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BIOKINETIC MODELLING OF AN INDIVIDUAL WASTEWATER TREATMENT UNIT

Introduction

Although the traditional centralised wastewater system could treat large amount of wastewater, the overall cost of the treatment including the transportation of sewage could be enormous. At low densely-populated areas or in territories, where the connection to the sewers are not economically sound, alternative solutions are favoured, e.g. individual wastewater treatment units or onsite sewage treatment facilities.

Decentralised wastewater treatment is suitable for both domestic and industrial sewage with a flow rate of 1–1000 m^3/day. Design an onsite facility applies the same sizing procedure compared the conventional large scale systems, whereas the input flow data and its variability, the model parameters could differ. The biomass could be either suspended or attached to a carrier. Suspended solids form flocs, which are well-mixed in the reactor zone. Appropriate mixing is attained by applying mechanical mixers or aeration. In order to achieve the desired pollutant removal (organic matter degradation and nutrient uptake by microorganism), various reactor compartments have to be separated based on the form of the oxygen in the system.

Sizing is based on mass balance (biokinetic) modelling, which solves various transport equations for the system variables. For this study simulation ASM2d model approach was used, which belongs to the ASM (Activated Sludge Model) family and gives a detailed description of the following processes:

– biomass build-up for heterotrophic and autotrophic microorganisms;
– degradation of organic material and nutrients;
– aeration;
– chemical processes (precipitation).

Stoichiometric and conversional parameters are default values in a simulation environment. The parameters of biomass yields, half saturation rates, maximum growth rates, hydrolysis rates, decay and conversional rates are described more in detail in literature [1]. Calibration of the mass balance model is based on direct measurement of kinetic parameters or followis reversed engineering by the knowledge of the actual plant effluent data [2].

Aim of this study is to present a technique, with which a small size wastewater treatment unit can be designed; and basic dimensions and capacity along with the operational parameters will be determined.

Modell setup

GPS-X 6.5 commercial simulation software was applied in this research. Model layout (Figure 1) demonstrates the basic elements of the unit. The raw influent flows to a buffer zone, where the flow is equalized, then it is directed to the biological zones, which are the aerobic, anoxic and aerobic zone. Last compartment is aerated by diffusers, and the flow is directed back to anoxic zone by applying internal recirculation, thus the denitrifiers are supplied with nitrate. Some part of the sludge is reverted back to the anaerobic zone to maintain the biomass concentration in the system and excess sludge is taken out from the system at a pre-defined rate in order to ensure the solid retention time of 12 hours required for the biological processes.

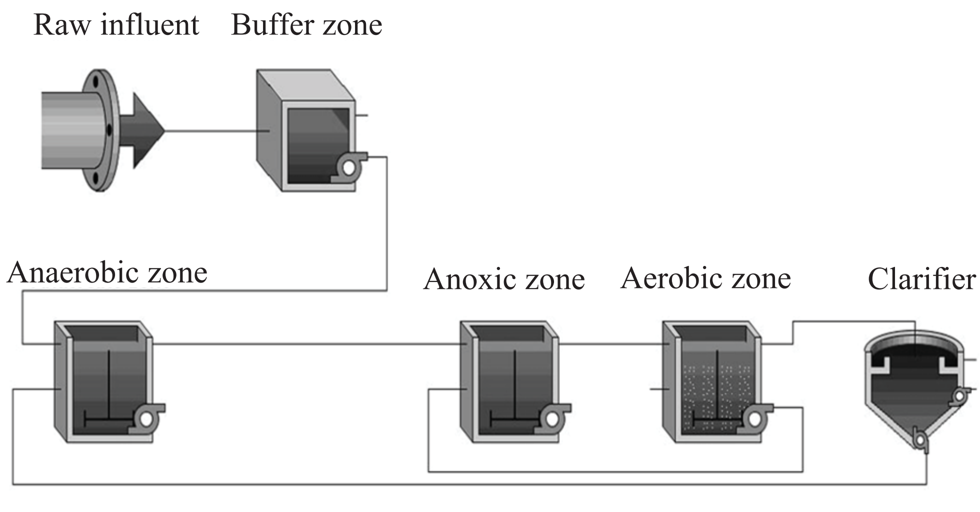

Figure 1 – GPS-X model layout – water line

Average wastewater discharge is 6 m^3/d, daily peak factor is 3. Mixed liquor suspended solid is: MLSS = 3.5 g/l. The dissolved oxygen (DO) in the aerobic reactor is 2 g/m^3. 12 % oxygen transfer rate was assumed at standard condition. Internal recirculation is 4 times higher the average flow, the sludge recirculation (RAS) has same amount as the daily average flow.

After the creation of plant layout, model input parameters were set, including influent characterisation. A typical Hungarian municipal raw wastewater average concentration was assumed with total COD = 700 mg/l, TSS = 400 mg/l, BOD_5 = 310 mg/l, TN = 80 mg/l, TP = 12 mg/l. Influent characterization performed was COD-TSS based; which required the influent Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS) as input variables. The COD fractions calculated were the following:

– inert soluble COD: 20 mg/l;
– particulate inert COD: 210 mg/l;
– slowly biodegradable COD: 330 mg/l;
– easily biodegradable COD: 140 mg/l.

Results and discussion

Volume of each reactor zone was calculated based on total biomass amount and the MLSS. Following Metcalf and Eddy's (2013) analytical procedure [3] the reactor zones' volume for buffer, anaerobic, anoxic, aerobic zones are 3, 1, 1, 3.9 and 1.1 m^3 respectively.

Steady-state simulation was performed to determine the treated effluent quality and to observe the component concentration in each reactor zone. The reactor compartments are completely mixed, therefore there is no changes in concentration inside the reactor zones. Table 1 shows the main wastewater components (COD, ammonium-nitrogen, nitrate-nitrogen and orthophosphate-phosphorous concentration in the reactor compartments.

It can be observed that in buffer tank, which main function is to equalise the flow, some sedimentation occurs and some part of the particulate solids and related organic content is removed. SRT of 12 days allows the full nitrification at this temperature. NH_4-N concentration decreases steadily along the reactor zones. Nitrification took place mostly in aerobic reactors, but the internal recirculation may direct oxygen back the other reactor zones as well.

Table – Main wastewater component concentration at average temperature (20 °C)

mg/l	Buffer tank	Anaerobic	Anoxic	Aerobic
COD	160	65	22	20
NH_4-N	29	19	7	1.2
NO_3-N	0	0	0.46	5.48
PO_4-P	8	29.9	10.7	0.77

Simultaneous denitrification occurs in aerobic zone, inside the flocs, and it is responsible for 30 % of the nitrogen removed based on simulation result. Enhanced biological phosphorous removal is also facilitated by anaerobic zone and sludge recirculation. Microorganism (mainly PAOs –

Phosphorous Accumulating Organisms) could store the phosphorous by luxury uptake in anaerobic conditions. resulting low TP effluent.

The design was also checked at winter operation assuming 12 °C of temperature. At this condition the full nitrification was lost, and changes in operational parameters were required. By increasing the DO level to 4.0 mg/l and the MLSS to 6.0 g/l the full nitrification could have been achieved.

Unsteady simulations were also performed in order to estimate the time required for biomass build-up. The purpose of this simulation was twofold: (i) quantify the excess sludge, (ii) give prediction on the recovery time of the system after a biomass washout and/or biomass inactivation. Figure 2 shows the total sludge amount in the reactor zones and it can be stated that 12 days are needed to reach the desired MLSS concentration.

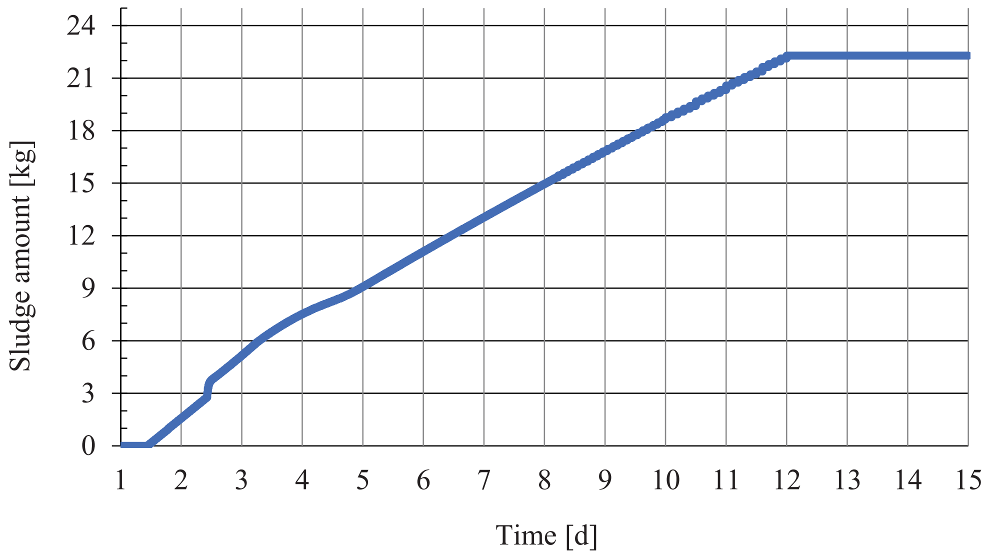

Figure 2 – Activated sludge recovery analysis

The excess sludge, which needs to be removed is 0.32 m^3/d (at 6.7 g/m^3 dry solid concentration).

Conclusions

Decentralised wastewater treatment are adequate alternatives to centralised wastewater treatment. Design procedures could be easily adapted to onsite sewage treatment systems. Biokinetic models could predict the treatment unit performance and could provide guidelines for optimal operations. DO setpoint of 2.0 mg/l and MLSS setpoint of 3.5 g/l is satisfactory at normal environmental conditions, but in extremities this shall be adjustable. The build-up of the system is about 12 days, but it can be improved by addition of biomass from external source. It can be added that the operation does not require any chemical addition (if there is no disinfection requirement for the treated effluent wastewater). Appropriate design is not enough, regular maintenance and well trained operators are also key elements.

Acknowledgement

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