Internal Behavior of Biological Nutrient Removal System for Advanced Wastewater Treatment

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Abstract**—**The purpose of this research was develop a biological nutrient removal (BNR) system which has low energy consumption, sludge production, and land usage. These indicate that BNR system could be a alternative of future wastewater treatment in ubiquitous city(U-city). Organics and nitrogen compounds could be removed by this system so that secondary or tertiary stages of wastewater treatment satisfy their standards. This system was composed of oxic and anoxic filter filed with PVDC and POM media. Anoxic/oxic filter system operated under empty bed contact time of 4 hours by increasing recirculation ratio from 0 to 100 %. The system removals of total nitrogen and COD were 76.3% and 93%, respectively. To be observed internal behavior in this system SCOD, NH_3-N, and NO_3-N were conducted and removal shows range of 25~100%, 59~99%, and 70~100%, respectively.

Keywords**—**BNR, nitrification, denitrification, organics removal, anoxic, oxic, advanced treatment.

I. Introduction

WATER/SEWAGE facility, one of the urban base facilities constituting a city, is an important infrastructure, and to manage it the nation has a systematic system established for a long time. In the mean time, recently the nation has recognized the importance of an ubiquitous environment to lead the future society and established ' u-Korea ' plan, and each local government is expanding the promotion of u-city construction projects connected to the ubiquitous environment [1]. At the same time, low-carbon green growth, a national project, and water quality standards of discharged water[2] continuously reinforced to improve the water quality of rivers has presented a new paradigm trend composed of improvement of existing wastewater treatment plants, application of advanced treatment technology and distributed wastewater treatment for tertiary treatment. Thus, cases for application of the biological nutrient removal system (BNR) have been on the rise to reduce the installation site, produce high quality treated water, and save labor and operating costs with automated operation [3]. The BNR system which has been developed mainly in Europe not only can maintain SRT [4] for a long time without separate operation and make free load changes but also does not require the secondary sedimentation tank and can secure high-concentration microbes, providing due to the shorter reaction time a higher degree of intensity for site requirement than the existing suspended growth process. Thus, the BNR system is advantageous in application to wastewater treatment plants located inside a city due to its easy underground or inside-building installation and its capacity to remove bad odor [5]. In addition, it can contribute to low carbon green growth due to greenhouse gas reduction since it has a low energy requirement and the sludge production is low. The objective of this research is to derive the treatment characteristics and optimum operating conditions by developing BNR system, using the attached growth microbes, on the basis of the BNR system, which is judged to be an alternative to wastewater treatment facilities in the field of U-environment of the ubiquitous city (U-city).

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II. Experimental

In this research anoxic/oxic filter system was applied to advanced treatment of wastewater. As a combination of attached growth processes this system consists of continuous upward-flow anoxic/oxic filter. The anoxic filter filled with Lock media is located at the front of the system to remove most of NO_3-N from influent wastewater and additionally denitrify the nitrate solution recycled from the aerobic filter bed. The oxic filter filled with plastic balls is located at the rear of the system and plays a role to remove residual organics in the effluent from the oxic filter and nitrate NH_4-N. The anoxic and oxic filters have upward flow and sample collection ports were installed with a certain interval from the entrance to the exit to confirm the internal behavior of the filter. Valves were installed to the port so that it may be open and close in case of sample collection or sludge withdrawal. The inflow of wastewater was made by peristaltic type Masterflex Pump of Cole Palmer. Each process is filled with media and the characteristics are shown in Table I.

TABLE I
PHYSICAL CHARACTERISTICS OF THE PACKING

Parameters	Anoxic filter (Lock)	Oxic filter (Plastic ball)
Materials	Polyvinylidene (PVDC)	Polyoxymethylene (POM)
Diameter(mm)	34~39 (36)	7
Volume(mm3)	11	35
Specific gravity	1.03	1.37
Mohs hardness	3~4	4~5
Porosity (%V/V)	95	53.3

The conditions of the influent used in this system are shown in Table II. HRT of this system is 4 hours (2.5 hour for anoxic and 1.5 hours for oxic filter), and the system was operated by increasing the recirculation rate and liner velocity step by step by 0~1 and 19.5~39 m/d, respectively. In case the nitrate solution is recycled, however, the actual HRT applied to each filter decreases and the linear velocity increases.

TABLE II
CHARACTERISTICS OF THE SYSTEM INFLUENT

Parameters	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 (mgCaCO$_3$/L)	110~148 (129)
TCOD$_{cr}$ (mg/L)	64~140 (112)*
TN (mg/L)	4.3~24.1 (18.1)
NH$_4$-N (mg/L)	5.7~17.7 (10.1)
NO$_3$-N (mg/L)	4.3~12.4 (8.9)
TP (mg/L)	1.7~2.3 (2.0)

III. Result And Discussion

The results from the research on the filter and the system indicate that COD removal efficiency of the system is on the average 94 %, the nitrogen removal efficiency is on the average 68% in case of 100 % recirculation rate and the nitrogen concentration is below 10 mg/L. The oxic and the anoxic filter showed the removal efficiency greater than 96.7 and 96.2 %, respectively. In case of the total phosphorus, the system showed relatively a low efficiency and it appeared that additional treatment with a chemical like Alum was necessary. The treatment results of the entire system are shown in Table 3.

TABLE III
STEADY STATE PERFORMANCE OF ANOXIC/OXIC FILTER SYSTEMS

	Results			
Parameters	System influent	Anoxic filter effluent	Oxic filter effluent	System removal (%)
pH	6.8~7.9 (7.3)	6.8~8.1 (7.6)	6.6~8.0 (7.5)	-
ORP (mv)	-60~23 (-12)	-75~29 (-18)	-88~14 (-42)	-
DO (mg/L)	3.8~8.7 (5.5)	0.4~8.1 (4.4)	4.1~8.6 (7.1)	-
Temperature (℃)	13.2~24.1 (21.5)	20.6~24.6 (22.9)	20.7~24.7 (23.0)	-
Alkalinity (mgCaCO$_3$/L)	110~148 (129)	120~142 (135)	58~136 (90)	-
Conductivity (μs)	374~752 (546)	378~778 (509)	338~761 (495)	-
TCODcr (mg/L)	64~140 (112)	0~16 (8)	0~16 (4)	75~100 (94)
TN (mg/L)	4.3~24.1 (18.1)	0.2 ~ 13.9 (6.6)	0.4 ~ 13.5 (5.2)	35.6~73.4 (67.9)
Organic nitrogen (mg/L)	0.00~0.01 (0.01)	0.00~0.01 (0.01)	0.00~0.01 (0.01)	-
Ammonia (mg/L)	5.7~17.7 (10.1)	1.1~13.9 (6.5)	0~4.3 (1.1)	97~99.8 (96.7)
NO_2^--N (mg/L)	0.00~0.01 (0.00)	0.00~0.01 (0.00)	0.00~0.01 (0.00)	-
NO_3^--N (mg/L)	4.3~12.4 (8.9)	0~2.1 (0.3)	0~11.2 (4.4)	90~98 (96.2)
TP(mg/L)	1.7~2.3 (2.0)	1.7~2.1 (1.9)	1.6~1.9 (1.7)	5.9~18.2 (13.8)

minimum ~ maximum (average)

To observe the internal behavior of this system, organics and nitrogen distributions for each height of the system (upper, middle and lower positions of both filters) indicate that as soon as the influent flows into the system from the bottom the removal of organics and nitrogen is completed. At the recirculation rate of 100 %, the organics were removed below the target water quality at the lower part of the anoxic filter and completely removed at the middle. Most of nitrification was completed at the lower part of oxic filter regardless of the recirculation rate, and most of denitrification was also completed at the lower part of the anoxic filter. At this time, according to the DO changes the anoxic filter bed was observed to maintain the no-oxygen condition and the oxic filter the aerobic condition as shown in Figure 1.

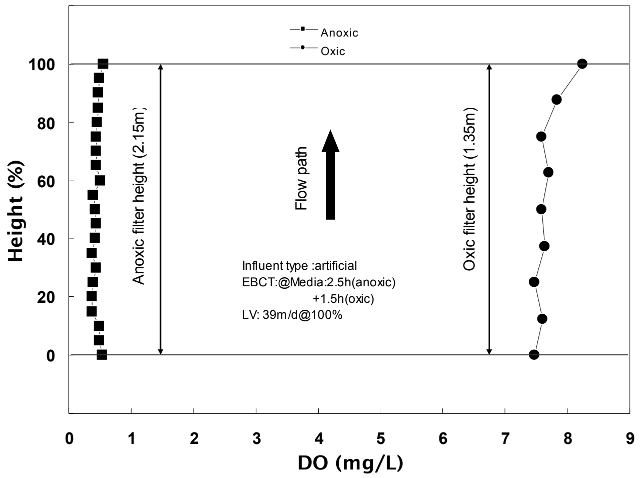

Fig. 1 Dissolved oxygen concentration change by filter height

IV. Conclusion

Results of the BNR system using the attached growth biomass indicate successful system operating. The system achieved high removal efficiencies of 94%, 68%, 96.7, and 96.2 % for COD, nitrogen, ammonia, and nitrate, respectively and achieved the target water quality. Through the organics and nitrogen distributions for each height of the anoxic filter and the oxic filter, both filters are found to remove nutrient at the lower part as soon as the influent flows into the system. These results are expected to be useful in size reduction of wastewater facility.

ACKNOWLEDGMENT

This work is financially supported by Korea Minister Ministry of Land. Transport and Maritime Affairs (MLTM) as 「U-city Master and Doctor Course Program. This work has been performed with the financial support in Seoul Regional Environmental Technology Development Center (SEST), KOREA

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