

The Study of Reclaiming Biomass Energy in Cornstarch Wastewater by Using UASB Reactors

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Abstract: A lot of wastewater contains high concentration organic matter was discharged from cornstarch production industry. It contains plentiful bioenergy. Upflow anaerobic sludge blanket (UASB) reactor for cornstarch industry wastewater treatment was constructed in a manufactory, and the biogas had been produced. The wastewater flux, influent COD_{Cr}, volume of UASB were 3900m³/d, 6200mg/L, 1700m³ respectively. The operation results showed that, at the COD_{Cr} loading rate of 7kg/(m³.d), temperatures in reactor was 30°C. COD_{Cr} conversion efficiency ≥ 90% and biogas productivity of 3.3m³/(m³.d) were obtained. 21810kg COD_{Cr} were reduced and 10740m³ gas was produced per day. The energy was transformed from biogas to electricity with generator, and 16110kW.h of power energy were obtained per day.

Keywords: cornstarch industry wastewater, UASB, biogas, bioenergy

1. INTRODUCTION

Corn is the one of the main raw material to produce starch in our country. The demands on starch grow day by day, and more and more manufacturers start to produce starch. Large amounts organic wastewater of high concentration. Wastewaters will cause serious aquatic environment pollution if they are drained off directly without treatment. Though the high COD concentration of wastewater, the biodegradability is higher. Changing wastewater into resources and reclaiming biomass energy from wastewater is a continuable treatment method for wastewater. UASB is an anaerobic technique of high efficiency [1]. Because of its high load and strong resistance to impact, UASB is fit to treat wastewater such as industry wastewater of high concentration, wastewater that contains sulphate; toxic wastewater and difficult-to-degrade wastewater [2,3].

In the process of wastewater treatment of a cornstarch factory in Shandong, UASB technique was used. The COD of wastewater decreased by anaerobic treatment, at the same time, large amounts of bio-gas was produced during the innocence treatment of wastewater, and bio-gas could be used to generate electricity. This project not only can ensure reclaiming and reusing energy, but also can protect environment and save resources.

2. WATER QUALITY, WATER QUANTITY OF WASTEWATER AND OPERATING CONDITIONS

At first, Wastewater drained by workshop enters into preliminary setting tank to reclaim protein, starch etc, and then enters into balance tank to balance

water quantity. The wastewater enters into UASB to carry on mesophilic treatment. Bio-gas produced by reactors is desulphate first, and enters into two stage water seal, passes flame arrester, and finally is load into bio-gas generator to generate electricity.

The number of treated wastewater is 3900m³/d, water quality of UASB influent that had been balanced is showed in table1.

Table 1: Water quality of UASB influent

COD _{Cr} (mg/L)	BOD ₅ (mg/L)	SS(mg/L)	pH
5400~7600	2850~3400	350~500	5~6

This project used two UASB reactors that were 18.2m in diameter, 7m in height, and the effective volume of single tank was 1700 m³.

There were advanced water distribution system and three phase separator in UASB reactors. Up-giving influent distribution system was used: Open channel was set in the peak of UASB. A triangular weir was set in every water distribution point, a distribution pipe was needed. The distribution pipe accesses to distribution point in the bottom of tank along the backflow gap between gather-gas shields of three phase separator, and the service area of each distribution point is 1.44m². This kind of distribution system is easy to find blockage in the distribution pipe, easy to clear, and ensure averaging water distribution. Each UASB reactor was equipped with two backflow pump, reflux ratio was 100%. The main design parameters of anaerobic reactor are: designed volume load is 7.5kgCOD/(m³ d), COD removal rate is above 85%, mesophilic anaerobic digestion is used, and the temperature is controlled between 32 and 33°C.

3. RESULTS AND DISCUSSION

3.1 Start-up stage

The inoculation sludge of USAB was from the sludge which had been digested in a wastewater treatment plant in Shandong province. The VSS/TSS of inoculation sludge was 0.54. The amounts of inoculation sludge were controlled to make the sludge concentration reach 20g TSS/L.

Inoculation sludge was added into UASB reactor, and then temperature rising was started. The range of temperature was not allowed exceed 3℃/d. Finally the temperature of anaerobic tank was controlled between 32 and 33 ℃. From the third day on, wastewater was pump into reactors. The start-up volume load was about 0.5 kg COD_C/(m³ d), upflow rate V_{up} was 0.1m/h, pH6.8~7.8, intermit inflow mode was used 3h once. At the same time, backflow pumps were turned on. After a week's running, the load was raised 0.5 kg COD_C / (m³ d)per week. After two weeks' running, the load was raised 1.0kgCOD_C/(m³ d) per week(or wait for the COD removal rate to reach 80%, and then raise the load), until full load.

In order to increase pH and alkalinity of influent in the early running stage, lime was added into influent to make sure the pH of UASB effluent was about 7.8. During the period, the COD removal rate kept about 85%, VFA was less than 400 mg/L. The running effect of reactors was fine.

Because of the accumulation of VFA, which will cause acidification of entire system and badly depress methanogen in reactors, VFA and pH were mainly measured to appraise whether the running of reactors is normal or not, when load is increasing. When VFA was less than 400 mg/L, reactors ran well. When VFA was 600 mg/L, it is noticed that the extent of load increasing shouldn't be too big. When VFA was more than 600mg/L and the pH was about 6.7, the load increasing should be stopped until VFA decreased to less than 600 mg/L. When VFA was more than 600mg/L and the pH of effluent was less than 6.5, the influent should be stopped, and only backflow pumps were turn on to recycle until the VFA and pH was normal, and the load of influent was 75% of that at last time.

3.2 Running effects of UASB

After the running was steady under full load, the COD removal rate of UASB kept steady. The running effects are showed in table 2. The content of methane was about 66% of bio-gas by measurement.

Table 2: Monitoring results of steadily running UASB

Date	COD of Influent (mg/L)	COD of Effluent (mg/L)	COD removal rate (%)	Bio-gas production (m ³ /d)
20031021	5480	610	88.9	9000
20031208	6200	600	90.3	10740
20040306	7168	790	89	12100
20040328	5770	690	88	9700

The garrulous sludge in the reactor could form granular sludge which was 0.5~3 mm in diameter in the effect of up-going gas and water. 3 months after the reactor's normal running, granular sludge appeared. As time passed, granular sludge became more and more, and most of them were 0.5~3 mm in diameter. By measurement, The VSS/SS of granular sludge was 0.71, which mean that biological activity was high.

3.3 Effect of volume load on COD removal rate

When sludge acclimation was accomplished, the COD removal rate was above 85%. As the volume load increased, the COD removal rate dropped a little. In order to study the effect of higher load on COD removal rate, one of the UASB reactors was selected to do an experiment to change load. When volume load was raised from 7 kg COD/ (m³ d) to 10 kg COD/ (m³ d), COD removal rate fluctuated, and finally declined to 75%. When volume load was 3kgCOD/(m³ d), COD removal rate was above 90%, after a week's running, the load was raised to about 10 kg COD/(m³ d) suddenly, COD removal rate declined sharply to 50%, and the treating effect of the reactor deteriorated. At that time, the load was reduced to make treating effect recover, and then was raised in less extent, when the load was raised from 3 kg COD/ (m³ d) to 5 kg COD/(m³ d) and further to 7.5 kg COD/(m³ d), COD removal rate was above 85%. It follows that the raising extent of volume affects the treating effect of reactors greatly.

3.4 Effect of pH on COD removal rate

Whether reactor has been acidified can be judged rapidly according to pH of UASB effluent. In the experiment, when pH of effluent was above 7.8, the treating effect was fine. Because of some protein in influent, higher concentration of ammonia nitrogen was released after anaerobic reaction. Ammonia nitrogen of UASB effluent could be up to 440 mg/L. This would increase the alkalinity greatly; enhance mixture's neutralization ability on VFA and buffer ability on pH. Therefore, when running was steady, the UASB influent didn't need to add alkali under the condition of backflow.

3.5 Effect of alkalinity on COD removal rate

The running effect of reactors can be reflected by alkalinity of UASB effluent. When alkalinity keeps higher, it means that the start-up running has been accomplished. During the whole running period, alkalinity of effluent ranged in the extent of 1800~2500 mg/L. At the beginning of start-up, because of low pH of influent, some lime was added to the influent. Later, as the enhancement of activity of bacteria in the reactor, the alkalinity ascended to above 2000 mg/L. When the load reached anticipation and the treating effect was steady, reduced the amounts of lime adding to influent until zero.

3.6 Effect of VFA on COD removal rate

Whether the activity of methane is good and the state that load of reactors reach can be judged from the variation of VFA in UASB effluent. When volume

load was less than 7 kg COD/ (m³ d), it was found that COD removal rate was higher, and the concentration of VFA kept lower. As load increased, COD removal rate decreased, and the concentration of VFA increased.

3.7 Effect of backflow on running

The backflow of UASB has the function as follows:

(1) Increase upflow rate in reactors, decrease the inhomogeneity of water distribution and dead area. (2) Enhance mixture's buffer ability on pH, and make the system steady without adding alkalinity. As reflux ratio increased, the system became steadier, and granular sludge formed more quickly. The inner structure of granular sludge of UASB was mainly made of coccus, bacillus, filamentous bacterium, and litter inorganic matter. Particle diameters were between 1 and 3 mm.

3.8 The main control condition of productive UASB running

The main control conditions of UASB running were obtained by debugging and productive experiment: ① Control of organic load: organic load can be raised by increasing the amounts of influent. ② Control of pH and VFA of effluent: pH is found not a necessary control condition during debugging. Because of higher concentration of ammonia nitrogen and introduction of backflow, as long as the amount of influent and backflow is controlled fine, the mixed water entering into UASB reactors could satisfied grow condition of methane commonly. pH and VFA of effluent is the key indicators for monitoring the whole anaerobic digestion. It is normal if VFA of effluent is less than 400 mg/L. ③ Control of temperature: the temperature of UASB reactors should keeps steady. Variation of temperature should keep less than 3°C/d. Because of lower temperature in winter in Shandong, it is necessary to warm influent.

4. ANALYSIS OF RECLAIMING BENEFIT OF BIOLOGICAL ENERGY

The factory's discharge of wastewater is 3900 m³/d, averaging COD is 6200 mg/L. COD discharge amounts can be reduced over 21810 kg/d by UASB treatment, and 10740 m³/d biog-gas can be produced in normal situation. The UASB system produced biog-gas was 320×10⁴ m³/a. The bio-gas had been used to generate electricity. Home-made generators were used. 1 m³ bio-gas can generates electricity 1.3 kwh. At present, nearly 410×10⁴ kwh can produced, and 2,050,000 ¥ can be obtained if electric expense is 0.5 ¥/kwh.

5. CONCLUSIONS

(1) It is feasible to use UASB reactors to treat cornstarch wastewater and reclaim biological energy. It is completely steady running can be realized and better granular sludge can be formed when hydraulic load is 0.3–0.6, and concentration COD is in the range of 5400–7600 mg/L.

(2) Stability can be enhanced, and formation of granular sludge can be speed up by backflow of UASB effluent.

(3) If alkalinity of UASB effluent is controlled less than 2000 mg/L, VFA less than 400 mg/L, and pH more than 7.5, higher COD removal rate and methane productivity can be obtained.

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