CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

Wood-hydrolysate, an hemicelluloses rich effluent generated principally from the rayon pulp industry is having high organic concentration, mainly of hemicelluloses and lignin, the COD proportion of which are 51.4 and 38.6%, respectively. Biomethanation of the effluent with biphasic reactor configuration offers an opportunity to reduce the environmental problems vis-a-vis generate substantial bioenergy most efficiently. In the present study, upflow reactor and anaerobic filter reactor have been used to carry out the acidogenic and methanogenic reactions, respectively. The upflow reactor was used for the acidogenic reaction of wood-hydrolysate for its simplicity, very low cost and ease of operation. Anaerobic filter reactor was used to maintain high solids retention time and to provide large surface area for biomass growth. Two separate experimental runs (Run 1 and Run 2) were conducted in two upflow reactors to study the acidogenesis of wood-hydrolysate under varying conditions. Fifty percent acidification of wood-hydrolysate was observed in the pH range of 4.5-5.5 in the batch reactor. Acidogenesis in continuous mode is dependent upon the operating conditions. Hydraulic retention time of 0.42 d and above resulted in acidification of 46.3-48.8%. Reduction of hemicelluloses and lignin, the major constituents of wood-hydrolysate, varies with the organic loading in the reactor; 82.6-98.5% hemicelluloses and 43.8-62.5% lignin get reduced at varying organic loading rates. Repeated change in the OLR
during the acidogenic reaction had very little effect on the hemicelluloses and lignin reduction. Though wood-hydrolysate contained molecules of less than 1000 Dalton, acidogenesis reduced the high molecular sizes of hemicelluloses and lignin. Acidogenesis have also great influence in altering the molecular structure of lignin: all the aromatic C-H bond and carboxyl group attached to lignin molecule were found to disappear. 13.8-18.8 per cent COD has been reduced by acidogenesis upto an OLR of 96.7 g COD/l/d.

Proportions of acetic acid and propionic acid decrease with increase in OLR: 0.47-0.31 for acetic acid and 0.23-0.06 for propionic acid in the operation range. On the other hand, butyric and valeric acids increase with the increase of OLR: 0.31-0.53 for butyric acid and 0-0.09 for valeric acid. Neither propionic acid type nor butyric acid type fermentation explain the acidogenic fermentation of wood-hydrolysate. A complex fermentation mechanism seems to be involved.

Hydrogen and the carbon dioxide are the major gases released during the acidogenesis. Methanogenic activity of the sludge could only be reduced to a nonsignificant level (< 1% methane in biogas) at very high OLR of 73 g COD/l/d, though COD loss by the release of gaseous products, H₂ and CH₄ sharply dropped to a level of < 0.1% at an OLR of 73 g COD/l/d. 9.6-15.2% of input COD was converted to biomass.

Biomass wash-out from the reactor did not follow any definite pattern. 93% of the net biomass growth got washed-out at an OLR of 72.1 g COD/l/d.
In spite of the scattering of the individual value of the first order reaction rate constant, in the plug flow reactor, the general trend is that k falls marginally with the increase of organic loading rate, the exact reason of which is not yet known.

The acidogenesis of wood-hydrolysate differs markedly with that of simple monomeric carbohydrates like xylose and glucose. Whereas degree of acidification is higher for xylose and glucose compared to wood-hydrolysate at equivalent level of OLR: 60% for xylose and 50% for wood-hydrolysate at an OLR of 17.5 g COD/l/d, and 71% for glucose and 46% for wood-hydrolysate at an OLR of 96.7 g COD/l/d.

Methanogenic activity of the bacterial biomass was found to exist at all levels of OLR in the upflow acid reactor. Lignin molecules in wood-hydrolysate inhibit the methanogenesis at higher OLR(s). Whereas butyric acid type and propionic acid type fermentations predominate for glucose and xylose respectively, a complex fermentation mechanism seems to play a key role in acidogenic fermentation of wood-hydrolysate. The value and pattern of change of first order reaction rate constant k, for substrate removal with OLR differs significantly between wood-hydrolysate, and xylose and glucose.

The response of the anaerobic filter as methanogenic reactor has been found to be very fast with the acidogenic effluent of wood-hydrolysate. A quick method of start-up of the reactor has been developed. With synthetic acid mixture consisting of acetic, propionic and butyric acids as feed for 120 days, the reactor biomass was enriched with methanogenic bacteria. Within 210
days, the methane reactor attained an OLR of 30.1 g COD/l/d with the acidogenic effluent of wood-hydrolysate. The corresponding HRT and feed concentration were 0.82 d and 24.63 g/l. At the peak loading condition of 30.1 g COD/l/d, the reactor biomass reduced 85% COD, 65% lignin, 57.5% hemicelluloses of acidified wood-hydrolysate. It reduced almost all the volatile fatty acids in the feed solution. Once acclimatized, the methanogenic reactor takes care of residual hemicelluloses and lignin: completely removes the high molecular residuals and modifies the lignin structure. The methane content in the biogas varied from 75.7 to 89.5%. At the peak loading condition, it was 76.5% and the specific methane yield was 9.77 l/l reactor volume/d, COD equivalent of which is 77 or 93.5% based on input COD or COD removed. 10.8% of input COD or 12.7% of COD removed was responsible for biomass growth. The first order reaction rate constant k, the values of which is more than 1.45/d has a direct relationship with the OLR.

For the anaerobic biomethanation of wood-hydrolysate, biphasic reactor system has been found to be highly economical in respect of the size of the reactor as the ratio of the reactor volumes is 1:1.6:2.03 for the biphasic reactor system, AF (mono-phasic), UASB (mono-phasic) reactors, respectively. The specific methane yield is also much higher for biphasic reactor system: 6.5, 4.53 and 3.98 l methane/l reactor volume/d for biphasic reactor system, AF (mono-phasic) and UASB (mono-phasic) reactors, respectively. There will also be substantial difference
in calorific value of the biogas generated from biphasic and mono-phasic reactors because of variation in CH₄ content.

Following recommendations are put forward for the future study based on the present investigation.

1) A detailed study to reveal the fermentation mechanism of wood-hydrolysate.

2) Effect of still higher organic loading on the methanogenic reactor to reduce the effective volume of biphasic reactor system.

3) Developing an appropriate model for the anaerobiosis in upflow acid reactor-anaerobic filter methane reactor.

4) Validation of the developed technology by pilot/commercial scale study.