Journal of Environmental Sciences Vol.14, No.2, pp.245—249, 2002

ISSN 1001—0742
CN11—2629/X

Article ID: 1001-0742(2002)02-0245-05 **CLC number**: X703 **Document code**: A

Addition of anaerobic tanks to an oxidation ditch system to enhance removal of phosphorus from wastewater

LIU Jun-xin[1*], J.W. van Groenestijn[2], H.J. Doddema[2], WANG Bao-zhen[3]

(1. Department of Water Pollution Control Technology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China. E-mail: jxliu@mail.rcees.ac.cn; 2. Department of Environmental Biotechnology, TNO Institute of Environmental Sciences, Energy Research and Process Innovation, P.O. Box 342, 7300 AH Apeldoorn, The Netherlands; 3. School of Municipal and Environmental Engineering, Harbin Institute of Technology, Harbin 150090, China)

Abstract: The oxidation ditch has been used for many years all over the world as an economic and efficient wastewater treatment technology. It can remove COD, nitrogen and a part of phosphorus efficiently. In the experiment described, a pilot scale Pasveer oxidation ditch system has been tested to investigate the removal of phosphorus from wastewater. The experimental results showed that influent total phosphorus(TP) was removed for 35% – 50%. After this, two anaerobic tanks with total volume of 11 m^3 were added to the system to release phosphorus. As a result, the TP removal efficiency increased by about 20%. At an anaerobic HRT of about 6 hours, a TP removal efficiency of 71% was achieved.

Keywords: phosphorus removal; oxidation ditch; wastewater treatment

Introduction

Eutrophication of water bodies has been attended many years by scientists and the public. Phosphorus in the water bodies originates from the atmosphere, agriculture and domestic and industrial wastewater; domestic and industrial wastewater being the largest source. Therefore, an efficient removal of phosphorus from wastewater is very important to prevent eutrophication. Phosphorus removal from wastewater can be achieved either through chemical removal, biological removal or a combination of both.

The oxidation ditch is an economic and efficient wastewater treatment technology. At present there are many thousands of wastewater treatment plants all over the world, which are based on the oxidation ditch principle. The primary feature of the oxidation ditch process is a low loading rate; therefore, it has capabilities of both efficient COD removal and nitrification. Nitrogen removal in the oxidation ditch can be carried out through the control of oxygen supply to form the aerobic and anoxic zones within one oxidation ditch(Liu, 1996a). However, it is very difficult to form the anaerobic zone within the oxidation ditch for biological removal of phosphorus because of the low loading rate. In order to form the anaerobic zone, the capacity of oxygen supply will be further reduced and the volume of the oxidation ditch will be increased. The flow velocity of the mixed liquor in the ditch will be decreased at the same time. When the flow velocity is lower than 0.3 m/s, the sludge in the ditch will settle on the bottom of the ditch(Poustan, 1993). Therefore, the efficiency of phosphorus removal in the conventional oxidation ditch was low. If an anaerobic tank is built separately from the oxidation ditch and the sludge from the clarifier is put into this tank, phosphorus can be released from it as ortho-phosphate. The sludge from the clarifier can quickly form the anaerobic state required for release of phosphorus in the presence of the absence of supplemental organic carbon in the anaerobic tank, because the organic matter contained in the sludge of the clarifier was enough to facilitate the release of phosphorus under anaerobic conditions(Liu, 1996b). Therefore, the organic carbon in the raw wastewater can be used for denitrification in the anoxic zone and the efficiency of denitrification can be raised. After sedimentation, the sludge that has released phosphorus can be returned into the oxidation ditch to absorb phosphorus again. The phosphorus rich water of the anaerobic tank can be treated by a chemical method. It is an economical and easy method to add anaerobic tanks to the oxidation ditch system to enhance phosphorus removal.

* Corresponding author

1 Materials and methods

1.1 Experimental equipment

A pilot scale Pasveer oxidation ditch system used in the experiment consists of a grit chamber, a single-channel ditch and a clarifier. For enhancing phosphorus removal, two anaerobic tanks with a diameter and depth of 2.0m and 1.75m respectively were added to the Pasveer oxidation ditch system. Its flow sheet is shown in Fig. 1. The top width, the bottom width, the water depth and the center length of the ditch are 3.6m, 1.2m, 1.0m and 68.5m respectively. The volume of the ditch is 150m^3. A brush is used as aerator in the ditch, and its length and diameter are 1.5m and 0.7m respectively. The brush rotates with a speed about 80 r/min. The clarifier consists of a cylinder with a diameter of 1.65m and a cone. The depths of the cylinder and the cone are 1.5m and 0.8m respectively. The grit chamber is cubic, and its volume is about 40m^3. The total volume of the anaerobic tanks was about 11m^3. In every tank a stirrer was placed to prevent sludge settling on the bottom. In the system, the return sludge from the clarifier to the Pasveer oxidation ditch first passed the anaerobic tanks to release phosphorus. In anaerobic tank 2, the rotation of the stirrer was slow to separate the sludge and the phosphorus rich water. The sludge that had released phosphorus was returned to the Pasveer oxidation ditch, and the phosphorus rich water was discharged but could have been continuously treated by a chemical method.

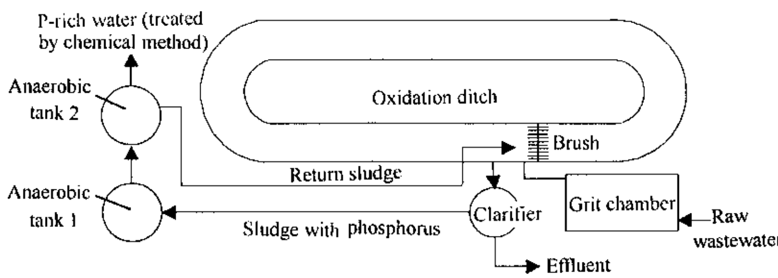

Fig. 1 The flow sheet of the oxidation ditch

1.2 Experimental conditions and analytical methods

The investigation lasted 17 months, 8 months without the anaerobic tanks and 9 months with the anaerobic tanks. The raw wastewater came from the sewer of Delft City (The Netherlands) and its characteristics during the investigation are summarized in Table 1.

Table 1 The characteristics of the test wastewater

Parameter	Range	Mean
pH	7.0 – 8.4	7.7
SS, mg/L	30 – 477	138
COD, mg/L	117 – 1267	462
NH_4-N, mg/L	30 – 110	75
NO_3-N, mg/L	0.5 – 1.4	1.0
NO_2-N, mg/L	0 – 0.3	0.1
TKN, mg/L	39 – 133	90.2
TN, mg/L		91.3
TP, mg/L	4.3 – 22.4	11.9
COD:TN		5.1
COD:TP		38.8

During the investigation, the temperature of mixing liquor in the oxidation ditch was 1 – 25℃ and its monthly mean values was 2.2 – 22℃. The influent flow rate was 50 – 100 m^3/d, which the corresponding HRT was 72 – 36 hours. The loading rates of TP, NH_4-N and COD in the oxidation ditch were 1.3 – 3.2g/(kgMLSS·d), 8.9 – 18.7 g/(kgMLSS·d) and 58.5 – 140.5 g/(kgMLSS·d), respectively. The MLSS in the oxidation ditch and the anaerobic tanks were between 1.7 – 3.9 g/L and 3.2 – 10.6 g/L, respectively. The ratio of MLVSS and MLSS was about 0.70 – 0.83.

Twice a week samples were taken and analyzed for: pH, DO-concentration, temperature, MLSS and MLVSS in the ditch; COD, NH_4-N, NO_3-N, NO_2-N, Kj-N, TP and SS concentration in the influent and effluent. The pH was measured with a PH91(WTW) pH meter. The DO concentration was measured with an OXI91(WTW) oxygen meter. NH_4-N, NO_3-N, NO_2-N and TP were analyzed according to DIN 38406-E5-1(Dr Lange cuvette test LCK 303), DIN 38405-D9-2(LCK 339), DIN 38405-D10(LCK 341) and DIN 38405-D-11-4(LCK 350) respectively. COD, Kj-N, SS, MLSS and MLVSS were determined according to Standard Methods(NEN6633, 1990; APHA, 1992). In addition, The flow rates of the influent and sludge were measured twice a week.

2 Results and discussion

2.1 Removal of phosphorus

The present investigation was divided into two steps: the first phase has been completed in a pilot scale Pasveer oxidation ditch; in the second phase, two anaerobic tanks with total volume of 11m^3 have been added to this oxidation ditch.

In the oxidation ditch, the anoxic and aerobic zones for nitrogen removal were created in the ditch through adjusting the brush submersion depth(Liu, 1996a), however, an anaerobic zone was absent. The monthly mean TP concentrations in influent and effluent were 7.4 – 14.2 mg/L and 4.8 – 7.3 mg/L respectively. The experimental results show, a SRT of 30 – 50 days, this oxidation ditch has a certain ability of phosphorus removal. In winter, the mean phosphorus removal was about 35%; in summer, 17.5℃ of mean temperature, the mean phosphorus removal was about 50%.

After investigating the phosphorus removal in the conventional ditch, the effect of added anaerobic tanks on phosphorus removal was tested. The SRT in the system was 30 – 60 days. The experimental results showed a clear increase of the efficiency of phosphorus removal in the system. The monthly mean TP concentrations in influent and effluent were 11.3 – 15.6 mg/L and 3.5 – 6.1 mg/L respectively. The extent of the increase related to the temperature and the sludge flow rate to the anaerobic tanks. In summer, 15.5℃ of mean temperature, and 1.8 m^3/h of the sludge flow rate to the anaerobic tanks, the phosphorus removal efficiency was 71%. In winter, the phosphorus removal efficiency of 52% was achieved. Therefore, after adding the anaerobic tanks, the phosphorus removal efficiency is about 20% higher than that of the conventional oxidation ditch.

Besides, the removal efficiencies of COD and TN were over 90% respectively in the oxidation ditch.

2.2 Factors affecting phosphorus removal

2.2.1 Temperature

In the oxidation ditch, the temperature changed with the seasons during the experiment. Fig.2 shows the influence of temperature on phosphorus removal without/with the anaerobic tanks. When the temperature is lower than 10℃, the decrease of the TP removal is clear.

2.2.2 The SRT of the ditch

In general, biological phosphorus removal requires an aerobic zone to take up phosphorus and an anaerobic zone to release phosphorus. The anaerobic zone is absent in the conventional oxidation ditch, therefore, phosphorus is only taken up by activated sludge of which a part can be removed by discharging excess sludge. Fig.3 shows the influence of the SRT on phosphorus removal in the experimental oxidation ditch without/with the anaerobic tanks. In the ditch without the anaerobic tanks the phosphorus removal efficiency clearly relates to the SRT which shortens with an increase of the sludge discharge rate. However, when the anaerobic tanks were added in the ditch system, the influence is not strong(Fig.3), most probably because the phosphorus taken up by the activated sludge has been released in the anaerobic tanks.

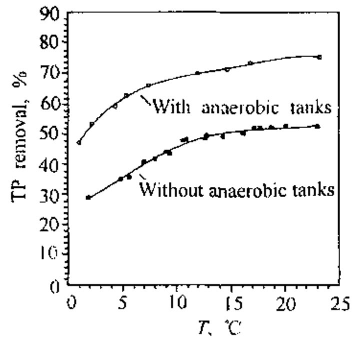

Fig. 2 Influence of temperature on phosphorus removal

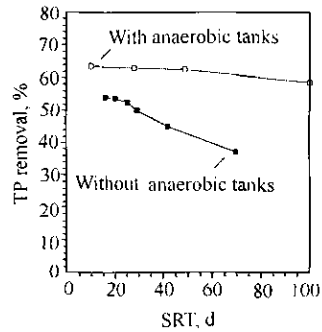

Fig. 3 Influent of the SRT on phosphorus removal

2.2.3 Anaerobic sludge amount

Phosphorus removal in the oxidation ditch system relates to the sludge amount in the anaerobic tanks. Fig. 4 shows the relation between the sludge flow rate to the anaerobic tanks, the anaerobic HRT and phosphorus removal in the oxidation ditch system when the temperature is between 15 and 23℃. As can been seen in Fig. 4, the anaerobic HRT decreases with an increase of the sludge flow rate to the anaerobic tanks and a maximum phosphorus removal occurs at a sludge flow rate of 1.8 m^3/h, corresponding to an anaerobic HRT of about 6 hours. When the flow rate is lower than 1.8 m^3/h, the amount of sludge treated in the anaerobic tanks per unit of time is lower and therefore the total amount of phosphorus released is lower in spite of a longer anaerobic HRT. When the flow rate is higher than 1.8 m^3/h, the shorter anaerobic HRT results in a decrease of the total amount of phosphorus released. The amount of sludge treated in the anaerobic tanks per unit time relates, besides the sludge flow rate, to the sludge concentration. Fig. 5 shows the relation between the ratio of the sludge amount in the anaerobic tanks and in the ditch and TP removal in the oxidation ditch when the sludge flow rate to the anaerobic tanks was about 1 m^3/h(corresponding anaerobic HRT was 11 hours). Though the sludge flow rate did not change, the increase of the sludge ratio was due to the increase of the sludge concentration, and resulted in an increase of the TP removal efficiency.

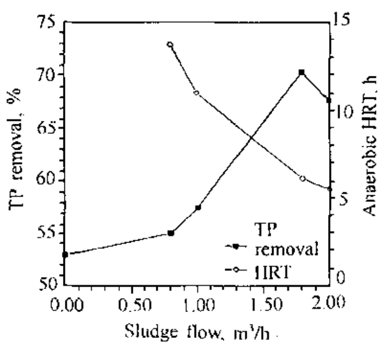

Fig. 4 The relationship of the sludge flow into the anaerobic tanks and phosphorus removal(temperature: 15 – 23℃) removal

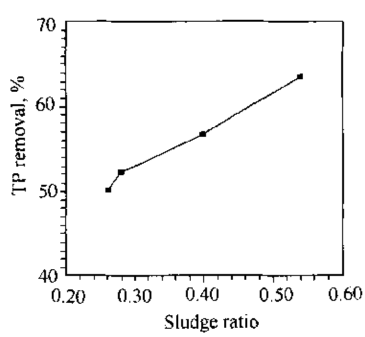

Fig. 5 The influence of the ratio of the amount of sludge in the anaerobic tanks and in the ditch on phosphorus removal(anaerobic HRT: 11 hours)

3 Conclusions

The experimental results show that it is possible to enhance biological phosphorus removal in oxidation ditch systems by adding anaerobic tanks separated from the ditch. The advantages of such separated construction are (1) a lower volume of the anaerobic tank compared with that of the anaerobic zone in the oxidation ditch, because of a high sludge concentration, and the ease to treat concentrated phosphorus rich water by chemical methods and (2) the amount of organic matter in the sludge is sufficient to cause phosphorus release in the anaerobic tank, therefore, the organic matter(COD) in the influent can fully be used for denitrification in the system.

The efficiency of phosphorus removal in the oxidation ditch is affected by factors such as the temperature and the amount of sludge in the anaerobic tank. Because phosphorus is released in the anaerobic tank, the influence of the SRT on phosphorus removal is not strong, therefore, the advantage of the long SRT of the oxidation ditch can be retained in oxidation ditch systems with added anaerobic tanks.

Acknowledgements: The authors thank Mr. K. Oskam, Mr. A. Cinjee, Mr. H. van Buijsen and Ms. E. Kats-Leyendekkers for their technical assistance during the experiments.

References:

APHA, 1992. Standard methods for examination of water and wastewater(18th Edition)[M]. Washington DC, U.S.A: American Public Health Assoc.

Liu J X, Groenestijn J W, van Doddema H J *et al*., 1996a, Influence of the aeration brush on nitrogen removal in the oxidation ditch[J]. European Water Pollution Control, 6(4): 25—30.

Liu J X, Groenestijn J W, van Doddema H J *et al*., 1996b, Removal of nitrogen and phosphorus using a new biofilm-activated-sludge system [J]. Wat Sci Tech, 34(1-2): 315—322.

NEN 6633, 1990. Anon Bepaling van het chemisch zuurstofverbruik(CZV)[M]. 2e druk. The Netherlands.

Poustan M, Chatellier P, Lefevere F *et al*., 1993. Separation of the two functions aeration and mixing in oxidation ditch: application to the denitrification by activated sludge[J]. Environmental Technology, 14, 841—849.

(Received for review February 26, 2001. Accepted March 28, 2001)