The paper presents a kinetic model of anaerobic digestion based on mass balance of substrate, microorganisms and methane production

Anaerobic fermentation is widely used as sludge handling technology in wastewater treatment plants. In bioreactor the organic substrate is mineralized to methane and carbon dioxide as the result of biochemical reactions performed by distinctive groups of microorganisms growing in the same medium,

Consists of two stages: macro cellular products into simpler compounds. The second is the acid digestion further breakdown into methane.

The main benefit of the process is the biogas production that can be used to decrease the operational costs of wastewater treatment plant. Modeling anaerobic digestion is very complicated because of the unsteady state behavior and the interaction of different parameters – physical, chemical, biochemical and hydraulical. The kinetics of the digestion process depends on several factors: a) temperature; b) pH level; c) concentration of organic matter expressed in DSS, sludge concentration; d) presence of inhibitors; e) mixing and external circulation; f) detention time; g) organic/mineral ratio; organic/nutrient ratio, especially nitrogen and phosphorus.

A single stage model it is developed in this paper to describe anaerobic kinetics

For modeling purpose, the biological reactor can be considered as a closed tank with the following hypothesis taken into account:

a) biochemical reactions occur only in the bioreactor;

b) complete mixing for sludge and microorganisms and also for temperature in order to maintain 360 C in the bioreactor,

c) steady-state regime

It is considered a schematic representation of a bioreactor with volume V (fig.1): • the inlet of sludge: Qni – flowrate of the sludge, Si –concentration of the substrate at the entrance, Xi – concentration of the anaerobic microorganisms at the entrance • the oultlet of digested sludge: Qne – flowrate of the digested sludge; Se – concentration of the substrate at the outlet; Xe - concentration of the anaerobic microorganisms at the outlet • biogas collection: Qg – biogas flowrate; Z – methane concentration in biogas

w. In non-steady-state conditions, taking into account complete mixing in bioreactor and neglecting endogenous decay of the microorganisms, the equations for the mass balance of the

microorganisms, of the substrate and respectively of the methane formation in control volume, can be written as: VrSQSQ dt dS V −−= neneini (1) VrVrXQXQ dt dX V −+−= dceneini (2) VKZQZQ dt dZ V eneini +−= (3) where: rn – substrate degradation rate; rc – growth rate of anaerobic microorganisms; rd – decay rate of anaerobic microorganisms; K – coefficient that takes into account the transformation of volatile organic compounds in methane.

The following assumptions are made: ♣ ZQ nini ⋅ = 0, ZQ nene ⋅ = 0 ♣ neni == QQQ ♣ D=Q/V – dilution rate and the equations (1), (2) and (3) become: dcei rrXXD dt dX )( −+−⋅= (4) nei rSSD dt dS )( −−⋅= (5) K dt dZ = (6) The equation for the mass balance of the microorganisms can be written: XKXXXD dt dX ei d )( µ ⋅−⋅+−⋅= (7) where µ - specific growth rate of microorganisms and Kd – decay rate of microorganisms. For the specific growth rate of microorganisms the Andrews relations is used, that takes into account substrate inhibition, [8]: i s K S S K ++ = 1 1 µµ max (8) The substrate degradation has to take into account the needs of the microorganisms, [3]:

The equations (7), (12) and (14) are used for theoretical simulation of microorganisms, substrate and methane concentrations in time. A customized model was developped in Matlab-Simulink, fig.2, using standard blocks from the Simulink library, [8]. The simulation input data were obtain during 3 months measurements campaign in 2010 at Wastewater Treatment Plant Contanța South, Romania. From the 4 digesters of the plant only 3 of them were in operation. Biogas flowrate was measured for 2 of them and for the third the flowrate was calculated using extrapolation. For the modeling purpose it is considered only 1 digester with the volume triple as the volume of one digester: V= 3 x 4000 = 12 000 m3 . The inlet sludge flowrates for the 3 months are 350 m3 /d, 298 m3 /d and 312 m3 /d. Thus, the dilution rates are 0.0292 d-1,

According to romanian standard NP118-06, [11], only 60-75% of the inlet sludge represents organic compounds.Thus, considering an average value of 8.38 g/l COD in influent sludge, as it was measured, only 5 g/l is organic matter, and this value is taken into account for inlet substrate concentration. Initial conditions for substrate concentration is S0 = 6 g/l and for microorganisms concentration X0 = 3 g/l. For kinetic coefficients it is used the values from the literature, [3], 4], [9], [10]: µm = 0.2…1.2 d-1; Ks = 7.1…360 mg/l COD; Kd = 0.02…0.04 d-1; Ki ' =0.5, 1.0, 10.0, 100.0; Yx = 0.3…0.82; Ys = 0.04…0.27; Yp = 4.35; Kmx = 0.4; Ksx = 0.983. The simulation data represent variation in time of methane concentration and measurements data represent biogas flowrate. In order to compare the results it is considered that 60% in biogas is methane and using methane density, ρCH4 = 0.717 kg/m3 , it is calculated methane flowrate: 717,06,0]/[]/[ 3 4 Q kg = dmQd ⋅⋅ CH biogas (15) Mass of methane produced in the simulation time is: MCH kg QCH kg 30]/[][ dd 4 4 = ⋅ (16) The concentration of methane will be: ][/][]/[ 3 = MlgZ CH4 kg mV (17) The simulations were done for dilution rates D = 0,0292 d-1, D = 0,02483 d-1 and D = 0,026 d-1, according with experimental measurements. For every dilution rate there was realized simulations for three values of the specific growth rate of microorganisms: µm = 0.35 [d-1], µm = 0.38 [d-1] and µm = 0.4 [d-1]. Some of the results of the simulations for May, June and July 2010 are presented in fig. 3 – 21.