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Development and Field Assessment of DO Control System in an Aeration Tank for Automation of Sewage Treatment Plant

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Abstract

Activated sludge sewage treatment processes are difficult to be controlled because of their complex and nonlinear behaviour, however, the control of the dissolved oxygen level in the reactors plays an important role in the operation of the facility. For this reason, this study is designed to present a system which accurately measures DO, MLSS, pH and ORP in the aeration tank to alleviate situations above and provide the automatization of a sewage treatment plant (STP) using new DO control system. The automatic control systems must be guaranteed the accuracy. Therefore, the proposed automatic DO control system in this study could be commercial applications in the aeration tanks by means of operating cost analysis and user-friendly for operation and maintenance. We could get accurate data from the lab tank which has water quality checker because there was no vortex and air bubble during the measurement process. Improvement of confidence in the lab tank enabled effective and automatic operation of sewage treatment plants so that operation costs and manpower could be saved. If this result is put in place in every sewage treatment plant nationwide for practical purposes, it is estimated to cost 18.5 million dollars in installing the lab tank and to save 9.8 million dollars in management cost a year, except for cost saved by automation.

Key Words : Aeration tank, Automatic DO control, Energy cost, Sewage treatment plant (STP), Traffic signal

1. Introduction

Dissolved oxygen (DO) concentration is considered as the most important control parameter in the activated sludge process. This is connected with the influence that DO concentration has on the several biological processes, that take place in the reactors and consequently on the final effluent quality, but also with the aeration operating costs[1,2].

Conventional methods related to sewage treatments or systems of sewage treatment are focused on the automation of the process. Successful automation of the process requires precise quality measurement of water being processed-sewerage and wastewater. However, the conventional method is to install a measuring sensor in the aeration tank. Therefore in case of an inaccurate measurement of water quality from the aeration tank, the automatic control is impossible to achieve.

In other words, various suspended solids and air bubbles in the aeration tank cause unstable conditions. There are many figurative errors in measuring DO and MLSS, and inaccurate measurement of DO and MLSS are also shown due to various locations of sensors. Additionally, the importance of measuring and controlling DO is extremely underestimated and consequently extra costs caused by inaccurate DO control incur a waste of electricity for an aeration tank, increased costs of chemicals and decrease the efficiency in removing nitrogen. To overcome these problems, several adaptive control strategies have been suggested recently for

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the DO control in the aeration basin[3,4]. The variation of the set point of the DO control loop has been proposed by Olsson[5] and applied successfully in nitrification denitrification (ND) plants[6].

On the other hand, Lie and Welander[7] and Fuerhacker et al. [8] reported that DO was found to have a negative effect on denitrification even at lower concentrations that can be measured with conventional DO probes (i.e.<0.1 mg/L). This strategy, if applied in a suitable way, could allow having a more settleable biomass together with energy savings and a higher standard effluent.

For an integrated management of a sewage treatment plant, an automatic control system should be set up in advance. And for more accurate management of the auto-control system, it is necessary to install various sensors which tell onsite conditions and electrical instrumentation system which converts electrical signals into mechanical ones.

Therefore, this study is designed to present a system which accurately measures DO, MLSS, pH and ORP in the aeration tank to alleviate situations above and provide the automatization of a sewage treatment plant using the system.

2. Materials and Methods

2.1. Sewage treatment plant

The Kang-byun sewage treatment plant is treating the sewage for the whole area of North, Sasang, Saha districts and partial areas of West district in Korea. There are 1,500 industrial wastewater discharging factories inside Sasang and Shin-pyung industrial complex within the area where Kang-byun sewage treatment plant covers, and the daily discharging rate goes up to 80,000 m^3. Inflow of pernicious industrial wastewater from the factories occurred 86 times in 2006 and 43 times till 2007 which shows that inflow of industrial wastewater is happening 1 to 2 times every week.

Therefore, the input of industrial wastewater has caused decline of microorganism activity in an aeration tank at sewage treatment plant. Kang-byun sewage treatment plant consists of I and II stages for different treating methods which are a conventional activated sludge and a conventional activated sludge with coagulation/flocculation. Capacities for I and II stages at Kang-byun sewage treatment plant are 330,000 tons/day and 285,000 tons/day, respectively. Two and three automatic DO control systems were installed in I and II stages, respectively. And DO, MLSS, pH and ORP were also measured in the aeration tank. Fig. 1 shows pH variations for influents from the Kang-byun sewage treatment plant and the Gamjeon channel. It was noticed that large amounts of industrial wastewater was flowed into Gamjeon channel by checking pH.

2.2. Automatic DO control system

The automatic DO control system in the sewage treatment plant presented by this study is described in Fig. 2 and made up of a proposed lab tank which contains measuring sensors and is installed in the aeration tank, a pump connected through feed pipes, a compressor, control parts and display parts. A proposed lab tank consists of an outlet for measured water on the side and an outlet for cleaning at the bottom, a baffle wall and a weir wall internally. A baffle wall is made up of perforated plates which has fixed diameter from ends of feed pipes connected with a pump to measuring sensors so that water from a pump is forced to flow over the sensors and a weir wall is higher than where the sensors are installed. As for the DO concentrations measured from the automatic DO control system, even when an operator of the facility does not know DO concentrations through a signal system connected with a printing device in the plant, he or she can check in the office whether DO concentrations in the aeration tank are appropriate or not (Red: below 1.4 mg/L DO, Yellow: above 3.6 mg/L DO, Green: between 1.5~3.5

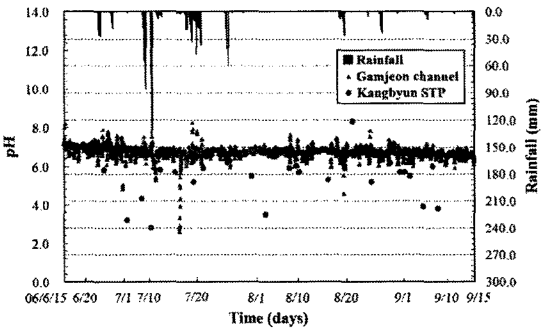


Fig. 1. Relationship of pH in sewage between Gamjeon channel and Kang-byun STP.

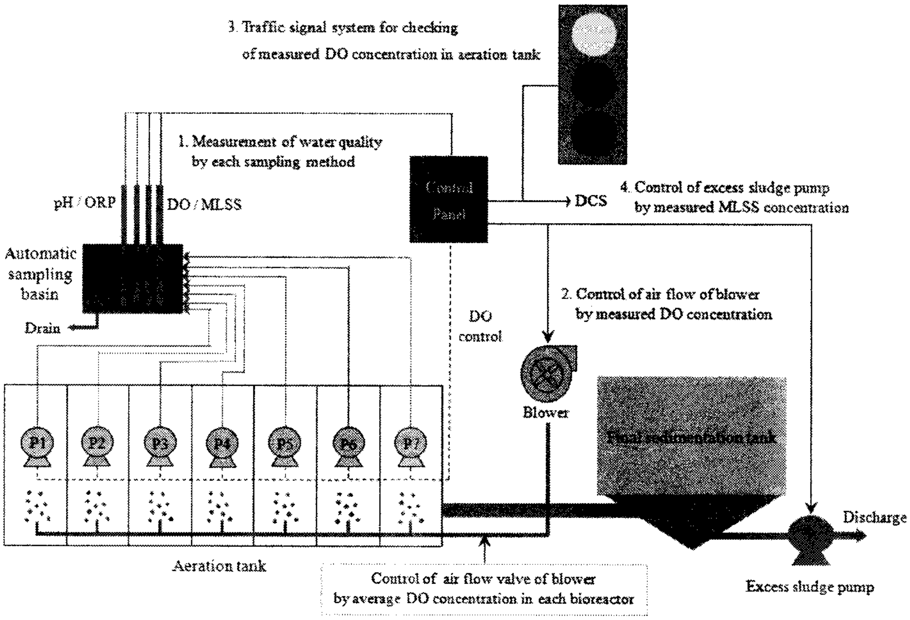
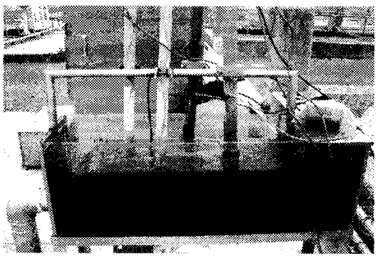
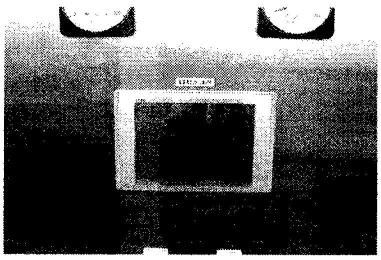
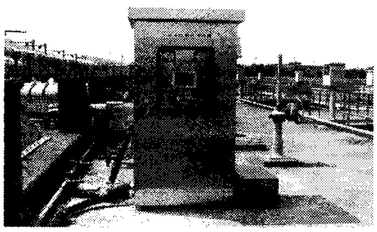


Fig. 2. Schematic of DO control system in aeration tank for automation of STP.


(a) Automatic Sampling Basin


(b) Touch Screen


(c) Control Panel

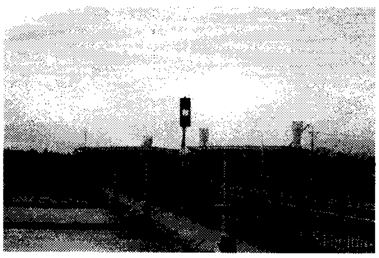

(d) Traffic Signal

Fig. 3. Photographs of DO(MLSS, pH, ORP) control system in aeration tank of Kang-byun STP.

mg/L DO) so that it provides convenient maintenance.

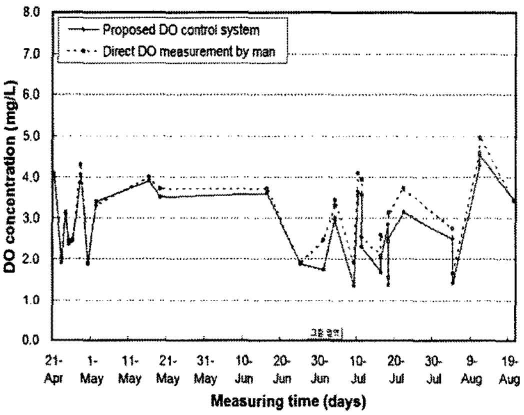
3. Results and Discussion

3.1. Evaluation of proposed automatic DO control system

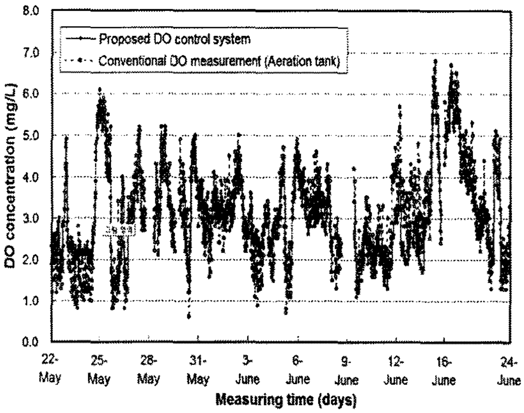
Table 1 and Fig. 4 present the comparative of DO, MLSS and pH concentration for three measuring methods; proposed DO control system, direct DO measurement by man and conventional DO measurement in aeration tank. The DO levels which were produced by measuring directly inside the aeration tank show the highest average DO level of 3.7 mg/L, presumably re-

Table 1. Comparison of DO and MLSS concentration for each measuring method

Measuring methods		Average	Aeration tank						
			No.1	No.2	No.3	No.4	No.5	No.6	No.7
DO (mg/L)	Proposed DO control system	3.27	1.5	4.5	3.3	2.9	3.2	4.3	3.2
	Direct DO measurement by man	3.42	1.6	4.8	3.3	2.9	3.3	4.5	3.6
	Conventional DO measurement (Aeration tank)	3.70	1.9	5.0	3.6	3.0	3.7	4.8	3.9
MLSS (mg/L)	Proposed MLSS control system	3,050	3,180	2,930	2,950	2,990	3,080	3,000	3,020
	Direct MLSS measurement by man	3,080	3,150	3,000	3,000	3,050	3,100	3,100	3,050
	Conventional MLSS measurement (Aeration tank)	3,130	3,250	3,050	3,050	3,100	3,100	3,150	3,150
pH	Proposed pH control system	6.3	6.3	6.3	6.4	6.3	6.3	6.3	6.4
	Direct pH measurement by man	6.3	6.3	6.4	6.4	6.3	6.3	6.3	6.4
	Conventional pH measurement (Aeration tank)	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3



(a) Proposed DO control system vs. direct DO measurement by man



(b) Proposed DO control system vs. conventional DO measurement in aeration tank

Fig. 4. Comparison of DO concentration for each measuring method.

sulting from air bubbling and the flow velocity of water inside the bio-reaction tank. This is because unstable measuring conditions of the portable checker caused serious hunting when measurement was processed inside the aeration tank. Moreover, by selecting stable water quality parameter which was measured within one minute after starting measurement, water quality parameter showed relatively low level, on the contrary the result which was measured inside the lab tank was stable and the most accurate because wastewater comes from various places at the aeration tanks. Added on this, the concentration of MLSS which was measured inside the aeration tank also was the highest level for the same reason with measuring DO, and showed high level when measured by the portable checker. In contrast, measuring inside the lab tank produced stable results, and it had the margin of error of MLSS 100~150 mg/L.

This study shows that it is possible to achieve optimal managements in terms of DO and MLSS in the aeration tank, which are the most significant parts of operating the sewage treatment plant. We could get accurate data from the lab tank which has water quality checker because there was no vortex and air bubble during the measurement process. Improvement of confidence in the lab tank enabled effective and automatic operation of sewage treatment plants so that operation costs and manpower could be saved. If this result is put in place in every sewage treatment plant nationwide for practical purposes, it is estimated to cost 18.5

million dollars in installing the lab tank and to save 9.8 million dollars in management cost a year, except for cost saved by automation.

Lee et al.[9] reported that the electric consumption of surface aerators for automatic DO control in the activated sludge process in a coke wastewater treatment plant was reduced up to 70% with respect to the full operation when the DO set point was 2 mg/L. The electricity saving was more than 40% of the electricity consumption when considering surface aerators.

3.2. Evaluation of traffic signal control system

The removal efficiency for effluent quality by the traffic signal control which is connected with measured DO concentration by the proposed automatic DO control system in aeration tank was presented in Table 2. Also, Fig. 5 and Table 3 show that the variations of DO concentrations and electric consumptions of the blower for before and after installing the traffic signal control system respectively. As shown in Table 2, BOD removal efficiency in the aeration tank was increased up to 7.3% and electric consumptions for the blower were decreased about 9.5%. It was estimated to save 92,300-dollar in management cost such as

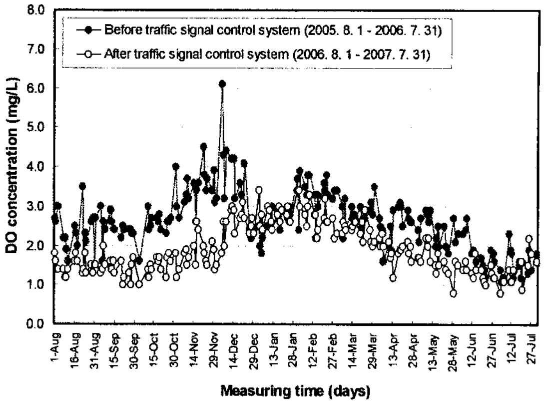


Fig. 5. Comparison of DO concentration before and after the traffic signal control system.

workforces per year by changing to the automation system. As a result of maintaining the DO constantly at the set point by the automatic DO control system and the traffic signal control system, the fluctuations of effluent quality were decreased and overall improvement of the effluent water quality could be achieved. Ferrer et al.[10] outlined that the cost associated with the aeration in WWTPs can reach 50% of the consumption of electric power and that a large saving of energy can

Table 2. Comparison of removal efficiency before and after the traffic signal control system

Items	Before the traffic signal control system			After the traffic signal control system		
	Influent (mg/L)	Effluent (mg/L)	Removal efficiency (%)	Influent (mg/L)	Effluent (mg/L)	Removal efficiency (%)
BOD_5	139.4	12.4	91.1	132.3	7.2	94.6
BOD_5 in aeration tank	74.3	12.4	83.3	76.7	7.2	90.6
SS	149.1	7.4	95.0	153.2	6.1	96.0
DO	2.8 (1.3~5.8)			1.7 (0.9~2.7)		
MLSS	1,859			1,818		
Temperature (℃)	20.0			20.8		

Table 3. Electric power of blower used in aeration tank of STP

Parameters	Before the traffic signal	After the traffic signal	Comparison
Sewage treatment quantity (10^3ton/d)	249.15	239.13	-
Electric power of blower (kWh/d)	24,415	21,200	-
Electric power per sewage treatment quantity (kWh/10^3ton)	97.99	88.65	-9.34 (9.5%)

be obtained by the application of a suitable aeration control action. Ahn[11] reported that the electric reduction costs of the blowers by DO control in the aeration tank could be achieved up to 1.4 dollars at facility capacity with 30,000 m^3/day. Also, if this result is put in place in every sewage treatment plants in Korea, it is estimated to save 24.5 million dollars (37% of total electric costs) for management costs per year.

4. Conclusions

Now, existing sewage treatment plants located in Korea have inevitable limits which are reducing manpower, introducing advanced wastewater treatment methods and using water quality monitoring system which is Tele Monitoring System (TMS). In order to overcome these problems, ON LINE operation system which is operated by automatic control system is necessary. The automatic control systems must be guaranteed the accuracy. Therefore, the proposed automatic DO control system in this study could be commercial applications in the aeration tanks by means of analyzing cost analysis and user-friendly for operation and maintenance. We could get accurate data from the lab tank which has water quality checker because there was no vortex and air bubble during the measurement process. Improvement of confidence in the lab tank enabled effective and automatic operation of sewage treatment plants so that operation costs and manpower could be saved. If this result is put in place in every sewage treatment plant nationwide for practical purposes, it is estimated to cost 18.5 million dollars in installing the lab tank and to save 9.8 million dollars in management cost a year, except for cost saved by automation.

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