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Enhancing denitrification phosphorus removal with a novel nutrient removal process: Role of configuration

Hongbo Liu [a,*], Mengling Zhu [a], Saisai Gao [a], Siqing Xia [b], Liping Sun [c]

[a] School of Environment and Architecture, University of Shanghai for Science and Technology, 200093 Shanghai, China
[b] State Key Laboratory of Pollution Control and Resource Reuse, Tongji University, 200092 Shanghai, China
[c] Tianjin Key Laboratory of Water Quality Science and Technology, 300384 Tianjin, China

HIGHLIGHTS

- A novel tow configuration (process) was proposed to enrich DPB treating low strength real wastewater.
- Configurational profiles of model intracellular compounds i.e. PHA and glycogen were characterized.
- Configurational mass flow characteristics were demonstrated.
- Two rules of thumb have been confirmed to enrich DPB with proper configuration.

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ABSTRACT

Role of configurations on enriching denitrifying phosphorus removing bacteria (DPB) by biological nutrient removal processes was discussed. Effects of configurations on enhancement of denitrifying phosphorus removal in a novel nutrient removal process, the STB (six-tank-bioreactor) process were investigated. Profiles of model intracellular compounds i.e. glycogen and PHA (poly-hydroxyalknoates) under different configurations were characterized in order to reveal the biochemical pathway that DPBs might follow in the STB process. Mass flow characteristics of main pollutants under different configurations were also illustrated. Results showed that a higher anoxic to total volume ratio and the multi-barrier bioreactor strategy were crucial factors to enhance denitrifying phosphorus removal in the STB process. Both of the configurations performed well with average removal efficiencies of 74%, 98%, 51% and 85% under configuration I, and 74%, 99%, 72% and 70% under configuration II for COD, NH_3–N, TN and TP respectively. A higher denitrifying phosphorus removal efficiency was achieved under configuration II than configuration I due to a bigger anoxic to total volume ratio.

1. Introduction

Eutrophication is a severe environmental problem that impairs fundamental water functions such as irrigation, drinking water source, and landscapes worldwide [1], with excessive anthropogenic discharge of nitrogen (N) and phosphorus (P) blamed to be chief culprits [2]. Effluent N and P discharging standards for waste water treatment plants (WWTPs) are increasingly stringent to meet mandatory nutrient removal requirements by most of the regulations [3]. So far biological nutrient removal (BNR) is much more environment friendly and cost-effectively than chemical and/or physical nutrient removal [4,5].

High efficient nitrogen and phosphorus removal is very difficult to realize simultaneously by BNR processes when influent carbon strength is insufficient, which leads to additional cost by dosing carbon sources such as methanol or by dosing phosphorus precipitation chemicals such as salts of calcium, iron, and/or aluminum [6]. Denitrifying phosphorus removal has been confirmed to be an effective way easing competition between denitrifying bacteria and phosphorus removing organisms (PAOs) for limited carbon resource, since it removes phosphorus and nitrogen simultaneously with frugal carbon consumption, which illustrates the old proverb that *shooting two birds (nitrogen and phosphorus) with one stone* (*carbon resource*) in an interesting way [7]. Occurrence of denitrifying phosphorus removal has been observed in many wastewater treatment configurations such as the so called A^2/O (anaerobic–anoxic–aerobic) process and the UCT (University of Capetown) process [8,9]; however, the fraction of anoxic phosphorus removal to total phosphorus removal in these configurations were not quite high, which caused inefficient saving of carbon resource and unstable N and P removal performances; the total carbon resource for both P and N removal would still be lacking even taking carbon saving of

* Corresponding author. Address: 516 Jungong Road, Shanghai, China. Tel.: +86 (21)54280896; fax: +86 (21)55275979.
E-mail address: Liuhb@usst.edu.cn (H. Liu).

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these configurations into account [10,11]. As a result, enrichment of denitrifying phosphorus removing bacteria (DPB) in BNR processes is very crucial and so far this task remains challenging [12].

Although researchers are arguing about biochemical and/or microbial mechanisms behind macro behaviors of DPB [13,14], they agree in consensus that DPBs can be enriched by proper configurations and that process performances can be enhanced by optimizing operational modes [8,15]. The anaerobic-anoxic–nitrifying (A_2N) process was configured to enrich DPB with anaerobic–anoxic cycles based on its biochemical behaviors. Ammonium concentration in the effluent of this process, however, is difficult to meet the discharging standard because a certain ratio of ammonium in influent was split from the main stream and subject to no nitrification [10,16]. The Dephanox process adds a small aerobic tank after the A_2N configuration to avoid biomass floating of the sedimentation tank [13,17]. Effluents from both the A_2N and the Dephanox processes were reported to need further polishing in most practices [13,16,18]. Some studies demonstrated that the BCFS process (Biologische-Chemische-Fosfaat-Stikstoverwijdering) could achieve an acceptable effluent by involving denitrifying phosphorus removal, but only few researches revealed how the performances were affected by process configurations [1,19]. In fact, two rules of thumb can be learnt from the BCFS process: (1) a higher anoxic to total volume ratio is beneficial to DPB enrichment and (2) the multi-barrier strategy with serial bioreactors is necessary to guarantee an acceptable effluent [20].

Previously, we have proposed a Six-tank-bioreactor (STB) configuration to enrich DPB with an anoxic to total volume ratio as high as 33% and results confirmed that denitrifying phosphorus removal accounted for more than 50% of the total phosphorus removal [21]. The STB process is characterized by a tow configuration with six compartments (tanks) identical in size (Fig. 1(a)). The compartments (tanks) were connected by installing plate valves between the shared sides, which makes the configuration flexible in operational modes. It could be operated as some major BNR processes such as A^2/O, UCT and BCFS with changing feeding positions and internal/external return places [22].

In previous studies, we focused on optimizing operational parameters such as HRT (Hydraulic Retention Time) of configuration I [21,22]. However, we also acknowledge that configuration II (Fig. 1(b)) could be another major modification and might be more favorable than configuration I since it saves an influent line. Up to now role of configuration in enhancing denitrifying phosphorus removal of the STB process still stand unclear and need more efforts before further application.

This study aims to demonstrate effects of configuration on enhancement of denitrifying phosphorus removal in the STB process. Performances of the process in terms of chemical oxygen demand (COD), N, and P removal under different configurations and operational modes were investigated; configurational profiles of intracellular compounds were characterized; mass flow characteristics were also illustrated.

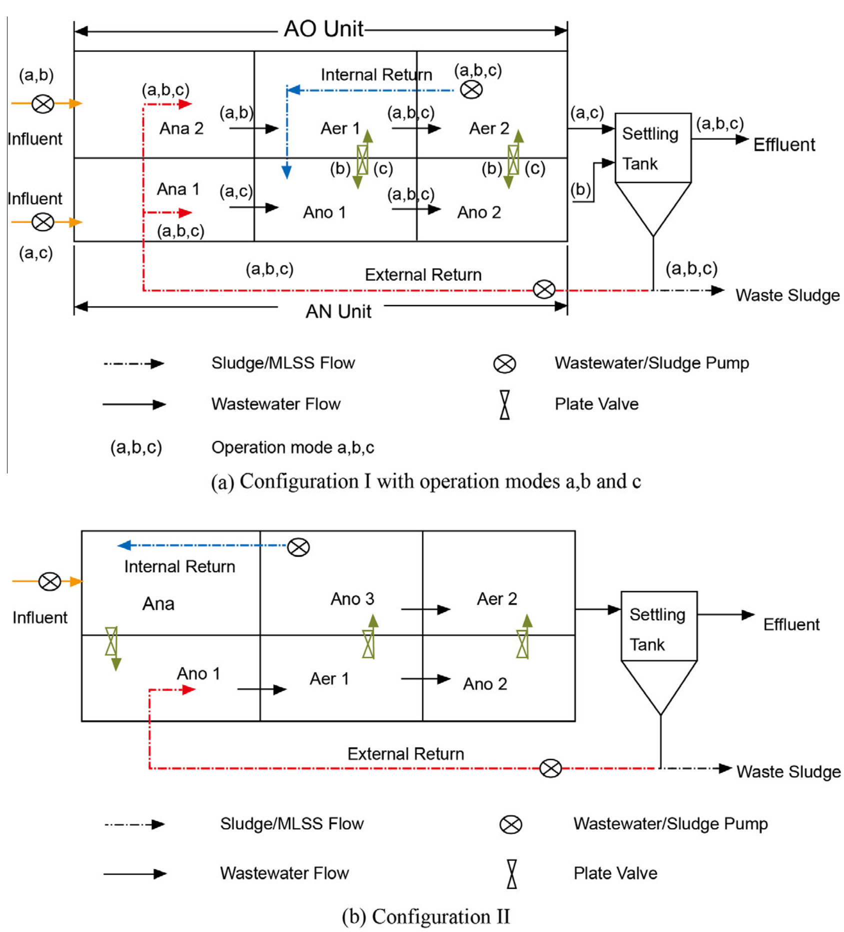

Fig. 1. Diagram of the Six-tank bioreactor process; differences between configuration I (a) and II (b) were highlighted with colors. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)