Fifth International Symposium on Anaerobic Digestion

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$BOD_5$ was reduced from 1479.5 mg/l to 133.0mg/l. This result showed that the disposal of sewage by the device was effective in controlling pollution. The sanitary effect had been continuously observed for more than five years in the 24 digesters. The main indices could meet the requirement of sanitary requlation.
The sanitary effect:
The fatality rate of the ascaris ova and hookworm ova was 100%.
E.coli of the average fatality rate was 98.8%.
The appearance of the treated sewage was clean in eyes, without odour.
Indices of physics and chemistry:
The COD was reduced from 3717-15283mg/l to 57.1-93.04 mg/l. The BOD was reduced from 720.7-4500mg/l to 26.1-60mg/l. The S.S. was dropped from 1305-2585mg/l to 20-43mg/l. The T.S. was decreased from 0.19-1.42 to 0.013 -0.043%.
2) The operation needs lower cost for daily management, dosen't consume any energy, covering biogas energy.
3) A living quarter needs a device for disposing sewage and excreta. The digester plays a key role in treating the waste in the towns and small cities where have no wastewater treatment plants.
4) The Round Multiplestage Anaerobic Digester adopts round slight shell construction, it saves a great amount steel for digester construction. The investment of the device was less than other devices which have been using for treating the same sewage.

At present, the Round-multiplestage Anaerobic Digester have been popularized in many cities and towns of the People's Republic of China successfully as the digester has the mentioned advantage and features.

# Anaerobic digestion and water hyacinth as a highly efficient treatment process for developing countries

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## ABSTRACT

A non-conventional sewage treatment process that combines a UASB reactor and a water hyacinth pond is presented. Results obtained from a small pilot plant confirm that it may be a good, adapted alternative to developing countries. The anaerobic reactor removes carbonaceous organic matter and the water hyacinth pond polishes the effluent, removing nutrients. The proposed treatment of the harvested biomass is a two stage anaerobic digestion. The experimental results of both phases are also presented.

## INTRODUCTION

The wastewater treatment scheme shown in Fig. 1 may give an answer to the urgent needs of water pollution control in developing countries. The main reasons are reduced costs of construction, operation and maintenance, and requirement of relatively unskilled labour, if compared with conventional aerobic processes. The system is being studied at bench scale separating their four components and altogether in a small pilot plant. It consist of a primary and secondary treatment in a UASB reactor, a tertiary treatment in a water hyacinth (WH) pond and a two stage treatment of the excess harvested WH.
The objetives of this projet are: a) study the anaerobic treatment of a municipal sewage, both at laboratory and small pilot scale, b) obtain a model for nutrient and heavy metal

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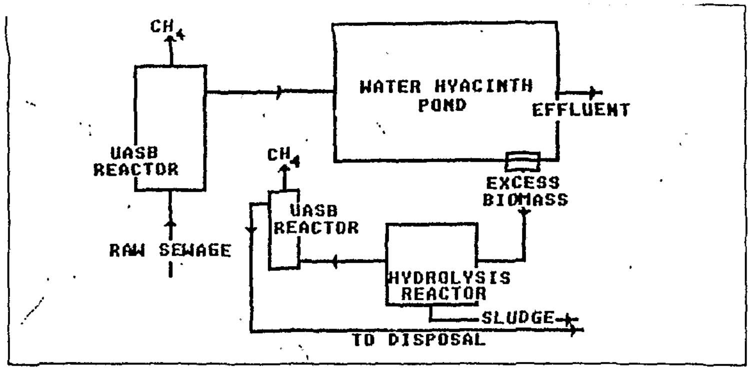


Fig 1. Block diagram of the anaerobic digestion-water hyacinth pond wastewater treatment process.

removal by WH, c) find a kinetic model on the hydrolysis of WH, and d) study the methanogenesis of the VFA obtained in c).

## ANAEROBIC TREATMENT OF SEWAGE

A small, pilot scale UASB reactor has been working for more than a year. The wastewater is pumped from the sewage of the university campus to a 110 l UASB reactor, and its effluent is then directed to a 0.64 $m^2$, 0.6 m depth tank where water hyacinth grows. The reactor was inoculated with anaerobically, batch adapted activated sludge (1.57 kg $VSS/m^3$, sludge volume index: 80 ml/g). The hydraulic retention time ($\theta$) was first fixed at 18 h and now it has been changed to 12 h. The water temperature has varied between 12 and 18°C. TABLE 1 shows results and the efficiencies achieved.

TABLE 1. Experimental results obtained with a UASB reactor coupled in series with a Water Hyacinth (WH) pond

| | pH | Alkal. * | COD | TSS mg/l | VSS | $E_{COD}$ % | $E_{TSS}$ |
|---|---|---|---|---|---|---|---|
| Influent | 8.15 | 618 | 465 | 154 | 118 | | |
| Effluent UASB | 8.05 | 635 | 162 | 41 | 25 | 65 | 73 |
| Effluent WH | 8.00 | 620 | 90 | 12 | 6 | 81 | 92 |

*mg/l as $CaCO_3$

In a parallel laboratory study with a UASB and a USFF (upflow stationary fixed film)reactors, similar results where obtained (effluent DQO: 157 mg/l for the UASB and 135 mg/l for the USFF). These results confirm the main limitation of the anaerobic treatment of sewage: The COD removal efficiency is limited between 60 to 80%, depending on sewage strength, mostly due to the $CH_4$, $HS^-$ and $S^{2-}$ dissolved in the effluent.Nevertheless, these compounds may be removed quite easily, together with nutrients (N and P) in water hyacinth ponds. The final effluent quality achieved in this study seems to prove it.



## NUTRIENT REMOVAL BY WATER HYACINTH

The main objective of water hyacinth ponds in wastewater treatment is for nutrient and toxic substances removal.
In order to use them efficiently they must be designed as maturation ponds. From literature and a series of experiments measuring the metabolic coefficient for N absorption under several N and P concentrations, a design equation, showing the inverse effect of the organic load, is obtained. An adimentional number (NRC) is introduced showing the rate of nutrient removal compared to the nutrient load input to the system (No);

$$\% \, Nr = 3.21\left(\frac{\mu}{Yn}\frac{X}{No}\right)^{0.2535}\left(\frac{2.32E06}{B_A}\right)^{.2647} \quad (1)$$

where NRC = ($\mu$X)/(YnNo). X is expressed as Ton WH per Ha and Yn as Ton WH per Kg of N.

Figure 2 shows plots of N removal efficiency as a function of the organic load at several NRC. When NRC>1, the system can receive up to 30 Kg BOD/Ha.d. For NRC<1 loads less than 10 Kg BOD/Ha.d are critical to significatively reduce 80% of nutrients at retention times less than 10 days.

## HYDROLYSIS OF WATER HYACINTH

The production of acetic acid (A) was studied and a kinetic model developed as a function of the initial concentration of water hyacinth fiber (So). Six different duplicated sets of milled (d=1.68 mm) and dried WH suspensions (10, 30, 50, 50, 75, 100 g/l) were mixed with 2.5 ml of enriched inoculum of cellulolitic bacteria (WH adapted cow manure) per g of dry WH and tap water under anaerobic conditions. The beakers were incubated at 35°C under agitation. The acetic acid production was followed and the rates (r) evaluated at 24 hrs. Their inverses were plotted against the initial WH concentrations (So) Fig. 3. At concentrations between 75 and 100 g WH/l the fastest rate was obtained producing effluents with concentrations greater than 5 g of VFA/l. The area under the curve corresponds to the space time. The corresponding equation can be

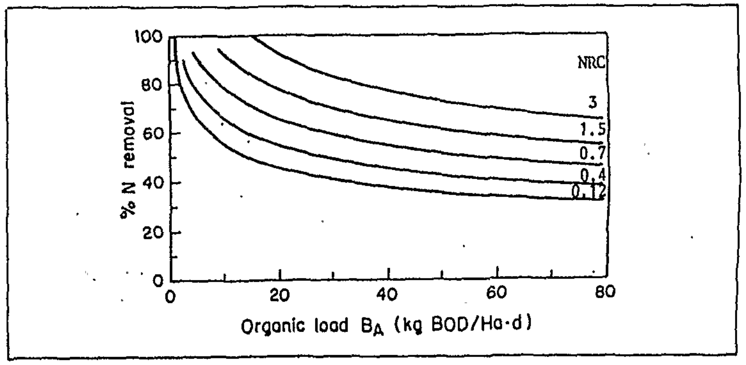


Fig 2. Performance of water hyacinth ponds at different organic and nutrient loads.

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obtained by the Simplex method of nonlinear regression:

$$\frac{1}{r} = \frac{dt}{dA} = \frac{(K + S)Y}{\mu_{max} XSY_p} = \frac{(893 + S)0.062}{1.25*S*0.3267} \qquad (2)$$

Experimental runs with a lixiviation reactor are in progress to try this model.

## METHANOGENESIS FROM VFA

The effluent of a mixed reactor for water hyacinth hydrolisis has been simulated (3.5 and 1 g/l of acetic and propionic acid, respectively) and fed to four laboratory scale anaerobic reactors: two UASB (4.5 l) and two USFF (4.75 l). Anaerobically batch adapted cow manure and activated sludge were used for seeding. The last one turn out to be a better seed material as it reached faster higher methanogenic activity and sedimentability. The research was carried at 32°C under a wide range of hydraulic retention times (74 to 2 h). The experimental results are shown in Fig. 4. Both types of reactors were successful in treating high organic loads ($B_v$:15 Kg COD/$m^3$·d with a COD removal efficiency of 92% and a θ of 12 h). At higher loads, efficiency decreased rapidly to 52% for a 60 kg COD/$m^3$·d and a θ of 2 h (for USFF 1).

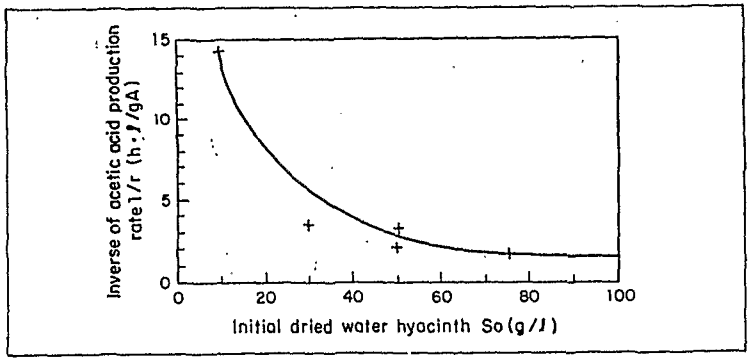


Fig 3. Water hyacinth hydrolysis kinetics.

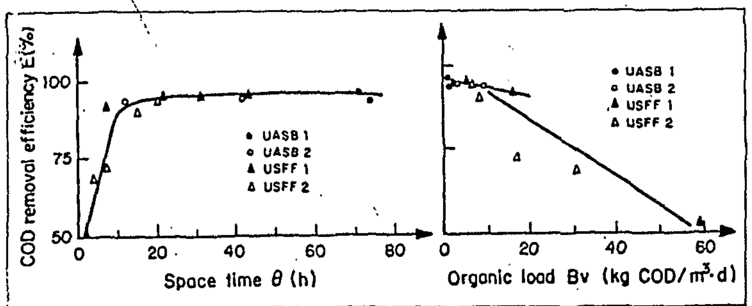


Fig 4. Organic matter removal efficiency related to space time and to organic load for UASB and USFF reactors.



A measurement of the sludge content in UASB 2 when operated at a θ of 12 h and a $B_v$ of 9.9 kg COD/$m^3$·d (E=94%) conducted to a specific substrate removal rate ($q_s$) of 9.3 kg COD/kg VSS·d, and a methanogenic activity ($q_{CH_4}$) of 3.46 l $CH_4$/kg VSS·d. These values, if compared with results of acetoclastic methanogenic activities reported in literature,show that the sludge was highly active, near to saturation, but still capable of achieving high removal efficiencies. The amount of biofilm in the USFF reactors were estimated with the void volumes at the end and at the beginning of the study. This rough approach led to a $q_s$ of 2.37 kg COD/kg VSS·d and a $q_{CH_4}$ of 0.73 l $CH_4$/kg VSS·d for USFF 1.USSF 2 had inferior (about a half) rates. The results confirm the capacity of UASB reactors to develop highly active methanogenic sludges. Finally, tracer studies on the USFF reactors showed the presence of important dead zones and short circuits.

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