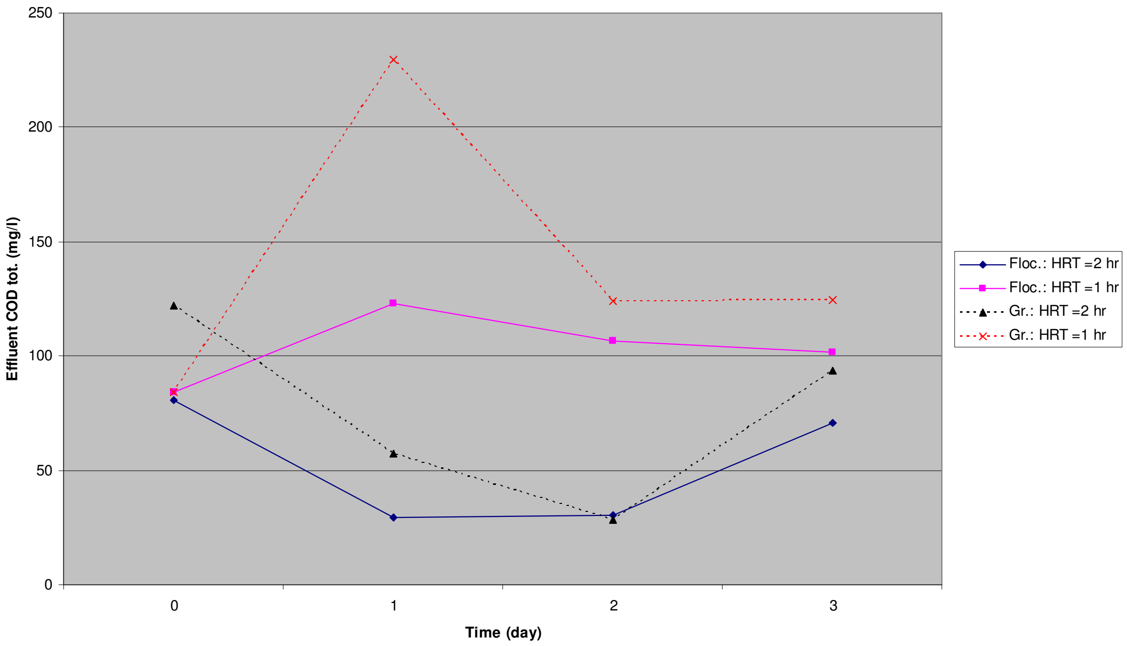

Figure 6: Effluent total COD for a period of 3 days during the shock loads runs

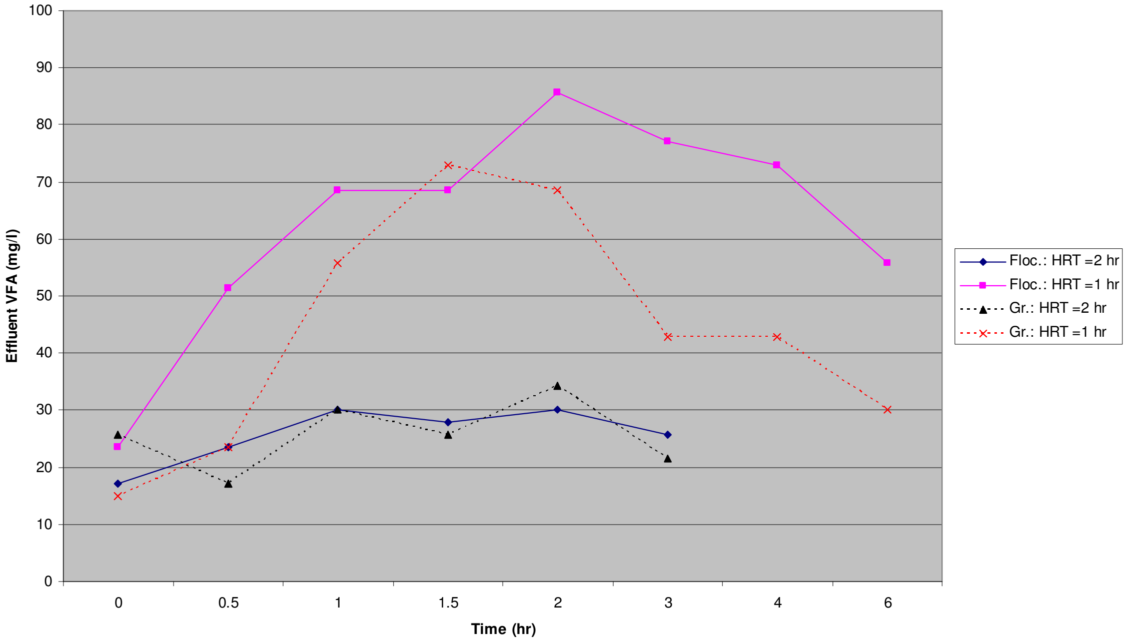

Figure 7: Effluent VFA at 2 hr and 1 hr HRTs