Effects of A_2ON Process on Denitrifying Dephosphatation

Lifang Guo (Corresponding author)
Faculty of Civil Engineering, Luoyang Institute of Science and Technology
Luoyang 471023, China
E-mail:guolf222@163.com

Shanquan Jiang
Chongqing University of Art and Sciences, Chongqing, China

Abstract

In combination with activated sludge process and biomembrance process, based on the principle of denitrifying dephosphatation, A_2ON processes for biphase sequencing batch reactor biological nutrient removal (BNR) treatment have been developed, with an emphasis on the effects of the ratio of COD to TN (COD/TN) variations on the BNR treatment. Results indicated that the process possessed stable effects, showed strong flexibility for water quality, could attenuate the aerobic requirement and decrease the competition of denitrifying and dephosphation for carbon source to a greater degree, and meanwhile guaranteed that nitrifying bacteria about a generation time could grow stably.

Keywords: Sequencing biomembrane batch reactors (SBBR), Denitrifying dephosphatation, Denitrifying phosphorus removing bacteria (DPB), A_2ON

Through the studies on the phosphorus accumulation mechanism of PAO bacteria in recent years, a type of phosphorus accumulation bacteria, viz. facultative anaerobic denitrifying bacteria have been found. DPB (Denitrifying phosphorus removing bacteria) could not only absorb phosphorus in aerobic environment, but also manage to phosphorus intake in hypoxia (without O_2, in the presence of NO_3^-) (Wanner,1992, PP. 445-448; Kube, 1993, PP. 241-252), and meanwhile possessed denitrification. A matrix with both effects of denitrification and dephosphorization was of important significance when wastewater carbon source was insufficient.

Currently, denitrifying dephosphatation reactor could be classified into single and double sludge system. In the process of single sludge system, DPB bacteria, nitrifying bacteria and be divided into single and double sludge system. In the single sludge process, DPB bacteria, nitrifying bacteria and non phosphorus accumulation heterotrophic bacteria simultaneously existed in a mixture of suspended growth, and experienced three kinds of environment, viz. anaerobic, anoxic and aerobic environment. Among those processes, UCT and BCFS were the most typical (Kuba, 1996, PP. 1702-1706; Falkentoft, 1999, PP. 3303-3310). In the double sludge system, nitrifying bacteria was independent of DPB and existed in a certain reactor singly. Double sludge processes mainly contained Dephanox and A_2NSBR (Shi, 2010; Feng, 2009). The former was continuous flow and the later was intermittent flow.

Although DPB in both single and double sludge system could use nitrate induced by nitrification as electron acceptor to exert denitrifying dephosphatation in the anoxic environment, researchers generally speculated that the latter was more stable with better treatment effect, because that double sludge system created the optimum growth environment for nitrifying bacteria and denitrifying dephosphatation, and SRT of nitrification and denitrifying dephosphation system.

The current double sludge system was also deficient, and the key issues were as follows:

① Exchangeable volume ratio in activated sludge process was low (moisture content of suspended sludge was high), and a large number of NH_4^+-N remained in sludge, which affected the removal rate of TN. The measure we took was that activated sludge process was replaced by biomembrane process as the main reactor for denitrifying dephosphatation.

② According to the dephosphorization mechanism, PAO bacteria in the process of anaerobic phosphorus release could only absorb low molecular weight organic compounds such as volatile organic acids VFA to synthesize PHB, and had great difficulty to utilize aerobic aeration only for nitrification because there were considerable refractory organic matters in the treatment water. After anaerobic environment, it was necessary to remove refractory organic matters.

1. Materials and methods

1.1 A_2ON process design

Based on our observations on A_2N (also called intermittent flow double sludge system), A_2ON process was brought forward (A_2O showed anaerobic-aerobic/anoxic, and N denoted nitrification). The process applied double sludge system, in combination with activated sludge process and biomembrance process, and operated in a sequencing batch manner. It was composed of a sequencing batch biomembrane reactor SBBR, a SSR and an intermediate regulating reservoir. Process flow was delineated in Figure 1 in detail. SBBR was responsible for anaerobic phosphorus release A, anoxic denitrifying dephosphatation A and aerobic decarbonization O; SBR dedicated nitrification N.

1.2 Experimental equipment

Experimental equipment was composed of a new type of SBBR, a SBR and an intermediate regulation reservoir, with a total volume of 20 L. Its main body was SBBR, and was filled with soft fiber filter with the packing ration of 20%. Mixer could be added to it. The diagram was as follows:

The smallest unit of filter was a hemispherical fascicule with the diameter of about 5 cm and large specific surface area (1500 m/m^3). Filling manner was wall surface mounting type, namely that the filter leaned against the wall, and arranged in the bracket centripetally like a meshwork. The array was neatly in order, and the distance from each unit could be adjusted. The system had 243 units together. The used reactor was single layer filter, and if the experiment was enlarged, it was easy to combine multi-layer filters.

1.3 Operation steps

Operation steps of each cycle were as follows:

Anaerobic-aerobic/anoxic SBBR (AO / A-SBBR)

① Anaerobic zone 3h Wastewater flew into SBBR, and was stirred. Phosphorus accumulation bacteria absorbed volatile organic acids (VFA), and released phosphorus.

② Aeration zone 2h Sticky sand pieces were undertaken blast aeration in order to reduce COD further.

③ Static precipitation 15 min After precipitation, all treatment water was drained into N-SBR.

④ Anoxic zone 3h Treatment water with the high content of phosphorus and nitrate resulted from the last cycle was deposited from intermediate regulation reservoir. DPB was undertaken denitrifying and phosphorus accumulation simultaneously under the condition of continuous stirring.

⑤ Kept static for 15 min, and then drained the wastewater.

Nitrication SBR (N-SBR)

① Nitrification zone 5 h Treatment water resulted from AO/A-SBBR was undertaken aerobic aeration for 5 h, and NH_4^+ was oxidized into nitrate.

② Precipitation 30min Supernatant with considerable phosphorus and nitrate was drained into intermediate regulation reservoir.

1.4 Analysis items and methods

COD: potassium dichromate method; pH: electrode method; NH_3-N: Nessler's Reagents spectrophotometry; NO_2^--N: N-(1-Naphthyl) Ethylenediamine spectrophotometry; NO_3^--N: phenol disulfonic acid spectrophotometry; TN: potassium persulfate digestion-phenol disulphonic acid spectrophotometry; TP: potassium persulfate digestion-molybdenum-antimony anti-spectrophotometric method; PO_4^{3-}-P: molybdenum-antimony anti-spectrophotometric method; MLSS: filter-weighing method; SV: graduated cylinder method.

1.5 Cultivation and domestication of biomembrane and nitrifying sludge

Domestic sewage came from a certain college living area, and its water quality fluctuated tremendously, with its parameters listed in Table 1. Sludge strains were sampled from laboratory activated sludge pool, and biomembrane and N-SBR were cultivated for 2 months respectively.

Cultivation and domestication process of biomembrane was divided into two stages. The first stage, activated sludge was added into the system, and thus the previously existing wastewater was undertaken anoxic aeration. The first stage operated for 40 d to make the system membrane-hanging successfully. The average thickness of biomembrane was 5 mm. Any single biomembrane carrier was rinsed and weighed, and the whole biomass converted by the weight was 8000 mg/L, which indicated that SBBR biomass was quite large.

The second stage was to cultivate the system SBBR phosphorus accumulation ability. First, cultivation and domestication was in an A/O manner, and each cycle was 12 h, 6 h for anaerobic process, 6 h for aerobic aeration. After 20 d, cultivation and domestication was in an A/A manner with the whole 40 cycles. When anoxic phosphorus removal ability attained 70%, SBBR was kept for further utilization.

Cultivation of N-SBR nitrifying sludge was also divided into two stages. The first stage, added activated sludge, and used domestic sewage continuous aeration to cultivate SBR biomass; the second stage, when MLSS attained 2 mg/L, changed influent with low COD and high ammonia nitrogen wastewater or effluent from cultivated biomembrane, and enhanced nitrifying ability gradually until ammonia nitrogen removal rate attained 90%.

At the beginning of the experiment, two reactors were incorporated into the system and applied together. Aeration rate was kept for 0.06m3/h.

In order to ensure the C/N, N/P ratio for experiments, glucose, NH_4^+Cl and sodium dihydrogen phosphate were added to the sewage. MLSS and SRT in SBR were 2 g/L and 50 d, respectively. Biomass of SBR was 8 g/L if converted into MLSS. SBBR was backwashed periodically (4-8 cycles), in order to speed the removal and release of biomembrane rich in phosphorus.

2. Results and discussions

2.1 Treatment effects

After the system operation was stable, a certain treatment cycle with a universal significance was selected to delineate major water quality indices-time curve.

Nitrogen, phosphorus and COD changes during a certain cycle treatment were depicted in Figure 3. In anaerobic zone, COD declined, phosphorus concentration increased, DPB began to hydrolyze its adenosine triphosphate (ATP) to release energy and phosphate and absorb organic matters to synthesize PHB (Xiao, 2005, PP. 7-9). Abundant external carbon source and quite long anaerobic time made DPB to release phosphorus sufficiently, COD deceased by 40% in 3 h, there were considerable refractory organic matters in the treatment water, and TP doubled approximately.

In aerobic zone, through diffused aeration, COD was continuously removed, and meanwhile a small amount of phosphorus (30%) was absorbed by PAO using oxygen as electron acceptor (Li, 2006, PP. 106-107). Aerobic heterotrophic bacteria propagated tremendously, and their organic matters for metabolism also contained carbon source absorbed by biomembrane, which made good preparation for the later anoxic denitrifying (In the case of treatment solution with carbon source, normal denitrifying bacteria tend to give priority to denitrification with no good for DPB denitrifying dephosphatation). In this stage, due to plenty carbon source and short aeration time, P and NH_4^+ removal was not obvious, because the competition for matrix, the dense special structure of biomembrane, and large proliferation of heterotrophic bacteria (zoogloea) during aeration in the surface impeded the facultative phosphorus accumulation bacteria to acquire oxygen. Consequently, phosphorus accumulation bacteria used oxygen inadequately in short term; the presence of carbon source also baffled nitrification, and nitrifying and heterotrophic bacteria's competition for oxygen caused the delay of nitrification in the same way. After aeration for 2 h, COD reduced to 100~120 mg/L. In addition, the biomembrane had low moisture content and its exchangeable volume ratio (water exchange rate) approached 100%, which could exclude the residues of NH_4^+ in biomembrane (DPB sludge) efficaciously.

In nitrification zone, treatment solution rich in P and NH_4^+ was drained into N-SBR. Sludge with long age enhanced the concentration of nitrifying bacteria in sludge, influent with low concentration of COD was helpful to exert the nitrifying function, at the same time proper COD concentration (100 mg/L or so) could avoid the excessive proliferation of filamentous fungus, and NH_4^+ was oxidized by nitrifying bacteria into nitrated with high efficacy. After calculation, nitrification rate was 0.055 mg NH_4^+-N/ (gMLSS•min). P concentration kept constant (N-SBR lacked two necessary conditions for phosphorus accumulation: anaerobic time and carbon source), and after 5 h, when NH_4^+-N concentration was quite low, supernatant was precipitated and drained into intermediate regulation reservoir.

In anoxic zone, nitrifying wastewater rich in P and nitrate from intermediate regulation reservoir was drained into SBBR, and as seen from Figure 3, TP and NO_3^--N concentration reduced gradually, which indicated that the simultaneous removal of nitrogen and phosphorus (Hang, 2010). With the considerable assimilation of P by DPB using nitrate as electron acceptor and internal carbon source as electron donor, NO_3^- managed to exert denitrification. When reaction was over, NO_3^--N <5 mg/L, TP<1 mg/L while NH_4^+-N was almost undetectable.

2.2 Effects of C/N on the removal of N and P

Figure 4 depicted the effects of influent C/N on the removal of N and P. In the present process, the optimum C/N ranged from 5 to 10.

Influent C/N had great impact on the treatment effect, and as seen from Figure 4 (a), C/N ranged from 5-10 with P removal rate of over 80%. When influent C/N was higher than 10, anoxic denitrifying dephosphatation caused incomplete P removal due to the shortage of nitrate nitrogen. When C/N was lower than 5, nitrate surplus occurred, which affected the effluent TN concentration. As seen from Figure 4 (b), N removal rate increased with the increasing of C/N, and when C/N was 5, N removal rate attained 80%, which indicated that high C/N was always in favor of N removal. Low C/N caused not only the over standard of effluent nitrate nitrogen, but also the loss of biomass, because long nitrate surplus would lead to the premature shedding of biomembrane. However, moisture content of sludge fixed by biomembrane was low, and fewer nitrate remained after each drainage, which commonly wouldn't affect the anaerobic phosphorus release of the next cycle.

3. Conclusions

In this experiment, A_2ON system showed a stable N and P removal ability. In the optimum condition, the removal rate of COD, TN and TP attained 91%, 85% and 87%, respectively, which indicated that SBBR could accumulate DPB bacteria and ensue obvious denitrifying dephosphatation. Because denitrifying dephosphatation could save carbon source, the system showed a better treatment effect when C/N was 5.

The establishment of aerobic zone in SBBR was helpful to the growth of zoogloea and the cultivation of biomembrane. In addition, results showed that SBBR aerobic aeration decreased the COD and TP concentration of treatment water, made the follow-up nitrification zone really dedicate nitrification and thus enhanced nitrification efficiency enormously.

Reactor using SBBR as the main body to remove N and P could extremely eliminate the residual of NH_4^+ in biomembrane (DPB sludge), and enhance the removal rate of TN greatly. Abundant biomass and diverse biological species of SBBR ensured the stable and efficient exertion of denitrifying dephosphatation. Furthermore, sludge production of SBBR was low and easy to maintain and manage. Attention should be paid to that biomembrane was prone to accumulating microorganism with long generation time, its sludge age was relatively high, but P removal was achieved finally through excluding sludge. Accordingly, biomembrane should be backwashed periodically, and shedding biomembrane should be eliminated timely.

References

Falkentoft, C.M. (1999). The significance of zonation in a denitrifying, phosphorus removing biofilm.Wat Res, 33(15): 3303-3310.

Feng, L.Y., Zhou, S.Q., & Wu, S.X. (2009). Study on nitrogen and phosphorus removal in biomembrane two-sludge SBR system. Chinese Journal of Environmental Engineering, 2.

Hang, Y., & Zhang, S.H. (2010). Basic study on short-cut denitrifying phosphorus removal. Journal of Wuhan University of Technology, 2.

Kuba, T. (1996). Phosphorus and nitrogen removal with minimal COD requirement by integration of nitrication in a two—sludge system.Wat.Res., 33(7): 1702-1706.

Kube, T., Smolders, G., & Van Loosdrecht, M.C.M.., et al. (1993). Biological phosphorus removal from wastewater by anaerobic-anoxic sequencing batch reactor. Wat.Sci.Tech, 27(5-6),241-252.

Li, J., Chen, Y.G., & Gu, G.W. (2006). Enhanced biological removal of phosphate by aerobic granular sludge. Environmental Science & Technology, 29(7):106-107.

Shi. J., Lv, X.W., & Wu, Y.F. (2010). Removal of organic substrates, phosphorus and nitrogen by two-sludge and induced crystallization process. CIESC Journal, 5.

Wanner, J. (1992). New process design for biological nutrient removal. Wat.Sci.Tech, 25,445-448.

Xiao, F., & Gu, G.W. (2005). Discussion on enhanced biological phosphate removal. Environmental Science & Technology, 28(6):7-9.

Table 1. Domestic sewage water quality

Parameter	COD	NH_4^+-N	TN	TP	pH
Range	180~550	25.0~55.0	30~60	4.00~12.00	7.04~7.68
Average	350	32	42	8	7.38

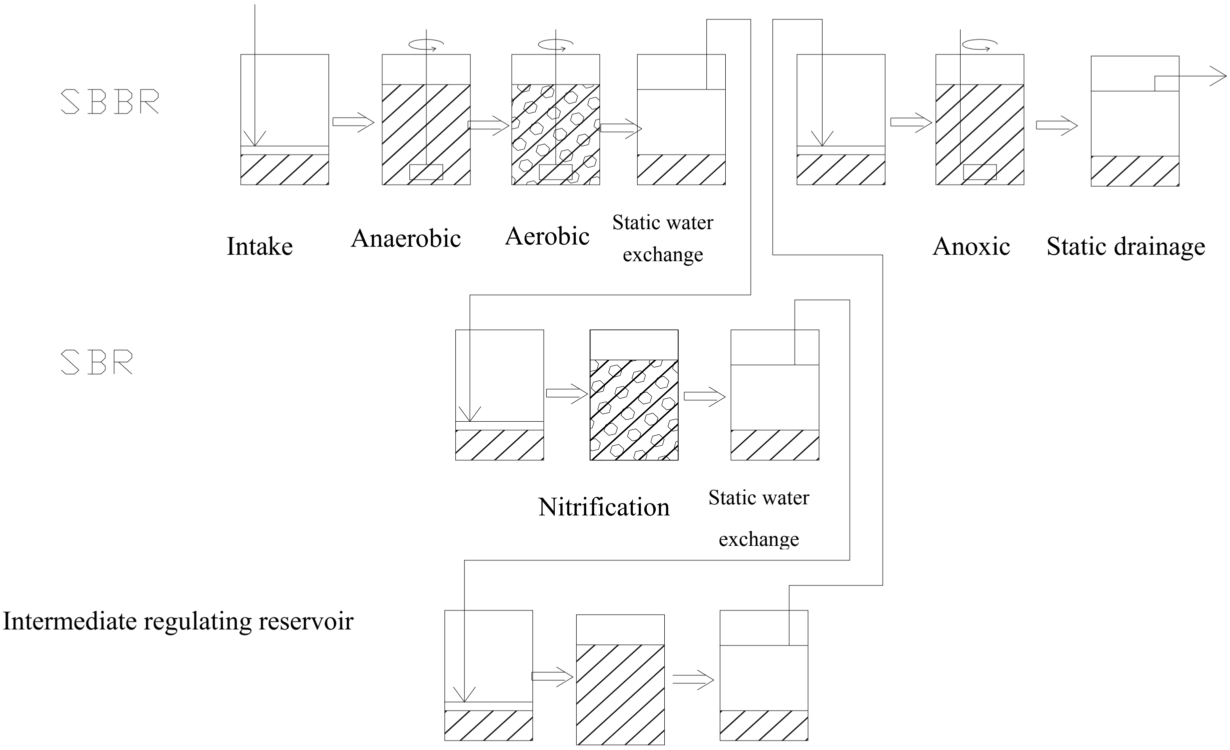


Figure 1. Technological flow chart

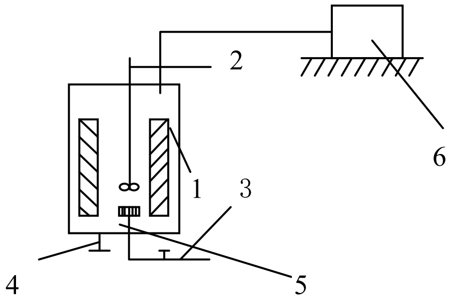
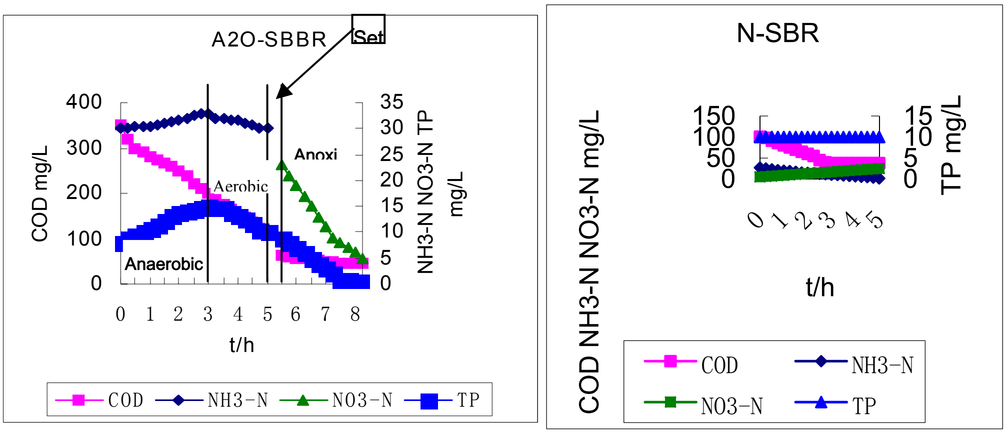


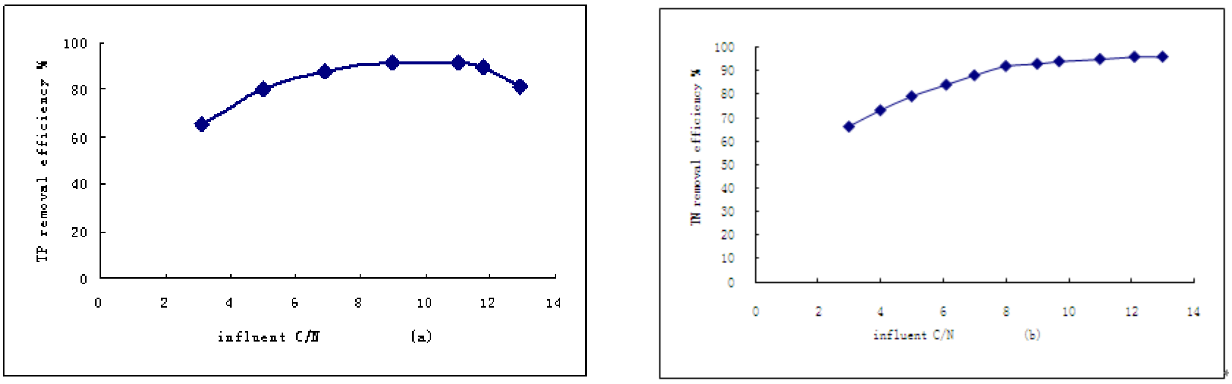
Figure 2. SBBR equipment

1 Meshy soft filter; 2 Screw mixer; 3 Aeration device; 4 Spoildisposal equipment; 5 Precipitation zone; 6 High water tank



(a) (b)

Figure 3. Treatment effects



(a) (b)

Figure 4. Effects of influent C/N on the removal of N and P