Nitrogen Removal in a High-efficiency Denitrification/Oxic Filter treatment System for Advanced Treatment of Municipal Wastewater

D. W. Kim , D. J. Ryu, M. J. Go, D. Chang,
S. B. Han, J. M. Hur, B. R. Chung, B. K. Kim and Yeon Hye Jin

Abstract**—**Biological treatment of secondary effluent wastewater by two combined denitrification/oxic filtration systems packed with Lock type(denitrification filter) and ceramic ball (oxic filter) has been studied for 5months. Two phases of operating conditions were carried out with an influent nitrate and ammonia concentrations varied from 5.8 to 11.7mg/L and 5.4 to 12.4mg/L,respectively. Denitrification/oxic filter treatment system were operated under an EBCT (Empty Bed Contact Time) of 4h at system recirculation ratio in the range from 0 to 300% (Linear Velocity increased 19.5m/d to 78m/d). The system efficiency of denitrification , nitrification over 95% respectively. Total nitrogen and COD removal range from 54.6%(recirculation 0%) to 92.3%(recirculation 300%) and 10% to 62.5%, respectively.

Keywords**—**Advanced treatment , Biofilter, Nitrogen removal, Two combined denitrification/oxic filter

I. INTRODUCTION

CONTINUED population growth, contamination of the both surface water and groundwater, uneven distributions of water resource, and peridoic droughts have forced water agencies to search for new sources of water supply. Use of hightly treated wastewater effluent, now discharged to the environment from municipal wastewater treatment plants, is receiving more attention as a reliable water source. In many parts of the country, wastewater advanced treatment is already an important element in water resources planning and implemention. While water advanced treatment is viable option, water conservation, effcient use of existing water supplies, and new water resources development and management are other alternatives that must be evaluated. As s result of increasingly strict regulation on treated effluent quality, many existing wastewater treatment works need to be upgraded, especially with regard to nitrogen removal. The European Directive recommends an enhanced nitrogen treatment for discharging water to protected areas, which means an average annual nitrogen removal of an least 70%. When compared to the post-denitrification ,pre-denitrification using the organic carbon of the municipal wastewater is more attractive from both an economic and environment point of view:less sludge production, less air consumption, no need or reduced need of an external carbon source, improvement if alkalinity balance. Furthermore, biofiltration nowadays represents a well-proven and robust process[1]. It is particularly suited to sites where a compact or modular design is required e.g. urban, coastal or mountain areas. Denitrification in tertiary filtration can be realised quickly and is a cost-effective alternative to extended denitrification in a biofilter system. Denitrification in tertiary filtration with the addition of methanol has been successfully practised in U.S.A for more than 15 years. Aerated biofilters are a compact wastewater treatment process with a high flexibility with regard to the combination with other wastewater processes. Biodegradation of organics [6,7,10], denitrification and also biological phosphorous removal are possible applications. Some researcher have developed biological filtration processes for tertiary nitrification[2,8,11]. biological filtration processes can be also effective for denitrification by combination of control systems with on-line sensors of nitrate and dissolved oxygen[3,4,5,9,12]. However, further optimization is required, especially with regard to automatic control of denitrification process.

D. W. Kim, D. Chang, B. K. Kim and H. J. Yeon are the Department of Environmental Engineering, College of Engineering, Konkuk University, Seoul 143-701, Korea (e-mail: jesam0305@hanmail.net)

M. J. Go is the Department of Advanced Technology Fusion, Konkuk University, Seoul 143-701, Korea (e-mail: lady0616@hanmail.net)

S. B. Han, J. M. Hur, B. R. Chung were the Green Technology Co., Ltd., Seoul, Korea (e-mail: borim89@naver.com)

II. MARERIALS AND METHODS

The sewer system is a type of combined sewer collection one, and a conventional activated sludge process is adopted for treatment. In this experiment, the effluent from the secondary sedimentation tank was used as the target water of treatment. The experimental devices consisted of two up-flow filter systems, denitrification filter and oxic filter. The diameter and the height of denitrification filter were 350mm and 2050mm respectively, and those of oxic filter were 350mm and 1250mm respectively. The denitrification filter filtration media used Lock type and made Vinylidene chloride with a relative Specific gravity of 1.62, diameter of 12.2~19.8mm and Porosity of 95% respectively. And the oxic filter filtration media used ceramic ball type and made Ceramic with a relative Specific gravity of 2.35, diameter of 7.5~8.5mm and Porosity of 56% respectively. The media were packed at 2000mm and 1200mm height from the bottom of denitrification filter and oxic filter, respectively. The empty bed volumes of the denitrification filter and oxic filter, made of plexiglass, were 1.97 and 1.2L, respectively. The denitrification was packed with three-stage modular Lock media, of which the depth corresponded to the upper 90% of the liquid depth of 2000mm. Denitrification filter was not aerated mainly denitrification. When the secondary effluent included ammonium nitrogen (NH^{+}_{4}-N) of less than 10mg NH^{+}_{4}-N/L and addition external carbon source by methanol(4mg Methanol/mg NO^{-}_{3}-N) and oxic filter was aerated mainly for nitrification. Denitrification/oxic filter treatment system were operated under an EBCT (Empty Bed Contact Time) of 4h at system recirculation ratio in the range from 0 to 300% (Linear Velocity increased 19.5 to 78m/d). The characteristics of the packing media are presented in Table 1. And Influent was collected at the end of the grit chamber in a combined municipal wastewater treatment plan in Gyeonggi-do, korea. The weak municipal wastewatert influent was typical of the municipal wastewater generated in Korea. The characteristics if the influent are summarized in Table 2.

TABLE I
PHYSICAL CHARACTERISTICS OF THE PACKING MEDIA

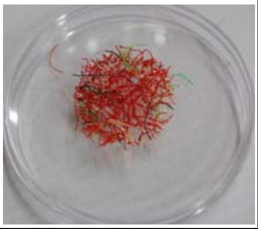
Parameters	**Denitrification filter**	**Oxic filter**
	Lock	Ceramic ball
Color	Red	Brown
Materials	Vinylidene chloride	Ceramic
Diameter (mm)	12.2~19.8 (cross section)	7.5~8.5
Specific gravity	1.62	2.35
Mohs hardness	2~3	5~6
Porosity (%)	95	56
Image		

TABLE II
CHARACTERISTICS OF THE INFLUENT MUNICIPAL WASTEWATER

Parameters	Biofilter system Influent
Temp. ( )	21.5~26.9 (24.3)
DO (mg/L)	3.8~8.7 (5.5)
pH	6.8~8.0 (7.2)
Alkalinity (mg$CaCO_3$/L)	86~208 (117)
SS (mg/L)	4.1~6.2 (5.4)
$TCOD_{cr}$ (mg/L)	18~56 (28)
$SCOD_{cr}$ (mg/L)	12~47 (25)
TN (mg/L)	13.9~19.8 (16.9)
NH_4-N (mg/L)	0.3~1.3 (0.9)
NO_3-N (mg/L)	5.8~11.7 (9.2)
TP (mg/L)	0.13~2.02 (0.86)

III. RESULT AND DISCUSSION

The overall system removals of nutrients in the denitrification/oxic filter system, are shown in Table 3.

TABLE III
STEADY STATE PERFORMANCE OF DENITRIFICATION/OXIC FILTER SYSTEMS

	Results		
Parameters	Denitrificatin filter effluent	Oxic filter effluent	System removal(%)
pH	6.8~8.1 (7.4)	7.2~8.3 (7.8)	-
DO (mg/L)	0.7~2.2 (1.4)	4.1~8.2 (7.1)	-
Temperature ( )	22.7~27.4 (25.0)	22.6~27.1 (24.9)	-
TCODcr (mg/L)	8~40 (21)	6~21 (16)	10.0~62.5 (39.2)
TN* (mg/L)	1.5 ~ 9.1 (3.6)	1.3 ~ 10.2 (4.4)	54.6 ~ 92.3 (80.6)
Ammonia* (mg/L)	1.3~9.5 (3.5)	0~ 1.1 (0.1)	95.1~100 (98.5)
NO_3^--N (mg/L)	0~2.5 (0.3)	0~10.7 (4.3)	96~100 (97.9)

minimum ~ maximum (average) * injection of additional ammonia nitrogen

The denitrification/oxic system achieved average removals of total COD, ammonia, and nitrate of up 39.2, 98.5, and 97.9 respectively, at a recirculation ratio of all. Total nitrogen removal efficiencies by post-denitrification and pre-nitrification were over 95% at effluent recirculation ratios of all, whereas its removal was only 2-5% when effluent recirculation was not applied to the system. No apparent effect of temperature on the overall removals was observed at 21.5-26.9

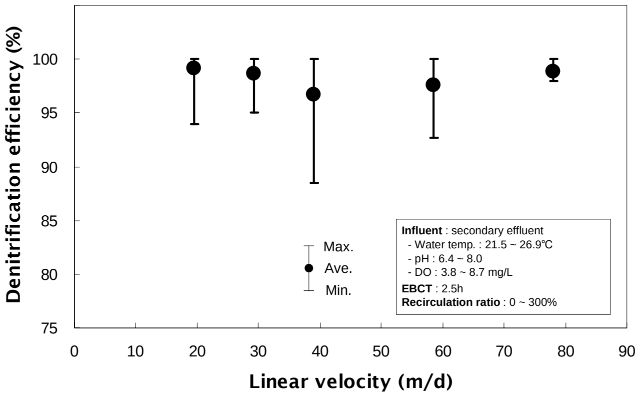


Fig. 1 Effet of the linear velocity on the denitrification efficiency

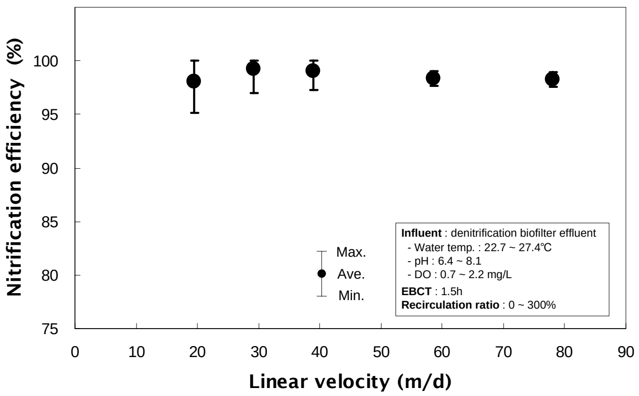


Fig. 2 Effet of the linear velocity on the nitrification efficiency

During operation of 0-300% by increasing the recirculation rate of linear velocity 19.5m/d to the 78m/d to the increased denitrification and nitrification are shown in Figure 1 and 2. Denitrification filter is also little effect on the denitrification efficiency but, in the oxic filter linear velocity increased nitrification efficiency was slightly decreased. However, in this case, a difference within 5%, only a very small, the actual nitrification efficiency of over 95% or more within the scope because it could keep the linear velocity will have no effect on the treatment efficiency is expected.

IV. CONCLUSION

The denitrification/oxic filter system employing effluent recirculation achieved efficient simultaneous removal of nitrogen in weak municipal wastewater. The denitrification and oxic filter in the system were complementary to one another in a phase-isolated manner of post-denitrification and pre-nitrification. The upflow denitrification filter packed lock media contributed to the substantial reduction in nitrate as well as to denitrification, and the following upflow nitrification filter packed ceramic balls performed not only the complete pre-nitrification but also an advanced treatment of organics. The denitrification/oxic system achieved average removals of total COD, ammonia, and nitrate of up 39.2, 98.5, and 97.9 respectively, at a recirculation ratio of all. The increase in recirculation flow rate was accompanied by the improved system removal of nitrogen.

ACKNOWLEDGMENT

This paper was supported by Korea Minister Ministry of Land, Transport an Maritime Affairs(MLTM) as U-City Master and Doctor Course Grant Program and Green Technology Co., Ltd and the Korea Research Foundation Grant funded by the Korean Government and Brain korea 21 project

REFERENCES

[1] Canler,J.P. and Perret,J.M. Biological aerated filter : assessment of the process based on 12 sewage treatment plants. Wat.Sci.Tech., Vol. 29 no.10-11, pp.13-22,1994.
[2] Dillon, G,R., Thomas,V.K. A pilot-scale evaluation of the "Biocarbone process" for the treatment of settled sewage and for tertiary nitrification of secondary treatment. Wat.Sci.Tech. Vol. 22 no. 10-11, pp.305-316,1990.
[3] Hidaka, T. Development of pre-coagulation and biofiltration process.ph.D Dissertation, Department of environmental Engineering. kyoto University, Kyoto, japan,2002.
[4] Hidaka, T., Tsuno, H., kishimoto, N., 2003a. Advanced treatment of sewage by pre-coagulation and biological filtration process. Water Res. Vol. 37, no 17, 4259-4269,2003a.
[5] Hidaka, T., Tsuno, H., jeong, J., Kishmoto, N., Oda, T. Utilization of pre-coagulation sludge in biological filtration process. J. Jpn Sewage Works Assco. Vol. 40, no. 487, pp.103-116,2003b
[6] Jepsen S.E., Laursen K., la Cour Jansen J. and Harremoes P. Denitrification in submerged filters of nitrified wastewater and pre-precipitated wastewater. In: Chemical Water and wastewater Treatment‖ ,Proc. 5th Gothenburg Symposium, Nice, France,1992.
[7] Mange P., Gros H. Biological treatment of communal wastewater by biofiltration on granular media and nitrification on a submerged filter. Conf. on Techn. Advanced in Biofilm Reactor, Nice, France,1990
[8] Payraudeau, M., Pearce, A.R., Gousailles, M. Tertiary nitrification in an upflow biofilter on floating media: influence of temperature and COD load. Wat.Sci.Tech. Vol. 44, no. 2-3, pp.63-68,2000.
[9] Payraudeau, M., paffoni, C., Goldsmith, R., Bigot, B., Wicquart, F. Experience with an upflow biological aerated filter (BAF) for tertiary treatment: from pliot trials to full scale implemention. Wat.Sci.Tech. Vol. 41, no 4-5,pp.21-27,2001.
[10] Rogalla F., Roudon G., Sibony J. and Blondeau F. Trade-offs between physico-chemical lamella separators and aerate biofiltration. ln: Chemical Water and wastewater Treatment‖ ,Proc. 5th Gothenburg Symposium, Nice, France,1992.
[11] Tschui, M.,Boller, M., Gujer, W., Eugster, J., Mader, C., Stenger, C. Tertiary nitrification in aerated pilot biofilters. Wat.Sci.Tech. Vol. 29, no 10-11, pp.53-60,1994
[12] Tsuno, H., Hidaka, T., Nakamoto, M. Development of pre-coagulation and biofiltration process for advanced treatment of sewage. Wat.Sci.Tech. Water Supply Vol. 4, no 1, pp.13-22,2004. Young, "Synthetic structure of industrial plastics (Book style with paper title and editor)," in *Plastics*, 2nd ed. vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 15–64.