Journal of Civil Engineering and Environmental Technology
Print ISSN: 2349-8404; Online ISSN: 2349-879X; Volume 1, Number 3; August, 2014 pp. 41-44

http://www.krishisanskriti.org/jceet.html

Enhanced Biological Phosphorus Removal in Aerobic Baffled Reactor

Dharmender Yadav[1], Keshwa Sharma[2], Sonam Gupta[3], Raja Sonal Anand[4], Pramod Kumar[5], Vikas Pruthi[6]

[1, 2, 4, 5]*Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee - 247667, Uttarakhand, India*
[3, 6]*Department of Biotechnology, Indian Institute of Technology Roorkee, Roorkee - 247667, Uttarakhand, India*

Abstract: **Enhanced biological phosphorus removal (EBPR) has been implemented worldwide to reduce phosphorus concentrations in municipal and industrial wastewaters preventing eutrophication in natural water bodies. Conventional EBPR process uses an alternate anaerobic and aerobic stage which is also known as anaerobic/oxic process (A/O process). Recent studies have shown that biological phosphorus removal can be achieved by removing the anaerobic stage and maintaining only aerobic conditions. In this investigation, we checked the feasibility of achieving net phosphorus removal under strictly aerobic conditions in an aerobic baffled reactor. Phosphorus removal efficiency was tested at different influent concentration of 1.4, 10, 20 and 30 mg/l of phosphorus. Experimental data showed that it was possible to attain biological phosphorus removal under obligate aerobic conditions as the removal efficiency was observed to be 100%, 92-97%, 91-97% and 63-69%, respectively. COD removal efficiency was also observed to be in the higher range of 86-89% when the reactor achieved steady state conditions. Further, it was concluded that feast-famine phases of completely aerobic EBPR systems are analogous to the anaerobic-aerobic phases of conventional EBPR process.**

Keywords: **Enhanced biological phosphorus removal (EBPR), Eutrophication, Aerobic process, Wastewater treatment.**

1. INTRODUCTION

Conventional Enhanced Biological Phosphorus Removal (EBPR) process uses alternate anaerobic and aerobic stages which is also known as anaerobic/oxic process (A/O process). The main micro-organisms that are responsible for the EBPR process are polyphosphate- accumulating organisms (PAOs). Under anaerobic conditions in EBPR process, PAOs consumes biodegradable organic carbon and store it as polyhydroxyalkanoate (PHA) in their cell mass. The energy needed for this biological reaction was supplied partly by the glycogen utilization but mainly from the hydrolysis of the intracellular stored polyphosphate. In the next zone, under aerobic conditions, PAOs use stored PHA to grow, consume ortho phosphorus and replenish glycogen. By wasting phosphorus-rich biomass, net phosphorus removal can be achieved (Nielsen et al., 2012).

Some studies showed the possibility to achieve net P-removal under strictly aerobic conditions (Ahn et al., 2002; Guisasola et al., 2004). Ghigliazza et al. (1999) found that anaerobiosis doesn't have any effect if EBPR system was cultured by *Acinetobacter lwoffi*. Wang et al. (2008) studied biological phosphorus removal in a sequencing batch reactor (SBR) in completely aerobic conditions using glucose as carbon source and obtained 90% and above phosphorus removal.

2. MATERIAL AND METHODS

2.1. Experimental setup

A baffled reactor of effective capacity of 10 L was used. The reactor was divided into 8 compartments using vertical baffle walls. A simple cylindrical tank made up of plastic was used for supply of synthetic wastewater. The total capacity of the tank is 100 L. Portable aerators, the type commonly used in household aquariums, in up-flow compartments to aerate the system. These units have a compressor and a fine bubble diffuser. The diffusers were kept at the bottom of the compartment. Dissolved oxygen (DO) concentration was maintained between 2-4 ppm, conducive for growth of phosphorus assimilating microorganisms. These aerators also serve the purpose of providing mixing inside the reactor. A hopper bottom type secondary settling tank was used to settle the sludge, desired amount of which was recycled to the reactor via the first compartment. Sludge retention time was equal to 10 days. Two peristaltic pumps were used. First pump maintained the desired constant influent flow rate to the reactor while second pump regulated the sludge recycling to the reactor. Reactor was started by seeding with 5 L of activated sludge obtained from recycling unit of activated sludge process at municipal wastewater treatment plant Kankhal (Haridwar), Uttarakhand, India. MLSS was kept in 3000-4000 mg/L range.

2.2. Synthetic wastewater

Synthetic wastewater was used in the research in which molasses was used as carbon source. COD was kept in the range of 400-600 mg/L by keeping molasses concentration in the feed almost equal to 0.5 mL/L. The P concentration was maintained by adding KH_2PO_4. The concentrations of other nutrients in the feed are as: 85.7 mg/L urea, 0.5 mg/L $MgSO_4$ and 0.5 mg/L $CaCl_2$.

3. RESULTS AND DISCUSSION

3.1 Long term performance of the reactor

Reactor was initially started at 12 h HRT, which was stepwise, reduced to the working HRT of 8 h. HRT was reduced only when reactor achieved PSS at previous HRT, as shown in figure 1. After attaining pseudo steady state at working HRT of 8h, dried powdered sludge was added to the reactor. Increase in COD removal efficiency was observed after adding this dried sludge which may be due to the improved settling characteristics of dissolved solids due to their attachment to the surface of powdered sludge. Reactor achieved pseudo steady state after adding this dried sludge in next 21 days and at that time COD removal efficiency was observed almost 86%. Significant increase in COD removal performance was observed with the passage of time, as shown in figure 1.

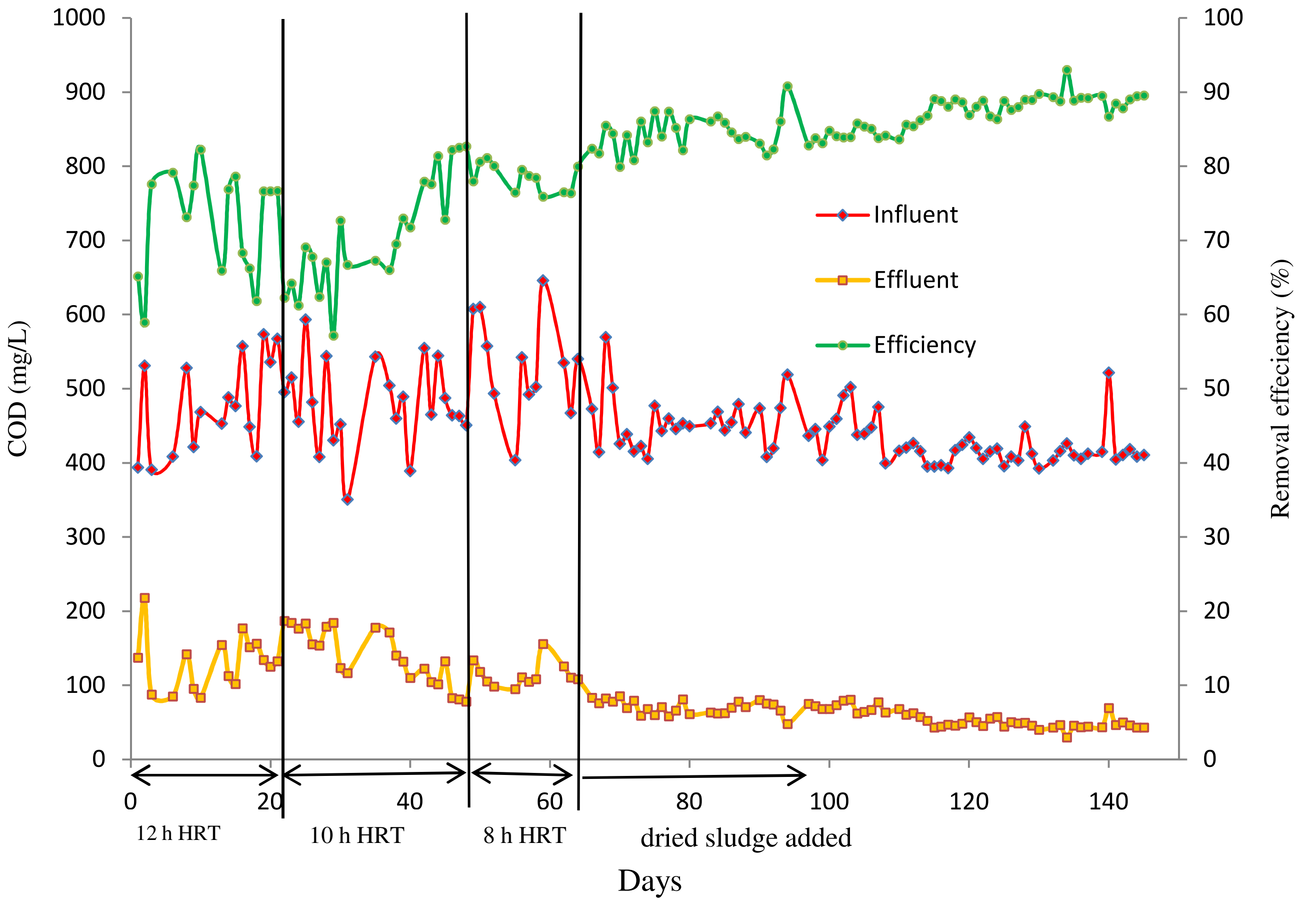

Fig. 1 COD removal at different conditions of the reactor

COD removal efficiency was almost 86% on day 84 (when reactor achieved steady state after adding dried powdered sludge), which was increased to about 89% till day 145. This increase in efficiency of the reactor may be due to the increase in temperature with onset of summer (from 29°C at day 84 to 41°C at day 145) because temperature increased microbial activities inside the reactor.

During the starting phase of the reactor phosphorus concentration was kept around 1.4 mg/L for the nutrient requirements of the micro-organisms present in the activated sludge. When reactor was stabilized, P concentration was increased to about 10 mg/L (on day 84). Reactor was operated at 10 mg/L of phosphorus concentration for 30 days. In the beginning, total phosphorus (TP) concentration at the outlet was as high as 2.9 (72% removal of TP), but thereafter removal efficiency of the system was increased, that's observed almost equal to 92-97% (with 0.3 to 0.8 mg/L TP in the outlet) at steady state condition of the system, as shown in figure 2.

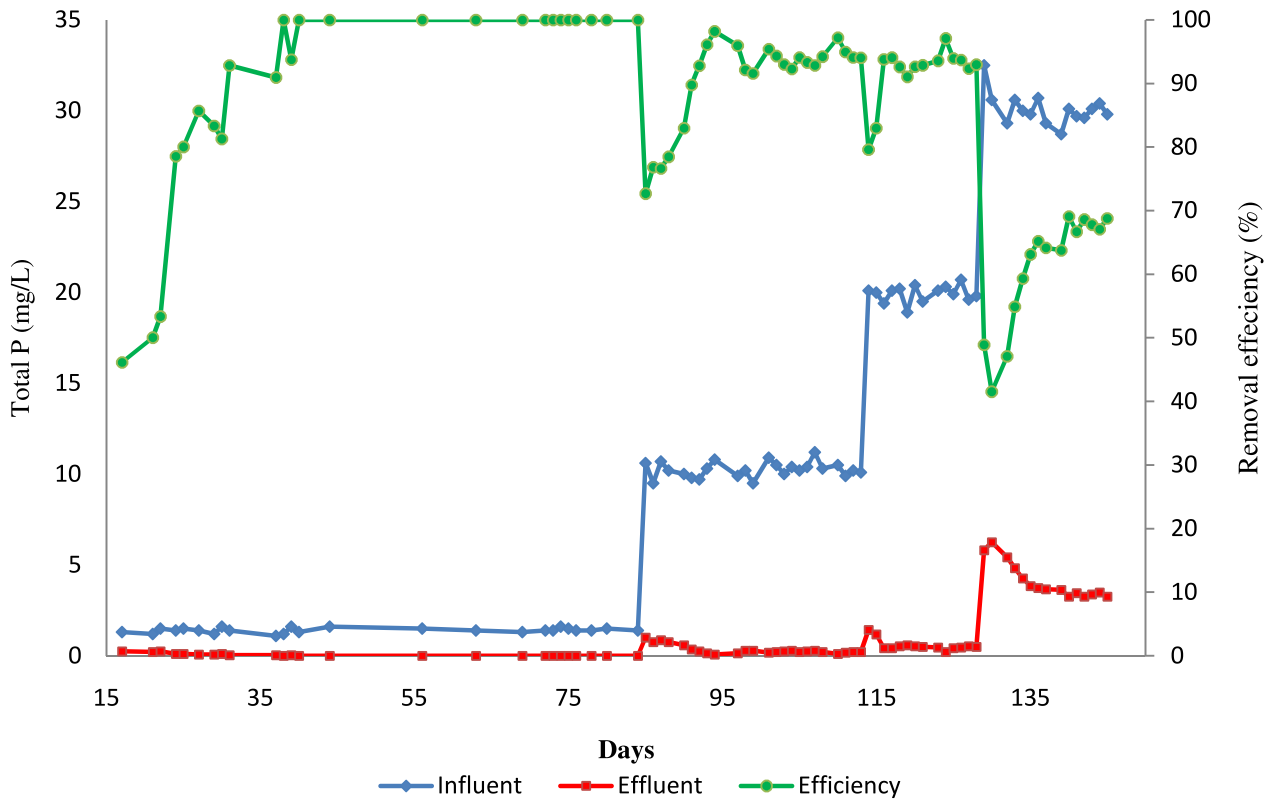

Fig. 2 TP removal during long term operation

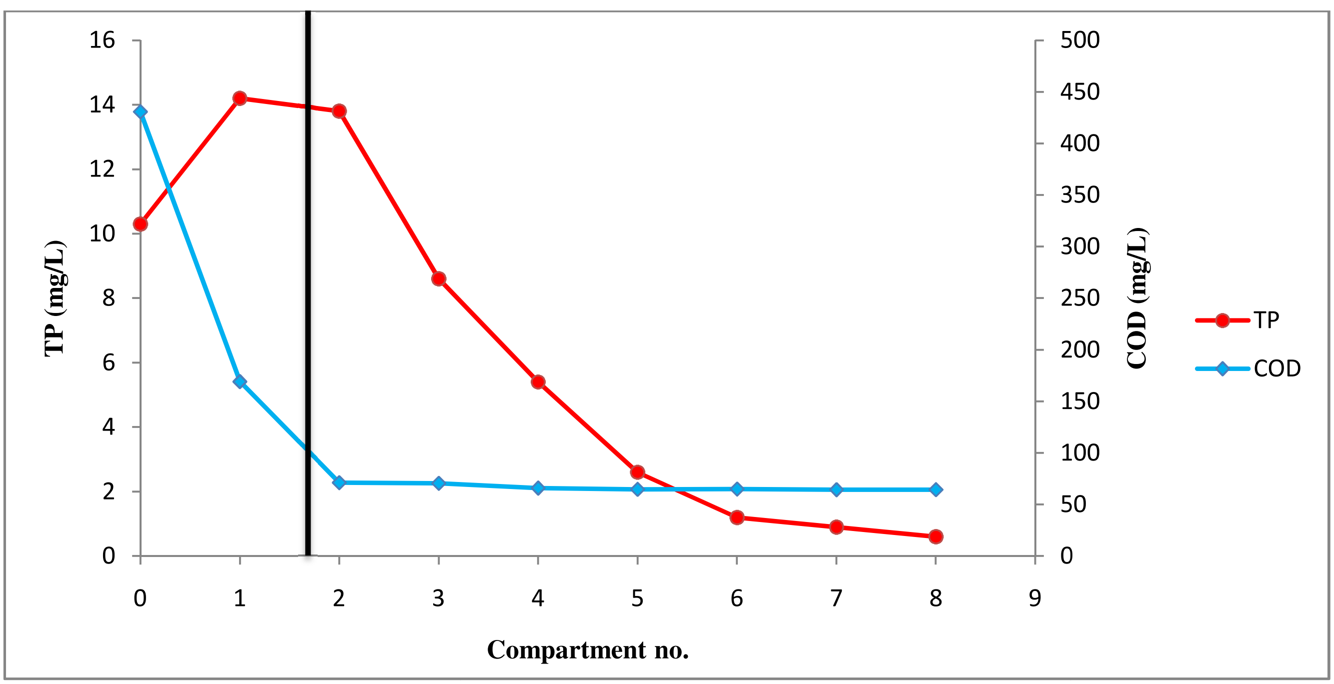

Fig. 3 Variations in TP and COD concentrations along the length of the reactor

Then P concentration was further increased to about 20 mg/L (on day 114) and effect of this increase in P loading was observed for 15 days. Net-phosphorus removal with a good efficiency (91-97%) was observed even at this increased loading of phosphorus in the feed, with outlet concentration of phosphorus in the range of 0.6-1.7 mg/L TP, as shown in figure 2. On day 129, P concentration was again increased to about 30 mg/L and effect of this increase in concentration was studied for 17 days. At steady state condition, almost 63-69% phosphorus removal efficiency was observed with corresponding concentration of TP at outlet almost equal to 9.3 to 11 mg/L, as shown in figure 2. From this observation, it may be concluded that PAOs including other microbes present in the activated sludge are not capable to remove phosphorus in excess of 19-21 mg/L.

3.2 Compartment-wise study

On day 105, compartment-wise variation in COD and TP concentration was analyzed, as shown in figure 3. From this figure, two different phases can be easily distinguished, namely feast and famine. In the famine phase, where very less food was available, phosphorus uptake was observed, whereas COD concentration remained almost constant. This phenomenon is similar as that's observed in the aerobic zone of standard EBPR process. From these facts, it may be concluded that feast-famine phases of completely aerobic EBPR systems are analogous to the anaerobic-aerobic phases of conventional EBPR process.

In synthetic feed $MgSO_4$ and $CaCl_2$ were used, so one possible reason of phosphorus removal could be through chemical precipitation of PO_4. But precipitation of P with Ca^{2+} ion needs a pH value greater than 10 and ratio of Ca/P > 5 (Ghigliazza et al., 1999). Since in present study pH value was observed between 7- 8.5 and maximum Ca/P = .05 (0.5 mg/L Ca and 10 mg/L TP), hence this possibility is excluded. Chemical precipitation as $MgNH_4PO_4$ requires a molar ratio of NH_4:Mg:PO_4 equal to 1:1:1 (Ghigliazza et al., 1999), which was not maintained in the feed. Hence this hypothesis is also excluded.

Therefore we argued that phosphorus was removed in the form of poly-phosphate which was discharged out with the excess sludge. Addition of dried powdered sludge also helped in the removal of phosphorus by increasing settling characteristics of the poly-phosphate rich active sludge composed of PAOs.

4. CONCLUSIONS

The configuration tested here, along with addition of dried powdered sludge, shows the feasibility to treat medium strength wastewater while removing biological phosphorus with high efficiency at the same time. The results of this study were also in the support of some previous work, that biological phosphorus removal could be achieved in a single stage oxic process without providing anaerobic phase, which was conventionally considered as a key phase of biological phosphorus removal.

REFERENCES

[1] Ahn J, Daidou T, Tsuneda S, Hirata A. Transformation of phosphorus and relevant intracellular compounds by a phosphorus-accumulating enrichment culture in the presence of both the electron acceptor and electron donor. Biotechnology and Bioengineering 2002; 79 (1):83–93.

[2] Ghigliazza R, Lodi A, Rovatti M. Phosphorus removal in aerated stirred tank reactor. Bioprocess Engineering 1999; 20:257-262.

[3] Guisasola A, Pijuan M, Baeza J.A, Carrera J, Casas C, Lafuente J. Aerobic phosphorus release linked to acetate uptake in bio-P sludge: process modelling using oxygen uptake rate. Biotechnology and Bioengineering 2004; 85 (7):722–723.

[4] Nielsen P.H, Saunders A.M, Hansen A.A, Larsen P, Nielsen J.L. Microbial communities involved in enhanced biological phosphorus removal from wastewater - a model system in environmental biotechnology. Current Opinion in Biotechnology 2012; 23:452–459.