Research Article

Technologies Used in the Wastewater Treatment for Nutrient Removal

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Abstract

In this paper will be showed some techniques employed effectively in wastewater treatment for nutrient removal. The results concerning biological phosphorus and nitrogen removal, from an anaerobic expanded bed reactor (AEBR), treating domestic wastewater, in an Intermittent Aeration Reactor (IAR) followed by dissolved air flotation (DAF); aiming to remove chemical oxygen demand (COD), nitrogen and phosphorus on the same unit. The DAF was used for separation of suspended solids. Conditions to obtain nitrification were assessed, denitrification and phosphorus removal in a reactor operated with alternate aerobic and anaerobic periods. The intermittent aeration system was operated with hydraulic detention time (θh) of 8 hour and 6 hours. The system with intermittent aeration (θh:6hr) showed stable results and presented average COD removal of 92% (90 to 94%) and average phosphorus removal of 90% (82 to 96%). For hour detention time, the average orthophosphate (PO_4^{-3}-P) removal was: 84% (60 to 94%) for raw samples and 94% (60 to 98%) for filtered samples (filter: 0.45 μm). Neither the use of the external carbon source nor pH correction was necessary.

Keywords: Biological phosphorus removal; Intermittent aeration activated sludge reactor; Dissolved air flotation

Introduction

In many developing countries, water scarcity and pollution pose a critical challenge in the area of environmental management. In urban areas, it is becoming difficult for the authorities to manage this question. The possibilities of wastewater reuse in agriculture, industry, urban uses, and environment, including groundwater recharge enhancement are discussed worldwide.

Water use has more than tripled globally lately. According to UNEP [1] these problems may be attributed to many factors as increasing population. Inadequate water management is accelerating the depletion of surface water and groundwater resources. Water quality has been degraded by domestic and industrial pollution sources as well as non-point sources. In some places, water is withdrawn from the water resources, which become polluted owing to a lack of sanitation infrastructure and services. Population growth in urban areas is of particular concern for developing countries and water issues are expected to grow.

The capacity building policy-making, institutional strengthening, financial mechanisms, and awareness rising and stakeholder participation are vital to implement these strategies for wastewater reuse.

In sanitary sewer, the phosphorus appears, mainly, as organic phosphorus, polyphosphate and orthophosphate [2]. The organic phosphorus comes from human and animal excretions, as well as from food remains. When organics passes through biological decomposition, they generate orthophosphates. In addition, polyphosphates may also derive from detergents [2]. That fraction has been suffering expressive growth due to increasing consumption of detergents.

The biological phosphorus removal (removal in "excess") is obtained by the selection of bacteria capable to store polyphosphate. The selection is made to expose the bacteria alternately to the anaerobic and aerobic conditions [3]. Under anaerobic condition, bacteria that accumulate phosphorus in excess, use the derived energy of the polyphosphates hydrolyses, to fix organic substratum, that are stored in the form poli-b-hidroxibutirato (PHB) or poli-b-hidroxivalerato (PHV) [3].

The removal of the phosphorus is more efficient in alternate conditions of aerobic and anaerobic [4,5]. Also it was verified, that the phosphorus removal is associated, among other factors, to the contact of the sludge recirculation with the raw affluent, in the initial zone predominantly anaerobic [6].

The technology of reactors with intermittent aeration, in continuous hydraulic permanent flow, constitutes an alternative to the conventional activated sludge. Specific conditions for aerobic and anaerobic activities are provided by these reactors [7].

Choi et al. [8] used synthetic wastewater to evaluate phosphorus and organic matter removal, in a single reactor, combining aerobic and anaerobic conditions. The removal efficiency was about 92%, for a total-P, 90% for PO_4^{-3}-P, while a great difference of phosphorus removal was observed with relationship to N/P ratio. Rittmann and Langeland [9] and Campos [6] observed that combination of nitrification and denitrification processes in same treatment system might result in an increase of phosphate removal efficiency.

For Kerrn-Jespersen et al. [10] the bacteria that store polyphosphate can be classified in two groups: a group which is capable to use oxygen or nitrate as electrons receiver, and another which is capable to just use oxygen. In agreement with the mentioned authors, the differences observed in the phosphorus removal rates, under aerobic and anoxic condition, are due to the fact that, in aerobic condition, both groups of bacteria are capable to absorb phosphorus from the medium. In anoxic condition, the bacteria that can use nitrate as electrons receiver has capacity to store phosphorus, what explains the phosphorus removal, in aerobic condition, it is larger than the removal under anoxic condition.

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Methods

There are different technologies and methods for wastewater nutrient removal (Table 1). The author has developed a fully operational laboratory scale one system (Figure 1) [7], being the first one an Anaerobic Expanded Bed Reactor (AEBR), built in steel carbon, with 14.9 m of total height and useful volume of 32.0 m³. The reactor was composed of two regions: reaction, and decantation. The reaction region presented cylindrical format with 12.0 m height, 1.5 m of base and 2.5 m of superior border diameter (operated with average θ_h of 3.2 hours) [11,12]. The second unit is an Intermittent Aeration Reactor (IAR) - with controlled dissolved oxygen (DO) concentration - seeking to the nitrification/denitrification, and subsequently, a unit of DAF. Both IAR and DAF units were in bench scale with continuous flow, being fed for only part of the of expanded bed reactor effluent, (range 11.5 to 15.5 L/hr).

An effluent portion of the anaerobic reactor flowed by the unit of IAR in which DO concentration was controlled. The aerated reactor had a useful volume of 0.092 m³, (width: 0.25 m, length: 0.82 m and height of 0.50 m). The effluent of the aerobic reactor was directed to a subsequent system of DAF, presenting width: 0.25 m, length: 0.10 m and height of 0.5 m with useful area about 0.025 m². The pressure was maintained in the strip of 456 ± 10 kPa in the saturation camera and the air amount was supplied with temperature and recirculation flow function. Part of the accumulated sludge in the flotation unit surface was returned to the beginning of the aeration system and the sludge excess was discarded by the system. The clarified liquid (effluent) was returned to feed the saturation camera, that, after having saturated with air, it was directed to the DAF. In the IAR, the total hydraulic detention time was maintained in 8 h, for 194 days, and of 6 h in the of 41 days, with an average flow of 15.3 and 11.5 L / h, respectively.

The affluent and effluent characteristics were monitored in each unit: pH, DO, temperature, Biochemical Oxygen demand (BOD), (COD), orthophosphate (PO_4^{-3}-P), total solids (TS) and total suspended solids (TSS), total Kjeldahl nitrogen (TKN), ammonia-nitrogen (NH_3-N), nitrite-nitrogen (NO_2^--N), nitrate-nitrogen (NO_3^--N) in the " liquor ". Besides those, were also monitored: MPN of denitrifying and nitrifying bacteria, Total organic carbon (TOC) and metals. All determinations were followed the rules of Standard Methods.

Discussion

System constituted by anaerobic reactor, followed by IAR associated with DAF, is a good alternative to promote biological phosphorus removal and also nitrogen and COD. That configuration constitutes quite attractive, capable to promote high a degree of domestic wastewater nutrient removal, without needing external carbon source and alkalinity addition. The intermittent aeration is a resource that results in operational cost reduction for activated sludge reactors fed with anaerobic reactor effluent. Operational changes in existing reactors can bring economy and in certain cases even efficiency increase in the N and P removal. Marchetto [7] observed that anaerobic reactor in series with IAR associated with DAF, presented a good performance in relation to the COD and phosphorus removal, mainly for a total treatment time (θh) of 8:00 and of 6:00 hours. The system can be an economical alternative for the biological phosphorus removal due to the short detention period needed.

The AEBR effluent presented, on average COD of samples without filtering: 183 mg/L, COD of the filtered samples: 76 mg/L; NTK: 26 mg/L; ammoniacal-N: 16 mg/L.

Working with θh on 6:00h was obtained PO_4^{-3}-P removal of 89% and 94% for the effluent without filtering and filtrates, respectively. In addition, for θh of 8:00h was obtained maximum removal of PO_4^{-3}-P, about 95%. Sasaki Kousei et al. [13], aiming at the simultaneous nitrogen and phosphorus removal, of a sanitary sewer, in system of activated sludge aerated intermittently (aerobic-anoxic), used θh on 20:00 h with the residues temperature varying among 9 to 33°C. The TSS concentration of the mixed liqueur varied between 3100 to 4300 mg/L and the reason of sludge recirculation among 150 to 200%. During the aerobic period, the DO concentration was maintained in 2.5 mg/L. The pilot installation was shown stable and with high BOD removal efficiency: (98%); KTN: (92%) and total phosphorus: (85%). Sasaki Kousei et al. [13] almost used θh three times superior to the used in this research;

	Preliminary	Primary	Secondary	Tertiary and Advanced
Purpose	Removal of large solids and grit particles	Removal of suspended solid	Biological treatment and removal of common biodegradable organic pollutant	Removal of specific pollutants, such as nitrogen orphosphorous, color, odor, etc.
Sample Technologies	Screening, Settling	Screening, Sedimentation	Percolating/trickling filter, activated sludge Anaerobic treatment Waste stabilization ponds (oxidation ponds)	Sand filtration, Membrane bioreactor, Reverse osmosis, Ozone treatment Chemical coagulation Activated carbon. wetlands

(Asano and Levine [18] and Campos et al. [19])
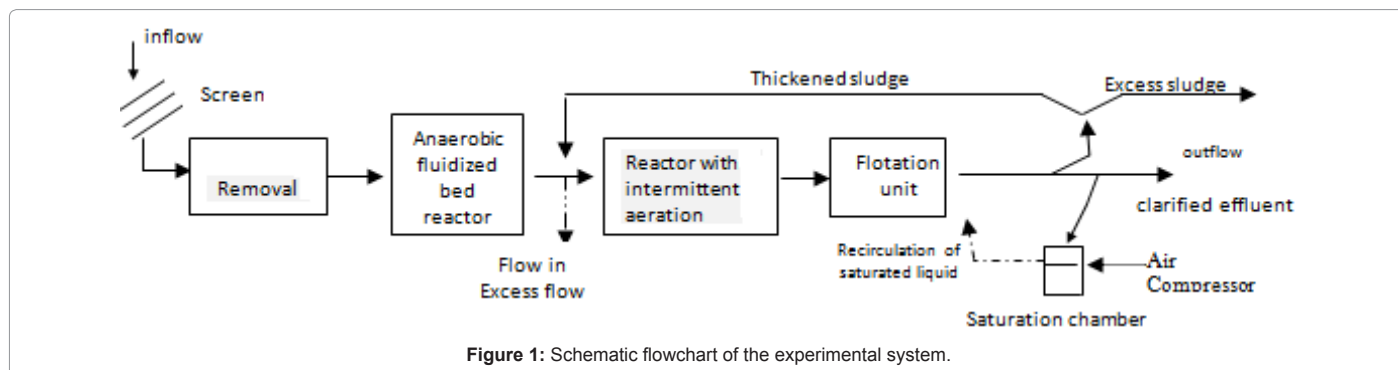
Table 1: Wastewater Treatment Process.

Figure 1: Schematic flowchart of the experimental system.

even so, they obtained inferior phosphorus removal.

In relation to the PO_4^{-3}–P concentration the results showed that, even for the period without aeration, the phosphorus residual of samples without filtering presented medium value of 1.5 mg/L, even for the period without aeration, the PO_4^{-3}–P residual concentration was of 4 mg/L, for raw samples and, 2.5 mg/L for the filtered samples. At the end of the period without aeration, that situation corresponds to the smallest removal efficiency of the (PO_4^{-3} -P), (80%) of the samples without filtering and (85%) of the samples filtered. The cycles were varied from 2:00 h, with aeration and 4 h, without aeration. Ikemoto et al. [14] observed that denitrification was dominant as a result of the competition between bacteria phosphate accumulative and bacteria sulfate reductors, in the organic matter degradation. In anaerobic conditions, the release of phosphate and the sulfate reduction happened simultaneously. The accumulative bacteria of phosphate competed with the bacteria sulfate reductors for organic acids, as propionate. However, the phosphate accumulative bacteria used the acetate produced by the sulfate redactors' bacteria.

It is interesting to observe when the DO concentration increased, the phosphate concentration decreased. It was verified that the values of the concentration of PO_4^{-3} –P began rising, in the corresponding time of 240 min, after 2:00 without the DO supply, (redox potential: -190 mV). This fact shows clearly that, after a certain period without the DO supply, the organisms tend to liberate phosphorus, unlike when it happens in aerobic phase, when phosphorus decrease gradation is verified along the period. It can be inferred that, only when the interior of the flake becomes anaerobic, it should happen the phosphate liberation for the liquid middle.

Finger and Cybis [15] observed that using two distinct conditions (anaerobic-aerobic) was efficient in the removal of phosphorus (81%); however, effluent presented high nitrate concentrations. Sorm et al. [16] also compared the rates of phosphorus removal in anoxic and aerobic conditions. The phosphorus removal rate in anoxic condition was harmed when concentration relatively high, of nitrogen in the nitrate form around 25 mg/L.

For Maurer and Gujer [17] the release of phosphate and substratum accumulation quickly biodegradable only happened under strict anaerobic condition (when there was not nitrate, nitrite or presence of oxygen); however, in agreement with the results of the present researches obtained with intermittent aeration followed by DAF, it was verified that in the periods without aeration, even with the presence of nitrate in the reactor with intermittent aeration, phosphate release was observed.

The organic matter absorbed by the bacteria is used by both purposes, what becomes an advantage, when the organic matter concentration is low, as it happens when the wastewater goes by a pre-treatment system. The anaerobic pre-treatment can reduce the competition significantly for organic substratum between the bacteria poly-P and the denitrifying.

Final Thoughts

The system constituted by (AEBR), followed by (IAR) associated with (DAF) showed a better alternative to promote biological phosphorus removal and also nitrogen and COD. That configuration constitutes quite attractive, capable to promote a high degree of domestic wastewater nutrient removal, without needing external carbon source and alkalinity addition. The intermittent aeration is a resource that results in operational cost reduction for activated sludge

reactors fed with effluent of anaerobic reactor. Operational changes in existing reactors can bring economy and in certain cases even efficiency increase in the N and P removal. This system can be an economical alternative for the biological phosphorus removal due to the short detention period needed. It was obtained efficiency of COD removal of 92% and of 95% for the samples filtered and without filtering, respectively.

The maximum removal of PO_4^{-3}–P in the system, of 95% and 96% of the raw samples and filtered samples, with average removal of 84%, for the raw samples and 88% of the filtered samples.

It can be verified that besides the alternate conditions of anaerobic and aerobic, the phosphate removal is directly related with the sludge recirculation, confirming the several authors' report.

Until 2005 the São Paulo state designed and constructed two wastewater treatment plants with an intermittent system for cities having population around 200,000 inhabitants. In this case, it was employed total hydraulic detention time (with and without aeration) in the range of 12 to 14 hr. Currently is necessary to do a survey to verify the number of existing plants.

Reuse of greywater has also been widely disseminated. Treatment technologies must be easily applied, low-cost implementation, operation and maintenance, aiming at environmental restoration of water bodies and improve the living conditions of the population. Thus, the use of recycled water and rainwater are alternative solutions to increase the supply of water, obeying specific standards and laws.

The reuse of gray water produced in homes, are alternatives to meet the needs in water supply, especially in activities that do not require noble quality standards as in domestic toilet discharges, washing floors and gardens.

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