STUDY ON APPLICABILITY OF THE CONTACT OXIDATION PROCESS IN REMOVAL OF ORGANIC POLLUTANTS FROM TEXTILE WASTEWATER

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Abstract

In order to evaluate applicability of the contact oxidation process in removal of organic pollutants from textile wastewater, COD removal performance as well as treatment stability of the process were investigated and compared with those of the activated sludge process. Simulated wastewater prepared from representatives of textile wastewater effluents, i.e. dyeing wastewater and sizing wastewater from a textile company was used for experiments. The results indicated that the contact oxidation process proves several benefits against the activated sludge process: The contact oxidation process shows significantly higher COD removal efficiency, around 83 % against the activated sludge process, 70 – 80 % depending on COD load. The least removal efficiency of dyeing wastewater COD during the treatment for the contact oxidation process was estimated to be approximately 70%, remarkably higher than that for the activated sludge process ranging from 40 % to 70 %. COD in treated water and COD removal efficiency of the contact oxidation process are less influenced by COD load, indicating that this process is more stable and more easily adapts to the change in influent wastewater characteristics. It is possible to apply a higher COD load for the contact oxidation process because of its higher COD removal rate. For example, a COD load of 2,0 $kg/m^3/day$ for this process, twofold higher than that for the activated sludge process can be applied when effluent COD is under 100 mg/L as according to Vietnamese standard. Concerning operating conditions, the contact oxidation process also shows other advantages such as no requirement of sludge return, easy process control, abilities of reducing excess sludge and eliminating bulking phenomenon.

1. Introduction

Water environment pollution caused by textile wastewater discharge has been becoming a pressing issue in several locations in Vietnam because of its extremely high concentration of organic contaminants as well as intense color [1-3]. Due to the recent rapid growth of the textile industry, wastewater discharge from this industry, which was estimated to be more than 30 million m^3/year in 1999 [2] is dramatically increasing year after year. Nevertheless, at present only around 10 % of this effluent is treated, mostly by simple coagulation and sedimentation processes, before discharge [1-3]. Treatment of textile wastewater, therefore, is a deep concern in Vietnam.

Aerobic activated sludge process has been widely applied for removing organic pollutants from textile wastewater. However textile wastewater contains hardly biodegradable substances such as dyestuffs, therefore the process must be operated at low organic load with long hydraulic retention time [4-7] in order to achieve desired treatment efficiency. Consequently, large reactor space is required for the construction of the process. Contact oxidation process, which employs support media for biofilm growth has also been developed for the aerobic treatment of wastewaters during past decades. In this process, because microorganisms attach and are fixed on the surface of contact media high biomass concentration can be achieved, resulting in short hydraulic retention time, high adaptability against the change of influent wastewater characteristics and high stability of treatment efficiency in comparison to suspended growth systems [8]. This process is especially appropriate and effective for the low cell growth rate systems, for example for treatment of low BOD wastewater and nitrification. With those benefits, the contact oxidation process is expected to be appropriate for treatment of textile wastewater that contains hardly biodegradable organic substances causing low biomass conversion. However, data on applicability of this process to textile wastewater are not available.

The aim of this study is to evaluate the feasibility of the contact oxidation process in removal of organic pollutants from textile wastewater. COD removal performance of the contact oxidation process was examined and compared with that of the activated sludge process. Treatment efficiency, COD removal rate and stability of the two processes will be discussed.

2. Experimental

Wastewater

Wastewater used in the study was simulated wastewater prepared from effluents generated from sizing and dyeing operations of a textile company (Minh Khai Textile Company). Textile wastewater usually contains both biodegradable and hardly biodegradable organic pollutants. The main biodegradable substance is starch, which is used for sizing and released into wastewater from sizing, desizing and kiering operations. On the other hand, the main recalcitrant one is dyestuff generated from dyeing operation. Therefore, starch and dyestuff can be considered as representatives for organic pollutants in textile wastewater. Our estimation based on the consumption data of starch from several textile companies indicated that starch in wastewater accounts for more than 50 % of COD in the whole wastewater effluent. Thus, wastewater for experiments was simulated with the ratio of sizing wastewater COD to dyeing wastewater COD of 1:1. As COD of the two selected effluents is much higher than COD of the actual combined effluent of textile companies, the two wastewaters were mixed together with predefined volumes and then diluted by tap-water to obtain desired total COD values similar to the real combined wastewater generated from textile industry. The experiments were performed in the typical COD range of wastewater from several textile companies in Vietnam between 300 mg/L and 600 mg/L [2, 9]. BOD to COD ratios of sizing wastewater and dyeing wastewater were 0.60 – 0.65 and 0.25 – 0.30, respectively, and that of mixed wastewater used for experiments was in the range of 0.42 – 0.47.

Experiments

Experiments with activated sludge process were carried out using an ASS-20PS activated sludge process device (Myamoto Co., Ltd., Japan) comprising an aeration tank of 20 L, a settling tank of 10 L and automatic controllers of pH, DO and temperature as in **Fig. 1**. Experiments with contact oxidation process were conducted in a COTT-4 contact oxidation test device (Myamoto Co., Ltd., Japan) comprising a contact oxidation compartment with an effective volume of 15 L and a setting compartment of 7 L as shown in **Fig. 2**. Contact media as microorganism carriers in the contact oxidation system were corrugated bundle plastic media having a specific surface area of approximately 200 m^2/m^3 and a void space of around 95 %.

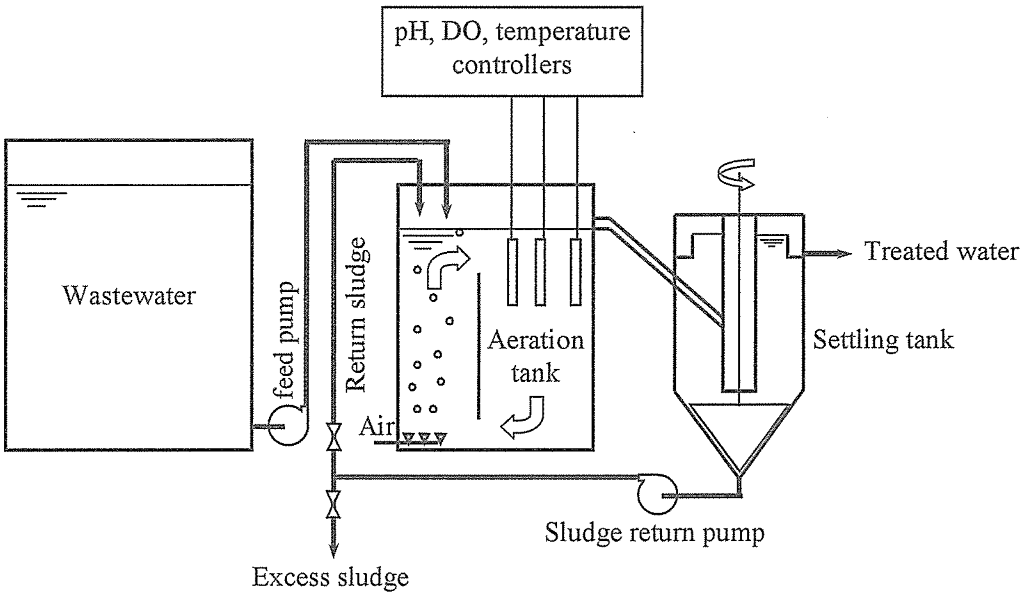

Fig.1 Experimental diagram of activated sludge system

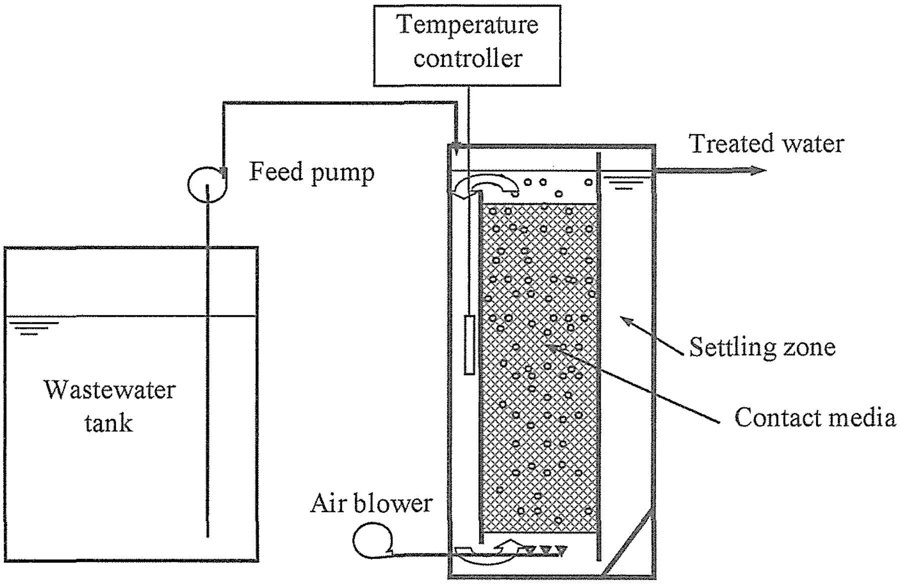

Fig. 2 Experimental diagram of contact oxidation system

Flow-rates of inlet wastewater were controlled by adjusting the speed of metering feed pumps. All experiments were conducted at temperature of 26 ± 0.5 °C, pH in the range of 7.0 – 7.5 and DO in the range of 2 – 3 mg/L. MLSS (mixed liquor suspended solid) in the aeration tank of the activated sludge system was maintained in the range of 2000 – 2400 mg/L. Nitrogen and phosphorus sources were added by $(NH_4)_2SO_4$ and KH_2PO_4 solutions with BOD: N : P ratio of 100 : 5 : 1. In the pre-cultivation stage an activated sludge culture taken from an industry wastewater treatment plant was adapted to experiment systems by continuous wastewater feeding. The start-up period was conducted for about one month. Experiments with the contact oxidation system were carried out without sludge return.

Analysis

COD was analyzed following the closed reflux - titrimetric method with potassium dichromate as oxidant using a TR320 thermoreactor (Merck, Germany). Experiment data for each different COD load were taken after the steady-state conditions were reached.

3. Results and discussion

COD removal efficiency

Fig.3 shows the effect of COD load on COD removal in the activated sludge and contact oxidation systems. COD load was changed by varying either influent COD in the range of 300 – 600 mg/L or hydraulic retention time in the range of 6 – 20 h, and calculated by the equation (1):

$$L_{COD} = \frac{COD_{in} \times 10^{-3}}{HRT} \qquad (1)$$

where, L_{COD} denotes COD load (in kg/m^3/day), COD_{in} is COD concentration (in mg/L) in the influent, and HRT is hydraulic retention time (in day).

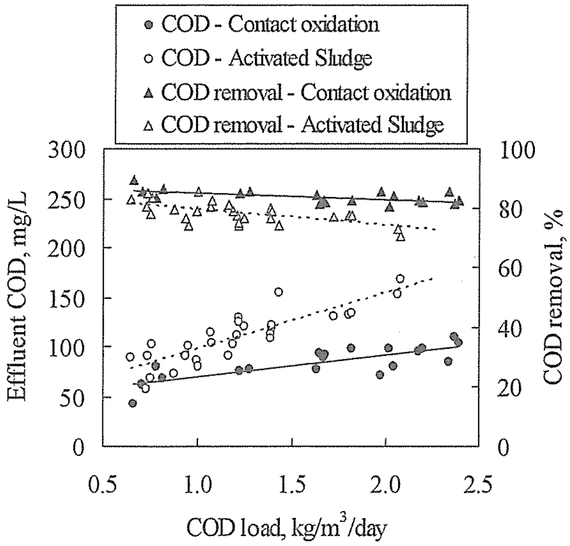

Fig. 3 COD removal efficiency versus COD load

It can be seen from Fig.3 that effluent COD and COD removal efficiency in the contact oxidation system are less influenced by COD load than those in the activated sludge system. In the activated sludge system, effluent COD increases and COD removal efficiency decreases when increasing COD load, while significant change in COD removal efficiency is not observed for the case of the contact oxidation system. Moreover, the contact oxidation system achieves higher COD removal efficiency, around 83 % more than the activated sludge system, in the range of 70 - 80 %. The obtained results indicate that, as expectation, the contact oxidation process is more stable than the activated sludge process in treatment of textile wastewater. In order to achieve effluent COD less than 100 mg/L to meet the Vietnamese discharge regulation, the operating COD load should be less than 1.0 kg/m^3/day for the activated sludge process, whereas it can rise twice for the contact oxidation process.

COD removal rate

Fig. 4 shows the effect of COD load on COD removal rate in the contact oxidation and activated sludge systems. COD removal rate was obtained from the equation (2).

$$r_{COD} = \frac{(COD_{in} - COD_{out}) \times 10^{-3}}{HRT} \qquad (2)$$

where, r_{COD} is COD removal rate, COD_{out} is COD concentration (in mg/L) in the effluent.

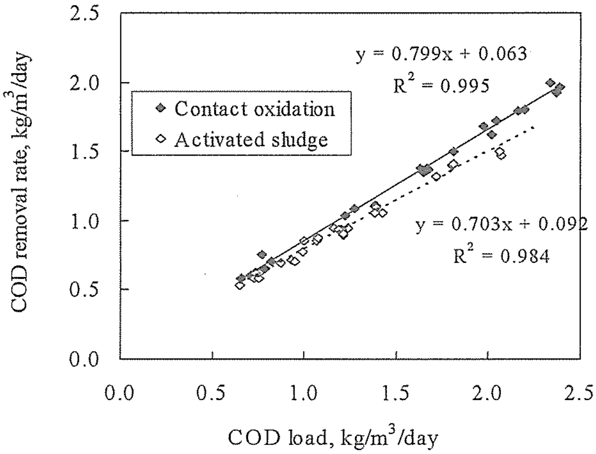

Fig. 4 COD removal rate versus COD load

It can be seen from **Fig. 4** that, in the investigated range, COD removal rates in both systems are proportional to COD load. However, COD removal rate in the contact oxidation system is higher. This indicates that the contact oxidation process is more effective in removal of organic pollutants in textile wastewater. From the experiment results, the following empirical relation between COD removal rate and COD load is obtained:

$$r_{COD} = aL_{COD} + b \qquad (3)$$

where, a and b are constants.

From equations (1) – (3), the relation between COD removal efficiency and COD load can be described as follows:

$$\eta = \frac{COD_{in} - COD_{out}}{COD_{in}} \times 100\% = (a + \frac{b}{L_{COD}}) \times 100\% \qquad (4)$$

where, η is COD removal efficiency.

The values of a and b respectively are 0.799 and 0.063 for the case of contact oxidation process, and 0.703 and 0.092 for the case of activated sludge process. The lower value of b for the contact oxidation process means that COD removal efficiency of this process is less dependent on COD load than that of the activated sludge process.

Dyeing wastewater COD removal possibility

It is worthwhile to estimate the elimination of COD of dyeing wastewater, which is one of the most recalcitrant effluents from textile industry during the treatment in the two processes. By assuming that most sizing wastewater COD was removed, and the effluent COD is mainly the residual COD of dyeing wastewater, one can evaluate the least removal efficiency of dyeing wastewater COD. **Fig. 5** shows the evaluation of least removal efficiency of dyeing wastewater COD. It can be clearly seen that the least removal of dyeing wastewater COD in the activated sludge system tends to decrease when increasing the load of dyeing wastewater COD, while that in the contact oxidation system is less sensitive to COD load. The least removal efficiency of dyeing wastewater COD in the oxidation system is about 70%, significantly higher than that in the activated sludge system ranging from 40 % to 70 %. These results again reveal that the contact oxidation process is more stable and easier to adapt to wastewater characteristics than the activated sludge process.

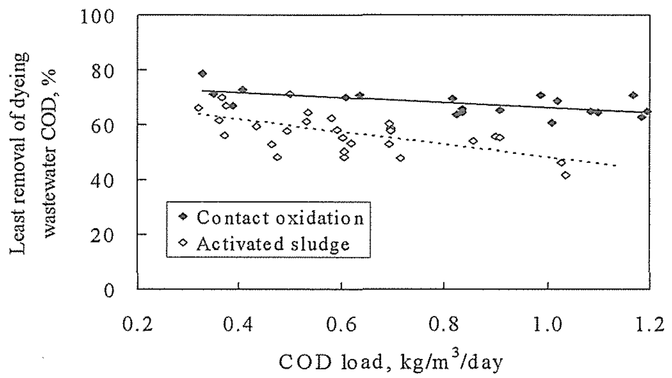

Fig. 5 Dyeing wastewater COD removal efficiency during the treatment

In addition, concerning operating conditions it is noted that settleability of activated sludge in the activated sludge system was quite good with sludge volume index (SVI) in the range of 100 – 150 when COD load under 2.1 kg/m^3/day, but bulking phenomenon was likely to occur with purer settleability (SVI of around 200) when increasing COD load. In comparison to activated sludge system, control of the contact oxidation system was quite simple since sludge return was not required for the system.

4. Conclusions

In order to evaluate applicability of the contact oxidation process in removal of organic pollutants from textile wastewater, COD removal performance as well as stability of the contact oxidation process were investigated and compared with those of the activated sludge process. Simulated wastewater prepared from representatives of textile effluents, i.e. dyeing wastewater and sizing wastewater from a textile company was used for the study. The results show that the contact oxidation process proves several benefits against the activated sludge process as follows:

- The contact oxidation process shows significantly higher COD removal efficiency, around 83 % against the activated sludge process, 70 – 80 % depending on COD load. It was also estimated that the least removal efficiency of dyeing wastewater COD during the treatment for the oxidation process is approximately 70%, remarkably higher than that for the activated sludge process ranging from 40 % to 70 %.
- Effluent COD and COD removal efficiency in the contact oxidation process are less influenced by COD load, indicating that this process is more stable and more easily adapts to the change in influent wastewater characteristics.
- It is able to apply a higher COD load for the contact oxidation process because of its higher COD removal rate. For example, a COD load of 2,0 kg/m^3/day for this process, twice higher than that for the activated sludge process, can be applied when effluent COD is under 100 mg/L as required by Vietnamese standard.
- Concerning operating conditions, the contact oxidation process also shows other advantages such as no requirement of sludge return, easy process control, abilities of reducing excess sludge and eliminating bulking phenomenon.

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