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Experimental investigation and modeling of innovative five-tank anaerobic-anoxic/oxic process

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ABSTRACT

A five-tank anaerobic-anoxic/oxic (A^2/O) activated sludge process was investigated as innovative configuration in the activated sludge process technologies which has advantage of save energy power, cost and enhance nitrogen and phosphorus removal whereas it does not need equipment for sludge and mixed liquor recycle and also it required small land for construction. The five-tank process achieved 89.1% ± 1.37%, 87.78% ± 1.15%, 73.62% ± 2.13%, and 83.78% ± 0.92% of chemical oxygen demand, NH_4^+–N, TN, and total phosphorus (TP) removal efficiencies, respectively, during a 16-month operation with the effluent meeting Chinese sewage discharge standard GB18918-Grade A. A computer program was built based on activated sludge model No. 2d for simulating the performance of each compartment in five-tank process. The difficulty of simulation is coming from the system operation condition where it is operated under unsteadily state condition in all its compartments .The results showed that the growth rate constant of autotrophic organisms was 2.4 day^{-1} and yield coefficient was 0.14. According to simulation results, heterotrophic organism; phosphate accumulating organism, and autotrophic organism are decreased in the anaerobic compartments because of the lysis reaction. Then these organisms are increased in the aerobic compartments due to aerobic growth. The heterotrophic organism; phosphate accumulating organism; and autotrophic organism are increased in quantities by about 56.6%, 36.12% and 74.31% in compartment one due to change the operation condition from anaerobic to aerobic and decreased in quantities by about 20.21%, 44.18%, and 0.142% in the compartment three due to change from aerobic to anoxic. The total nitrifying species to total active biomass was fluctuated between 1–11.89% in the process reactor.

1. Introduction

Over the last ten years, a number of biological nitrogen and phosphorus removal processes have been used to remove phosphorus with simultaneous nitrification and denitrification process. Most of the enhanced biological nutrient removal processes consist of a sequential anaerobic and aerobic phase for biological phosphorus removal, and recycle mixed liquor suspended solids (MLSS) into anoxic zones to hold up the removal efficiency of total nitrogen. This method is increased energy required for mixed liquid recirculation or addition of additional carbon source for denitrification process in anoxic zones. According to that, the operational cost of these processes will increase. Phosphorus and nitrogen removal was improved via reconfiguring biological nutrient removal processes through canceling internal mixed liquor and sludge recirculation. This method was prepared by configuring the process into anaerobic, aerobic, anoxic, aerobic zones in sequence in

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southeast university of China. A flow was fed into the anaerobic/anoxic zone by changing intake location. Many different kinds of organic compounds are formed in the complex biological transformation processes, such as heterotrophic organisms, phosphate accumulating organisms, and autotrophic organisms. In order to recognize bacterial reactions in biological nutrient removal processes, many different types of mathematical models have been proposed [1–3] and applied in the biological nutrient removal processes [4–7]. Some of them two-stage nitrification models [8–10] and others multi-stage denitrification models [11–13] were proposed in the biological nutrient removal processes. Although these models could predict nitrification or denitrification successfully but the application of these models were merely related to nitrogen removal. That was, the behaviors of heterotrophic organisms, phosphate accumulating organisms, and autotrophic organisms in both nitrogen and phosphorus removal process were not taken into account simultaneously. Activated sludge model No. 2d represents a model for biological phosphorus removal with simultaneous nitrification –denitrification in activated sludge systems. ASM2d is extension of ASM2 model where it expanded to include the denitrifying activity of the phosphorus accumulating organism (X_{PAOs}). Since ASM2d model can be described denitrification and phosphorus removal simultaneously so that the objectives of this study are listed as follows: (1) to establish an model (Activated Sludge model No. 2d) in which denitrification and phosphorus removal were taken into account simultaneously, (2) to validate the model by exploring the consistency between simulated and observed values of different components including soluble COD S_S; NH_4^+–N; NO_3^-–N and PO_4^{-3}–P in five-tank A^2/O process, and (3) to analyze the kinetics of different microorganisms including heterotrophic organisms, phosphate accumulating organisms and autotrophic organisms in the process reactor.

2. Materials and methods

2.1. Experimental equipment

The main parts of a pilot plant utilized in this study are the main body which are rectangular box 750 × 630 × 900 mm, air compressor, pre-static pumps, mechanical agitation mixers, PLC programmable logic control, LCD display screen, inlet wastewater electromagnetic valves, outlet water electromagnetic valves, aeration electromagnetic valves, sludge discharge electromagnetic valves, and PVC pipes and others. The principle diagram of pilot plant with all major components is shown in Fig. 1. The effective water depth in the five-tank continuous flow activated sludge system is 650 mm while the total depth is 900 mm. A plane dimension of compartment two, compartment three, and compartment four are square plane while compartment one and compartment five are rectangular plane whereas the effective volume of compartment two, compartment three, and compartment four are 250 × 250 × 650 mm while compartment one and compartment five are 380 × 290 × 650 mm which make volume ratio between rectangular and square compartments 1.75. An operation cycle is composed of two half-cycles with same running schemes, in which the raw wastewater flows from compartment one to compartment five during the first half-cycle, and from compartment five to compartment one during the second; the first half-cycle is similar to second half cycle. The scheme of first half cycle is shown in Fig. 2; it is divided into four phases named as phase I–IV, respectively. In this scheme, compartment one, compartment two, compartment three and compartment four operated as reactor, and compartment five as settler. The direction of flow was changed automatically via changing of intake location so that the system achieved automatic recirculation without equipment to return sludge and mixed liquor.

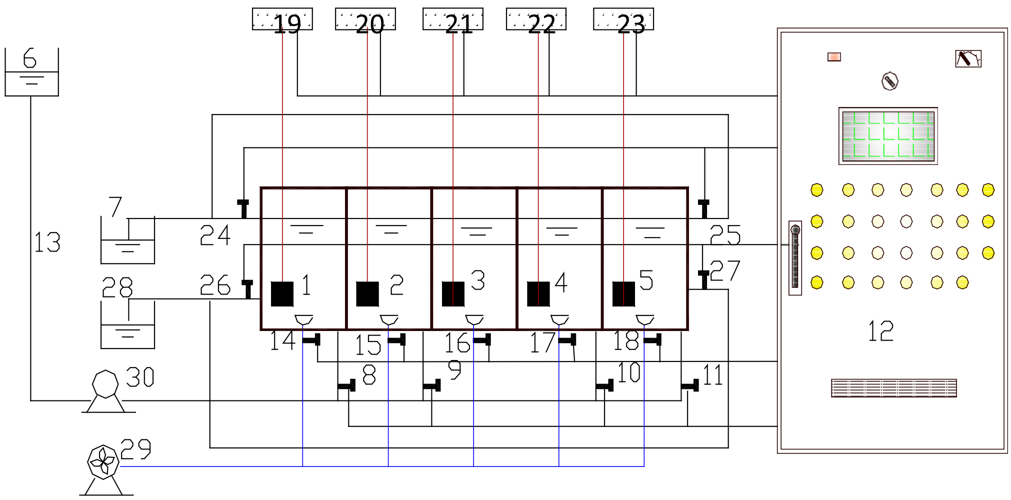

Fig. 1. Configuration of five-tank device with all main parts. 1–5-five compartments, 6-inlet reservoir, 7-outlet reservoir, 8–11-inlet electromagnetic valve, 12-PLC programmable logic controllers, 13-inlet pipe, 14–18,-aeration electromagnetic valves, 19–23-mixer, 24, 25-effluent electromagnetic valve, 26, 27-sludge electromagnetic valves, 28-sludge tank, 29-Air compressor, 30-prestatic water pump.