SHORT COMMUNICATION

Pilot scale experiment on aeration control system for upgrading single-stage activated sludge process for latex rubber industrial wastewater: Phase I: operational problems of using online sensors

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Abstract

Chevakidagarn, P., Puetpaiboon, U., and Wanseng, W.
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Songklanakarin J. Sci. Technol., 2006, 28(4) : 871-876

The aim of this experiment was to upgrade the operation of conventional activated sludge treatment plants to save aeration energy and at the same time to provide better utilization of existing plant capacity for nutrient removal without major financial investment. In this study, pilot-scale experiments of the single stage activated sludge process (ASP) as operated in existing ASP in southern Thailand, were investigated under conditions of simultaneous nitrification-denitrification. This first stage of the experiments was to observe the

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Received, 3 August 2005 Accepted, 5 January 2006

possibility of using oxidation-reduction potential (ORP) for aeration control in treatment plant fed with the wastewater from the latex rubber industry. Wastewater from the representative factory contained high carbon and solids. The F/M ratio was up to 1.5 kg of COD/day/kg of MLSS. The results proved that the ORP was greatly affected by the change in air supply. However, it was also affected by the fluctuation of wastewater temperature, which contributed to the bulking sludge problem.

Key words : activated sludge process, latex rubber industry, oxidation reduction potential

บทคัดย่อ

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การทดลองระดับเทียมจริงเพื่อการควบคุมการเติมอากาศสำหรับการปรับปรุงระบบแอกทิเวเต็ดสลัดจ์แบบขั้นตอนเดียวในโรงงานน้ำยางข้น - ระยะที่ 1: ปัญหาในการทำงานด้วยเครื่องตรวจวัดแบบออนไลน์

ว. สงขลานครินทร์ วทท. 2549 28(4) : 871-876

จุดประสงค์ของการทดลองครั้งนี้คือ การปรับปรุงการทำงานของระบบบำบัดน้ำเสียแบบแอกทิเวเต็ดสลัดจ์แบบดั้งเดิม โดยมีเป้าหมายหลักเพื่อการประหยัดพลังงานและในเวลาเดียวกัน เพื่อที่จะให้ระบบที่มีอยู่เดิมทำงานได้อย่างมีประสิทธิภาพในการบำบัดธาตุอาหารได้มากขึ้น โดยไม่ต้องมีการลงทุนก่อสร้างเพิ่มเติม ในการศึกษาครั้งนี้ การทดลองระดับเทียมจริง (pilot-scale) ได้จำลองการทำงานของระบบแอกทิเวเต็ดสลัดจ์ขั้นตอนเดียวที่ใช้กันอยู่ทั่วไปในภาคใต้ของประเทศไทย โดยเลือกใช้สภาวะแบบไซมอนทาลเนียสไนตริฟิเคชั่น-ดีไนตริฟิเคชั่นในขั้นแรกของการทดลองเพื่อสังเกตความเป็นไปได้ในการใช้ค่าออกซิเดชั่น-รีดักชั่นโพเทนเชียล หรือค่าโออาร์พี สำหรับควบคุมปริมาณออกซิเจนในระบบที่ถูกป้อนด้วยน้ำเสียจากโรงงานน้ำยางข้น น้ำเสียจากโรงงานนี้มีความเข้มข้นของคาร์บอนและของแข็งสูงมาก ค่าอัตราส่วนอาหารต่อจุลินทรีย์ สูงถึง 1.5 กก.ซีโอดี/วัน/กก.MLSS ผลการทดลองในขั้นแรกนี้ชี้ให้เห็นว่าค่าโออาร์พีมีผลกระทบจากการเปลี่ยนแปลงของปริมาณอากาศที่ถูกป้อนให้กับระบบ แต่อย่างไรก็ตามค่าโออาร์พีเองก็มีผลกระทบจากการเปลี่ยนแปลงอุณหภูมิของน้ำเสีย ซึ่งส่งผลให้เกิดปัญหาตะกอนลอย

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In the southern part of Thailand, industry is based mainly on para rubber products. The wastewater from these factories contains high organic carbon and sulfate. Nowadays, the Activated Sludge Process (ASP) has been applied to these factories to reduce the land requirement for treatment plants and to increase the treatability. Chevakidagarn and Ratanachai (2004) surveyed the ASPs for latex rubber industry in southern Thailand. Their report showed that existing activated sludge treatment plants are mostly conventional activated sludge processes and are operating without a concern for nitrogen removal. Chemical analysis and calculation of removal efficiencies showed that there were high removal capacities for BOD_5 and COD, about 98-99 percent. But, the suspended solids (SS) removal capacity was less than this (about 80 percent). However, nitrogen removal was to a moderate degree. It is possible that the simultaneous nitrification-denitrification processes resulted in the removal of 54-60 percent of total nitrogen removal what was observed, although nutrients in the form of both organic and inorganic nitrogen were still discharged into the receiving watercourses.

The major reason for inadequate treatment was likely to be the insufficient oxygen concentrations. Plant operators pump air to aeration tanks at

a constant rate corresponding to a plant design value of 2.0 mg/L dissolved oxygen (DO) concentration. The DO concentrations vary because of the fluctuation in organic loading. At the same time, the settling ability of sludge floc in the ASP was poor (Chevakidagarn and Ratanachai, 2004).

The settling ability problems are mainly caused by the bulking- and rising-sludge problems, which take place in aeration and settling tanks, respectively. The operator cannot prevent a large amount of solids from escaping, and, frequently their effluent does not comply with Thai effluent standards. However, these problems might be reduced by applying the optimal oxygen control system.

The oxidation-reduction potential (ORP) is the electromotive force developed when oxidizers or reducers are present in aqueous solution. ORP regulation, as a means of controlling operation, has been shown to be an efficient method for optimizing pollution removal and energy consumption (Charpentier *et al*., 1987). Collivignarelli and Bertanza (1999) showed that the ORP could be the parameter for monitoring the nitrogen removal in the extended aeration activated sludge plants, which are fed with municipal wastewater. They recommended that ORP be maintained at constant values, which must be determined for each specific case. It should be noted that their experiments were conducted at a constant DO concentration in the range of 0.3-0.6 mg/l and low sludge-loading rate (about 0.1 kg of BOD_5/day/kg of MLSS).

Therefore, in this study, the ORP was introduced as an efficient parameter for optimizing DO control. The pilot-scale experiments were conducted to identify suitable values for application to such a strong concentration of latex rubber industrial wastewater.

Methods

The process was used in a pilot-scale plant in which online analyzers and real time control systems were available (see Figure 1). It involved completely mixed ASP fed with wastewater from the latex rubber industry. Once a week, the wastewater from the representative factory was collected and kept in a refrigerator under temperature controlled at 4ºC.

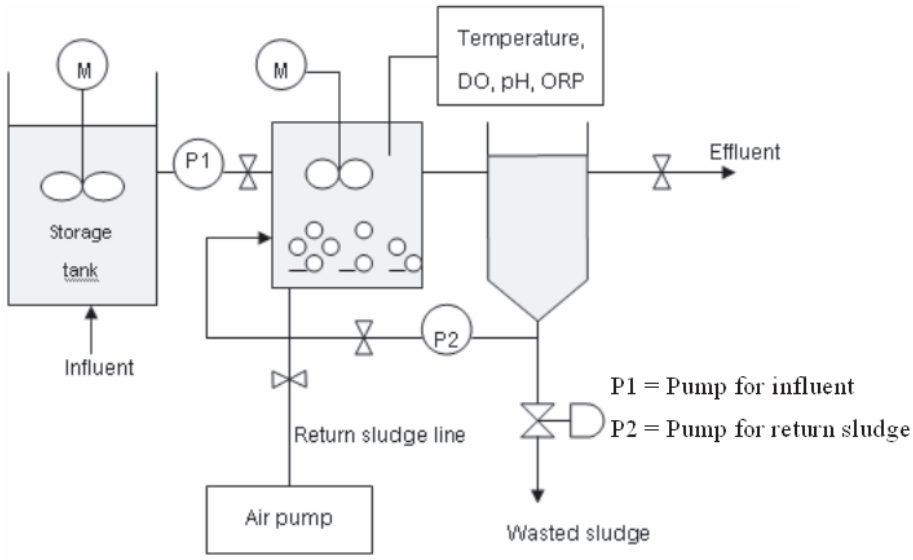

Figure 1. Schematic representation of the pilot-scale ASP experiment and location of the online analyzers

The ASP in these experiments used the simultaneous nitrification-denitrification process without temporally or spatially alternating anoxic/oxic conditions. The process was operated at low, but variable, DO concentrations. The aeration rate was varied from 10 to 40 L/min.

The pilot-scale with about a 75 liter aeration capacity was used for the experiments. The temperature, ORP, pH, and the oxygen concentration were recorded every 5 to 10 minutes by online-analyzers. An air pump in the experiments was automatically controlled based on the ORP values. The volume of surplus sludge was controlled to maintain a solids content of 3.5-4.0 g/l. The sludge retention time (SRT) was not a concern, because, in the actual situation, it is very rare to find the treatment plant in which surplus sludge was discharged regularly. Most of the operators are concerned only with the SV_{30}.

The ORP values were observed and controlled by means of the real-time control system to achieve high removal capacities of carbon and nutrient, in terms of COD and total nitrogen, respectively.

Results and Discussion

This first stage of experiments was to observe the possibility of using ORP for aeration control in treatment plant fed with the wastewater from the latex rubber industry. The average COD concentration was 8621±5379 mg/L (from 15 samples in 15 weeks). The influent concentration from latex rubber industry is very strong and fluctuated.

Under the simultaneous nitrification-denitrification condition, the ASP was operated with the hydraulic retention time of 36 hours. The ORP varied from -415 to -454 mV with an average value of -440±10 mV. Figure 2 shows the example of the measured ORP over 84 hours. The average F/M ratio in these 84 hours was 1.5 kg of COD/day/kg of MLSS.

The objective was to reach the simultaneous nitrification-denitrification process, so the experiment was expected to operate with low oxygen concentration. However, the DO concentration measured in the aeration tank fluctuated as shown in Figure 3. This phenomenon might be explained for the high organic concentration of wastewater from latex rubber industry, causing slime to be produced which then coated the membrane of the DO sensor. The operator cleaned the sensor every morning, but the DO sensor malfunctioned for aeration control in this experiment.

However, with onsite measurement by using pH/Oxi 340i WTW GmbH & Co.ltd, the DO concentration fluctuated from 0.8 to 1.8 mg/L (see Figure 4). The sludge volume index (SVI) was used as the main parameter for identifying the

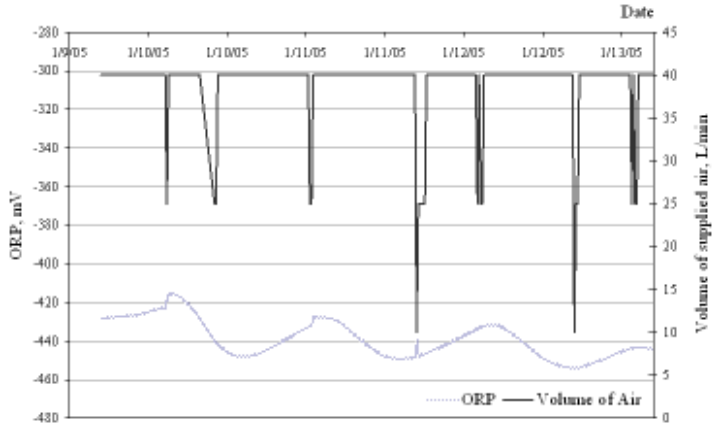

Figure 2. Variation of the ORP and volumes of supplied air from the experiment over 84 hours, with an HRT of 36 hours at 28ºC

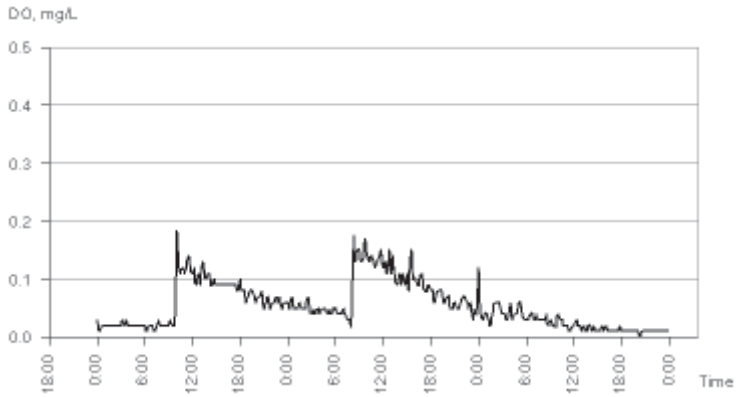

Figure 3. Daily DO fluctuation after cleaning and calibration

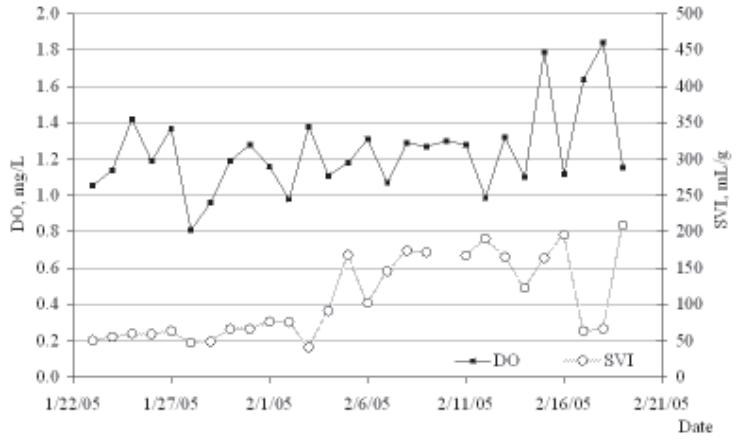

Figure 4. Variations of the DO concentrations and the SVI values from the experiment over 30 days

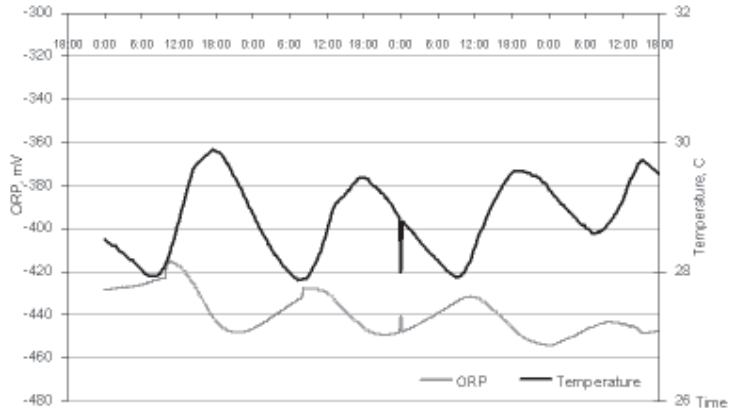

Figure 5. Trend of the ORP values affected by the change of temperature in the simultaneous nitrification-denitrification process

bulking sludge problem in this study, because the filamentous microorganism could grow relatively quickly at low oxygen concentration (ATV working report 2.6.1, 1989). The SVI values were measured daily for 30 days. The results in Figure 3 show that the SVI values increased from 51 mL/g to 209 mL/g, in one month. The SS concentration in effluent increased from 350.0±115.0 mg/L to be 678.0±164.0 mg/L.

Nevertheless, the ORP fluctuated depending on the operating temperature. Figure 5 shows that the temperature fluctuated from 28ºC to 30ºC daily, and the ORP was strongly affected by the change of temperature. This fluctuation of temperature might cause an abrupt change in conditions, which caused the bulking sludge problem. The control temperature might be required for the further experiments.

Conclusion

The results in this first stage indicate the simultaneous nitrification-denitrification process might not be suitable for treating high organic loading in the latex rubber industry. However, in this first stage, the process could prevent the escaping of the sludge blanket caused by the rising sludge problem in the final settling tank.

The DO sensor could not function as aeration control for this experiment in a high organic concentration. The ORP was applied as the main parameter for oxygen control in this study. It was affected by the wastewater temperature. The observed results showed that the ORP was greatly affected by the change in air supply. This phenomenon confirms that the ORP can be applied as an aeration control system.

The bulking sludge problem occurred in the simultaneous nitrification-denitrification process. However, it is not certain that the main cause is from the fluctuation of DO concentration or from the one of the wastewater temperature.

Expected results

Further experiments (next phases) are required to identify the strategy, and appropriate details of time intervals and amounts of air supplied to the aeration tank to improve control system reliability. Moreover, computer programming is required to provide a better understanding of the relationship between the ORP values and the operating parameters. These results will lead to innovation in aeration control systems without the requirement of chemicals, and at low maintenance costs.

Acknowledgement

This research was supported by Prince of Songkla University, Hat Yai, Songkhla, Thailand.

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