ACIDOGENIC ANAEROBIC DIGESTION OF URBAN SEWAGE WATERS IN SBR AT DIFFERENT TEMPERATURES

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Abstract

An anaerobic sequential batch reactor (SBR) was used for volatile organic acids (VOA) generation as intermediate in anaerobic organic matter degradation. VOA yield, maximum VOA concentration and the time necessary to reach this maximum concentration were the most important variables to be determined. Additionally, the behaviour of an anaerobic culture was evaluated at different temperatures and a kinetic model which simplifies the process scheme was proposed. The kinetic model permitted to predict the evolution of the different carbon forms involved in the anaerobic digestion of urban sewage water, showing the occurrence of a reduction in kinetic constant values parallel to a drop of temperature. Concretely, temperature had more influence over the hydrolytic steps kinetics, corresponding with the organic matter transformation to volatile organic acids, than over the methane generation, getting slower when temperature decreased for all the anaerobic mechanism steps.

Introduction

Among the processes of biological wastewater treatment, activated sludge and anaerobic digestion are adapted for the decomposition of organic matter. The purification of urban sewage water, for spilling in sensitive areas to eutrophization, includes the joint removal of carbon, nitrogen and phosphorus compounds. When the objective is the simultaneous carbon, nitrogen and phosphorous removal, organic matter transformation into VOA is more interesting than complex disposal due to phosphorous and nitrogen bacteria need biodegradable organic matter to carry out their metabolism for removing both nutrients (Wu and Rodgers, 2010).

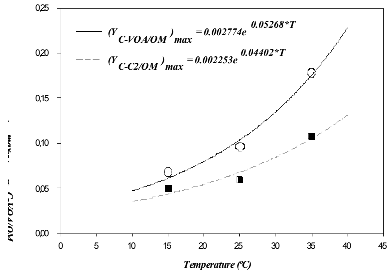
Methods

The composition of the synthetic domestic wastewater includes carbon, nitrogen and phosphorous sources (KH_2PO_4 0.066g/L; Urea 0.064 g/L; Molasse 0.600 g/L and CH_3-COOK 0.133g/L). Some macronutrients were added by a commercial vitamin complex (Supradin, Roche), being in the range of the typical values for real domestic wastewater reported in the literature (Elmitwalli *et al*, 2002). With the aim of evaluating the aerobic biodegradability of the dissolved organic matter and VOA generation, a set of experiments were conducted in a sequential batch reactor (SBR). Some authors consider really advantageous the utilisation of this technology due to its flexibility (Irvine and Davis, 1971). It consists of a 2 L glass cylinder. Temperature was maintained at 25 °C. The automation was controlled by OMRON robot, CQM1-H model, programming by SISWIN software, and providing system with a SCS-SISMAC SCADA of the same blender. The reactor was inoculated with 3 g VSS methanogenically-active granular biomass. The inoculum remained active and with adequate settlement properties through the experimentation. The hydraulic retention time (HRT) was fixed at 12 h, including all processes steps: load, reaction time, settlement and fluxing.

In order to minimize all human intervention, and simultaneously to automatize the procedure, the reactor was connected to a programmed logic controller (PLC) which controls every stage transition and presents data in an human-machine interface. Anaerobic digestion of the synthetic wastewater was studied in the liquid phase. Soluble total organic carbon (TOC) a Shimadzu Total Carbon analyser was used. Variation of TOC allowed evaluating the substrate removal kinetics. Separate volatile organic acids (C_2-C_6) were determined using a gas chromatograph Hewlett-Packard HP-5890 equipped with a 15 m x 0.53 mm (I.D.) Nukol-silica semi-capillary column and a flame ionization detector.

Results and discussion

During anaerobic digestion process, the removal of organic matter and formation of short chain acids were observed. The evolution of acetic, propionic and butyric acid concentrations presents a maximum value for decreasing to produce eventually biogas (methane and CO_2) in spite of the acid pH environment. Figure 1B shows the variation of the mean maximum concentration of acetic acid $(C\text{-}C_2)_{max}$, which was the predominant acid, and volatile organic acid $(C\text{-}VOA)_{max}$ with the time in which the maximum VOA concentration appeared at each temperature. When temperature decreased, the volatile organic acid production was smaller (become smaller or decreases too), although it can be concluded that hydraulic retention times higher than five hours were not required in any case.



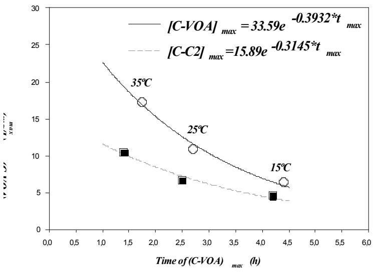


Figure 1A . Mean value of maximum VOA yield versus temperature *Figure 1B. Mean value of maximum VOA concentration versus reaction time of maximum VOA concentration.*

Summarizing, time and maximum VOA concentration at each temperature were really important in order to fix the hydraulic retention time in an acidogenic reactor oriented to produce acid. The subsequent phosphorous removal ability depends on the biodegradable acid availability. In the wastewater selected, when the maximum acid yield was reached (Figure 1A), 7, 10 and 18% of initial carbon was found as short chain acidified carbon at 15, 25 and 35°C, respectively. According to the results obtained in this research the optimum times of acidogenic digestion were approximately 1.5, 2.5 and 4.2 h when the objective was phosphorous removal. Taking into account the proposed mechanism (Figure 2) and additionally supposing that the decomposition of every previous compound takes place with first order kinetics, a differential equations system was formulated. OM is the total organic matter concentration, OM_{nb} the non biodegradable organic matter concentration, I is an intermediate compound, C2, C3 and C4 are acetic, propionic and butyric acid concentration, respectively, and Biogas is biogas generated per reactor volume (all the concentration as carbon). K_i represents the specific kinetic constants of the carbon compounds transformation and t is the time. Its solution allows simulating the concentration evolution of the different carbon species considered in the mechanism. Figure 3 shows the variation percentage of the kinetic constant with temperature. As can be seen, temperature had high influence over acetic and propionic acid formation (K_1, K_6) (variation higher than 90%). Similar behaviour was observed for propionic and butyric acid formation, due to K_3 and K_4 decreased approximately 84% in both cases. Acetic acid formation from propionic acid did not suffer a significant variation while methane production (K_2) shows a relevant influence, decreasing 33% from 35°C to 15°C. In general hydrolytic steps had higher drop than the methane production step.

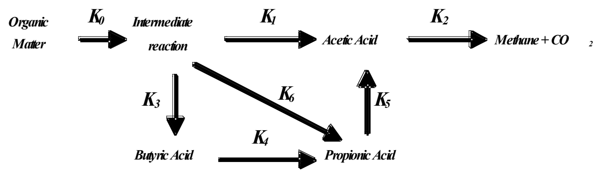


Figure 2. Scheme of the mechanism proposed for the acidogenic anaerobic digestion of the organic matter.

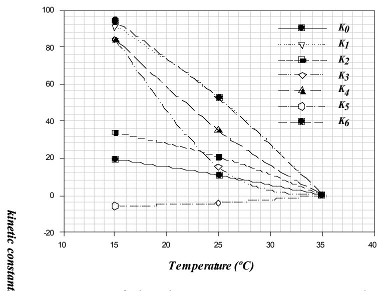


Figure 3. Differential equations system and variation percentage of the kinetic constants with temperature.

Conclusions

It was possible to predict the organic matter evolution through a first order kinetic model as the model parameters allow comparing the anaerobic microorganisms behaviour in the range of temperature studied. The short chain volatile organic acid generation was observed at the three temperature studied (35, 25 and 15°C), decreasing the maximum concentration value when temperatures decreased. The predominant acid was acetic acid, which facilitated the subsequent phosphorous removal, although it was deteriorated at low temperature due to the low availability of biodegradable acids. The kinetic model proposed was able to predict the evolution of the different carbon forms involved in the anaerobic digestion of this wastewater, showing the occurrence of a reduction in kinetic constant value parallel to the temperature drop. Temperature had more influence over the hydrolytic steps kinetics, corresponding with the organic matter transformation to volatile organic acids, than over the methane generation, getting slower when temperature decreased for all the anaerobic mechanism steps.

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