UASB TREATMENT OF MONOSODIUM GLUTAMATE WASTEWATER; DYNAMIC AND KINETIC BEHAVIOUR OF THE START-UP OF THE REACTOR

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ABSTRACT

Simple reactors were used to carry out the feasibility study of the anaerobic treatment of monosodium glutamate (MSG) wastewater by granular sludge and the determination of Monod kinetic constants. Aerobic flocculent sludge was compared with the granular sludge. It took one month for a UASB reactor seeded with granular sludge to increase the space loading rate of MSG wastewater from 1.87 kgCOD/m³·day to 18.9 kgCOD/m³·day. The maximum influent concentration of COD ranged between 4500 to 5000 mg/L, and the removal efficiency was around 80%. Gas production and process stability was satisfied. Preliminary design parameters and some recommendations were given. Sludge bed expanding and wash-out during start—up process were observed and discussed. The application of the kinetic constants obtained from the feasibility study to the UASB start—up process indicated that the activity of the granular sludge increased substantially; they could not be used to describe the UASB process.

KEYWORDS

Industrial wastewater treatment, anaerobic process; granular sludge, reactor, kinetics.

As a widely used food adding reagent, monosodium glutamate (MSG) has been produced in China on a large scale, but no simple and economical process for the treatment of its effluent has been developed so far (Cao, et al., 1991). This study consisted mainly of two phases. 1. The feasibility study of anaerobic treatment of MSG wastewater, including the determination of activity and kinetic parameters for granular sludge and aerobic flocculent sludge. 2. Start—up of a UASB reactor seeded with granular sludge to treat MSG wastewater, including the observation and discussion of sludge bed expanding, sludge wash—out etc., especially the application of the kinetic constants obtained in the feasibility study to the UASB start—up process. These questions are significant for the understanding and modelling of the UASB process, not only limited to MSG wastewater treatment.

MATERIALS AND METHODS

For sludge cultivation and acclimation, synthetic wastewater was treated with two kinds of sludge first before MSG wastewater was fed.
Seed sludge. The size of granular sludge taken from the nearest full-scale granular sludge UASB reactor (250 m³) (Wuxi, China) was less than 0.5 mm (picture not shown). Its parameters: TSS 16.4 g/L, VSS 9.2 g/L (ash component was high), SVI 49.1 mL/g. The aerobic sludge was from the sludge thickener of a domestic wastewater treatment plant (Suzhou, China). The relevant parameters: TSS 22.4 g/L, VSS 14.2 g/L.

Wastewater characteristics. Table 1 shows the composition of MSG wastewater from Suzhou Monosodium Glutamate Production Plant. This industrial wastewater is of high strength but is not a complex organic wastewater, and it is feasible to use a granular sludge UASB reactor to treat it (Sayed, et al., 1987). The high concentrations of NH₃-N and Cl⁻ will exhibit an inhibition effect, but the relative amount of phosphate content is small and extra adding is necessary. The composition of the synthetic wastewater: glucose 1000 – 5000 mg/L, (NH₄)₂SO₄ 100 mg/L, KH₂PO₄ 100 mg/L, NaHCO₃ 1650 mg/L, and some trace elements.

Reactor for the feasibility study. Ten simple reactors with five ratios of the feed to the effective reactor volume were used as CSTR to determine the activity and Monod kinetic constants of the two kinds of sludge. Data taken when the gas production and the compositions of the gas and wastewater were constant, were used for the determination of the kinetic constants.

**Table 1. Characteristics of MSG Wastewater**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>Turbid</td>
<td>2-4</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>4890</td>
</tr>
<tr>
<td>TSS (mg/l)</td>
<td></td>
<td>1950</td>
</tr>
<tr>
<td>VSS</td>
<td></td>
<td>29090-36900</td>
</tr>
<tr>
<td>COD total</td>
<td></td>
<td>25750-32660</td>
</tr>
<tr>
<td>COD_f</td>
<td></td>
<td>16300</td>
</tr>
<tr>
<td>Cl⁻</td>
<td></td>
<td>5000-8700</td>
</tr>
<tr>
<td>NH₃-N</td>
<td></td>
<td>5520-9600</td>
</tr>
<tr>
<td>P total</td>
<td></td>
<td>20-40</td>
</tr>
</tbody>
</table>

**Table 2. Monod Equation Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sludge</th>
<th>Granular Sludge</th>
<th>Aerobic Sludge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kₚ(day⁻¹)</td>
<td>0.97</td>
<td>0.433</td>
<td>0.288</td>
</tr>
<tr>
<td>Kₚ(mg/l)</td>
<td>2900</td>
<td>284</td>
<td>8113</td>
</tr>
</tbody>
</table>

Lab scale UASB. The granular sludge was used as seed sludge. The sizes of the reactor, internal diameter 0.13 m, height 1.18 m, effective volume 15.6 L, the total volume including a gas—liquid—solid separator 19.6 L. Operating temperature 38±1 °C. NaOH was used to regulate pH of the influent within a range 6.5—7.2. The sludge concentration in the reactor was 9.16 kg/m³ (based on the whole reactor volume).

Analytical items. The methods were according to standard methods (American Public Health Association, 1975).

**RESULTS AND DISCUSSION**

Kinetic determination. The Monod kinetic constants (Table 2) were obtained through Lineweaver–Burk regression (correlation coefficients > 0.92). These constants indicate that MSG wastewater can be treated by anaerobic process, and the granular sludge was much more active than the aerobic flocculent sludge.

Start—up process of the UASB reactor. The total time for the treatment of MSG wastewater was one month. The COD removal can refer to Fig. 1. The space loading was increased from 1.87 kgCOD/m³·day to 18.9 kgCOD/m³·day, and it is three times as large as a conventional digestor used to treat MSG wastewater (Gian, 1986). The influent COD was raised to 5000 mg/L from 1760 mg/L. The main reason for stopping the experiment was equipment problem and time limitation, otherwise further increase of loading was still possible. Process stability was investigated through feeding in day time and stopping at night. The lower values of COD removal
in Fig. 1 came from these runs. Normally after two hours of feeding the gas production started again and it returned to a normal situation after 5–6 h.

Gas production It is shown in Fig. 2. The average gas coefficient was 0.3–0.4 m³/kgCOD rem. The methane content of the gas was 60–80% (volume). The maximum specific methanogenic activity was 605 mLCH₄(STP)/gVSS·day, almost six times as large as that in the feasibility study.

![Fig 1. Influent COD and its removal of MSG wastewater during UASB start-up process](image)

Expanding of sludge bed and wash—out of the sludge Fig. 3 illustrates that when the retention time decreases from 40 h to 12 h, the expanding ratio for three different days is 200%, 175%, and only 125% respectively, although the gas production at the final stage is much more than the early stage. At the end of the experiment the sludge exhibited the characteristics of a fixed bed. Not much literature mentions this aspect, although it is important to understand the flow pattern of UASB reactor.

Fig. 4 indicates that the sludge wash—out expressed by the values of the total COD minus the filtered COD of the effluent, does not only depend on gas production as some researchers mentioned (Yian et al., 1989).

![Fig 2. Development of volumetric loading and gas production in the treatment of MSG wastewater during UASB start-up process](image)

![Fig 3. Sludge bed expanding and hydraulic loading during start-up process](image)

![Fig 4. Sludge wash-out and gas production during start-up process](image)

After two months of operation the sludge concentration on the bottom of the reactor was more than 40 kg/m³. The fine granular particles of the sludge developed into particles 0.5–2 mm in diameter (picture not shown). It was only 42 cm reactor decreasing the influent COD from 2772 mg/L to 710 mg/L, the removal efficiency was 75.4%, therefore the COD decomposition mainly took place in the sludge bed.

Preliminary design parameters for the UASB reactor Space loading 10–15 kgCOD/m³·day, influent COD
5000 mg/L, COD removal efficiency 80%, effluent COD 1000 mg/L, operating temperature 38±1 ºC. According to Chinese Environmental Protection Regulation (1989), this effluent can be discharged into the sewer systems connected with a municipal wastewater treatment plant. For regions without such a system the suggestion is to set up an aerobic biological post treatment system because the BODs/COD of the effluent of the UASB reactor was bigger than 0.30. The NH3-N in the effluent of the reactor can be removed by conventional stripping process behind the reactor. To decrease the cost of chemicals controlling pH of the influent of the UASB reactor, it is suggested to recycle the effluent.

Application of the kinetics To analyses the kinetic characteristics of the UASB reactor, the Monod kinetic constants obtained in the feasibility study was applied to compare the theoretically calculated value of COD with the measured value. Two flow patterns i.e. plug flow and continuously stirred reactor (CSTR) were assumed and the equations to calculate their retention time θ i.e. \[ \int_{S_i}^{S} \frac{ds}{r_s} \] and \[ \frac{S_e - S}{r_s} \] (kinetic equation) were used to calculate S. Data used to do calculations include the kinetic constants from the feasibility study, some operational and measured data such as: influent COD 2772 mg/L \((S_0)\), volumetric flow rate 40 L/day, the corresponding reactor volume of 42 cm height of the reactor (from the bottom) 6.15 L and the retention time \( \theta = 0.157 \) day; the corresponding sludge concentration X estimated from the measured sludge profile 28000 mg/L. The calculated COD values \((S)\) at 42 cm height of the reactor for two flow patterns are 1228 mg/L and 1386 mg/L respectively, both of them bigger than the measured value 710 mg/L. This means that the intrinsic kinetics of the granular sludge in UASB reactor was much more active than that in the feasibility study otherwise the calculated COD value for a plug flow should be smaller than the measured value (Levenspiel, 1972). In fact the difference of six times with respect to methanogenic activity between sludge in the feasibility study and in the UASB reactor indicates that the activity of the granular sludge in UASB increased a lot after two months running. The microscope test indicated that at the beginning of the experiment the dominant bacteria coccus—bacillus coexisted, but at the end of the experiment the dominant bacteria were coccus. It might be the reason for the change of kinetic characteristics. Therefore special precautions are needed for the determination and the application of biokinetics.

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REFERENCES


