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Treatment of high organic carbon industrial wastewater using photocatalysis process

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ABSTRACT

In Thailand, agricultural machinery manufacturing companies are known to generate high organic carbon wastewater from painting and leak testing processes. Chemical oxygen demand (COD) value in leak test wastewater is found to be in the range of 3000–5000 mg/l. In this study, three scales including lab-scale, pilot-scale and industrial-scale photocatalytic reactors were developed to investigate the efficiency of wastewater treatment. In lab-scale, the 800 ml reactors were set up to optimize the best condition for pH and TiO_2 loading. The results suggested that the pH had no effects on the COD removal, whereas the COD removal efficiency was increased by TiO_2 loading. The highest COD removal efficiency of 85% was found at the TiO_2 loading of 1 g/l. The 200 l reactor of pilot-scale and the 3000 l reactor of industrial-scale were established and continuously operated for 30 days. The results revealed that the COD removal efficiency was > 90%, and the COD concentration was reduced to 250–300 mg/l in the treated wastewater. The COD value of treated wastewater met the standard set by the Industrial Estate Authority of Thailand to discharge into a central wastewater treatment plant, which verified the successful implementation of process to the actual industrial wastewater.

1. Introduction

The agricultural machinery manufacturing industry is considered to be one of the key industrial sectors in Thailand. The most common products of the industry are tractors, agricultural implements and harvesters. There are several manufacturing processes including surface etching, painting, assembly and leak testing. During leak testing, grease which is used for preventing rust contaminates the water, called leak test wastewater, which is difficult to treat by traditional treatment processes. The leak test wastewater contains a high grease content of 40 mg/l and its chemical oxygen demand concentration (COD) which is referred to as organic carbon contamination is in the range of 3000–5000 mg/l (Siam Kubota Corporation, 2014). Normally, the industry treats leak test wastewater by chemical precipitation to reduce the organic carbon of about 80%, and then the wastewater is further treated in a central wastewater treatment plant of an industrial estate (Siam Kubota Corporation, 2014). According to the chemical precipitation process, the organic carbon content is efficiently removed, however the chemical solid waste which is a by-product of the process, is generated and requires further treatment and disposal. The industry spends millions of dollars every year for such chemical solid waste treatment and disposal. To reduce the treatment and disposal costs, the industry is interested in finding more efficient and cheaper alternatives. The advanced technology of the photocatalysis process which has no toxic waste as a by-product is a potential process for the leak test wastewater treatment.

Photocatalysis is known as one of the advanced oxidation processes, it is applicable in the treatment of high organic carbon wastewater (Chong et al., 2010; Ghaly et al., 2011). According to the conceptual photocatalysis process, a catalyst such as TiO_2 is exposed to light and exhibited oxidative decomposition and super hydrophilic properties of $\cdot O_2-$, and $\cdot OH$ under an aeration. These two forms can decompose organic carbon from wastewater to intermediate forms and continued to become carbon dioxide (CO_2) and water (H_2O), as shown in Eq. (1) Banu et al. (2008).

$$Organic\ Compound \xrightarrow[light]{TiO_2+O_2} intermediates \xrightarrow[light]{TiO_2+O_2} CO_2 + H_2O \quad (1)$$

However, the application of the photocatalysis process in actual industrial wastewater treatment, has been very limited. There are only a few reports available. For example, Ghaly et al. (2011) used photocatalysis and H_2O_2 oxidation to treat paper mill wastewater which

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Table 1
Characteristics of leak test wastewater from the agricultural machinery industry.

Parameter	Concentration	Unit	Analysis method
pH	9.2	–	Electrometric method
Biochemical Oxygen Demand (BOD_5)	170	mg/l	5-day BOD test
Chemical Oxygen Demand (COD)	3200	mg/l	Close reflux
Suspended Solids (SS)	150	mg/l	Dried at 103–105 °C
Total Dissolved Solids (TDS)	3940	mg/l	Dried at 103–105 °C
Total Kieldahl Nitrogen (TKN)	198	mg/l	Macro-Kjeldahl method
Oil and grease	36	mg/l	Liquid-liquid, partition gravimetric

Table 2
Summary of operating conditions of photocatalytic reactors.

Reactor	pH	TiO_2 loading (g/l)	Reactor volume (l)
Lab-scale			
Effect of pH	6	1	0.8
	7	1	0.8
	8	1	0.8
	No adjustment	1	0.8
Effect of TiO_2 loading	No adjustment	0	0.8
	No adjustment	0.1	0.8
	No adjustment	1	0.8
	No adjustment	5	0.8
	No adjustment	10	0.8
Pilot-scale	No adjustment	0.1	200
Industrial-scale	No adjustment	0.1	3000

contains the high COD level of 2000 mg/l, the COD removal efficiency was approximately 75%. Further, the effective photocatalytic reactor was established to treat the effluent from an anaerobic bioreactor in the dairy industry; the COD and nitrogen concentrations in the wastewater were approximately 300 mg/l and 60 mg/l (Banu et al., 2008). However, both wastewater in previous studies had no oil and grease contamination which possibly negatively effects on the performance of photocatalysis process.

The intention of the present study is to investigate the efficiency of the photocatalysis process for industrial wastewater containing high non-biodegradable organic carbon. The COD removal efficiency is used as an indicator to identify the performance of organic carbon removal. Firstly, lab-scale of photocatalytic reactors were used to study and clarify the optimal pH and TiO_2 loading. Later, the pilot-scale and industrial-scale of photocatalytic reactors were implemented at the industry site for investigating performance under long-term operational conditions.

2. Methodology

Leak test wastewater from the agricultural machinery industry is used as a case study in this study. The characteristics of the wastewater is summarized in Table 1 (Siam Kubota Corporation, 2014).

In the experiments, commercial TiO_2 particles were used as a catalyst. The characteristics of TiO_2 particles are shown in previous study (Yuangpho et al., 2015). The various scales of photocatalytic reactors as developed, are indicated as follows:

2.1. Lab-scale reactor

In the lab-scale reactors, the effects of pH and TiO_2 loading were studied. The pH of wastewater was adjusted to 6, 7 and 8 using H_2SO_4. Then, 800 ml of adjusted wastewater was added into three 1 l beakers. Wastewater with no pH adjustment was used as a control. Although the enhancement of photocatalysis activity was reported at a low pH value (Akpan and Hameed, 2009), the cost-effectiveness of chemicals

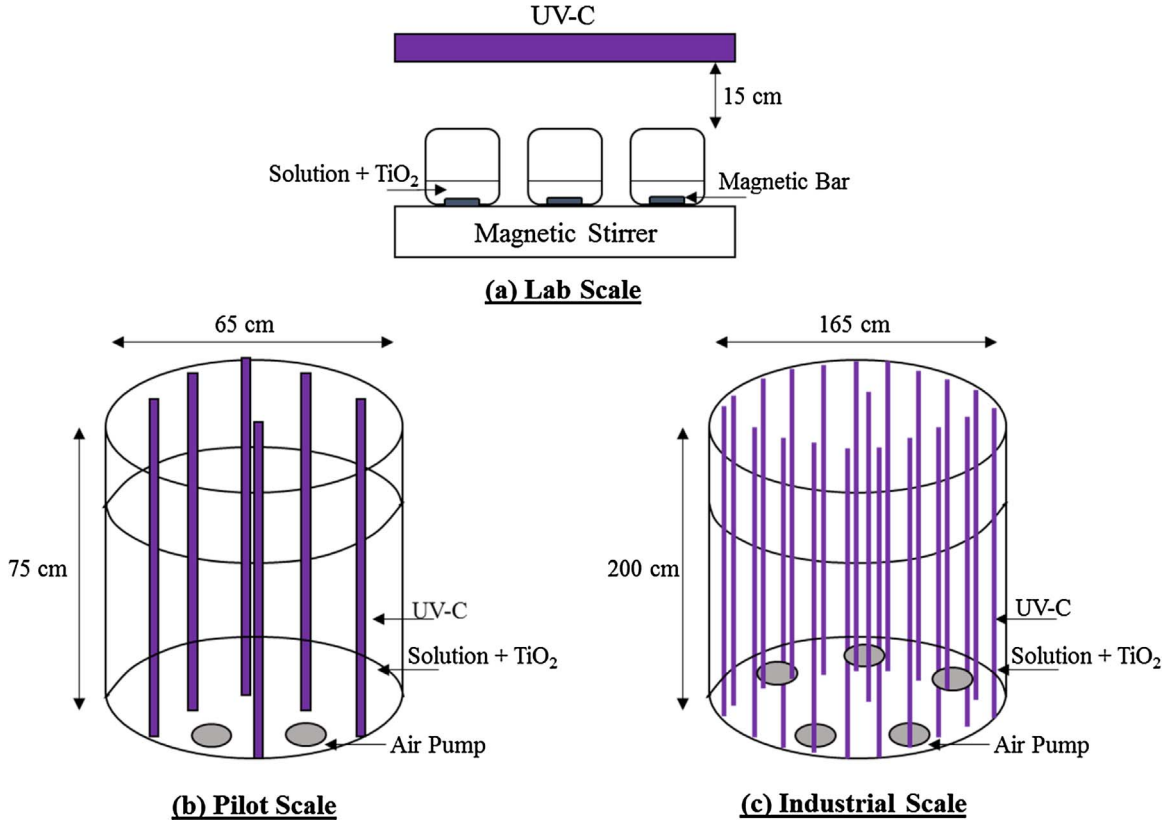

Fig. 1. Schematic diagram of (a) lab-scale, (b) pilot-scale and (c) industrial-scale of photocatalytic reactors for actual industrial wastewater treatment.