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Effects of Operation Conditions on Oily Wastewater Treatment Efficiency of Coalescer Process
ผลกระทบจากสภาวะเดินระบบต่อประสิทธิภาพการบำบัดน้ำเสียปนเปื้อนน้ำมันของกระบวนการโคอะเลสเซอร์

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Abstract

This research aims to study the effects of operating conditions on oily wastewater treatment efficiency of coalescer process. The experiments were conducted for separating the synthetic oily wastewater concentration 0.5-2 g/L by polypropylene tubes packed as a coalesce media in a rectangular tank. The bed lengths of 3-10 cm were applied in both vertical and horizontal flow conditions with the fluid velocities of 6.1-18.9 m/h. The results showed that, under the proper operation, the coalescer gave the treatment efficiency up to 78%. Study of the effects of the parameters found that increasing the flow velocity the efficiencies of coalescer decreases in both vertical and horizontal. Increasing the bed length resulted in higher treatment efficiency only in the vertical coalescer.

Keywords : treatment; oily wastewater; coalescer; bed; combined process

บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาผลกระทบจากการเดินระบบที่มีต่อประสิทธิภาพในการบำบัดน้ำเสียปนเปื้อนน้ำมันของกระบวนการโคอะเลสเซอร์ การทดลองใช้น้ำเสียปนเปื้อนน้ำมันสังเคราะห์ความเข้มข้น 0.5-2 กรัมต่อลิตร ใช้ตัวกลางพอลิ-โพรไพลีนแบบหลอดบรรจุในชั้นตัวกลางที่มีความหนา 3-10 เซนติเมตร เดินระบบแบบแนวตั้งและแนวนอนโดยใช้ความเร็วการไหล 6.1-18.9 เมตรต่อชั่วโมง ผลการทดลองแสดงเห็นว่าในสภาวะการเดินระบบที่เหมาะสม กระบวนการโคอะเลสเซอร์มีประสิทธิภาพในการบำบัดสูงสุดที่ร้อยละ 78 การศึกษาผลกระทบของตัวแปรพบว่าการเพิ่มความเร็วการไหลทำให้ประสิทธิภาพของกระบวนการโคอะเลสเซอร์ลดลงทั้งในแนวตั้งและแนวนอน และการเพิ่มความหนาชั้นตัวกลางส่งผลให้ประสิทธิภาพการบำบัดเพิ่มขึ้นเฉพาะในกระบวนการโคอะเลสเซอร์แนวตั้ง

คำสำคัญ : การบำบัด; น้ำเสียปนเปื้อนน้ำมัน; โคอะเลสเซอร์; ชั้นตัวกลาง; กระบวนการร่วม

Introduction

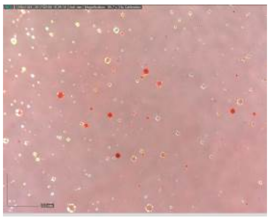
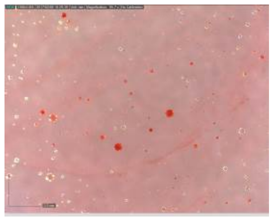
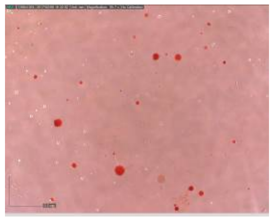
Rapid growth in economy and population is the main reason of increasing oily wastewater production [1]. Without good management, oil can cause severe effects on environment [2] making it as one of most concerned environmental problems. Oily wastewater is mostly found in form of emulsion in water, which can be divided into 2 types [3]. First, stabilized emulsion consists of water, oil, and surfactants. The surfactant made the surface tension of water and oil drops and causes the surfactant electrode (Zeta potential) on the surface of oil droplet that causing electrostatic repulsion between the oil droplets and made the oil particles cannot be combined with other particles. The second type is non-stabilized emulsion consists of only water and oil only. This emulsion is formed by the dispersion of oil due to added energy, such as mixing or agitation. Without this energy, oil droplets can easily coalesce and separate from water themselves. Therefore, stabilized emulsion is the main problem in handling of oily wastewater since it is difficult to separate by conventional physical processes (e.g. API), due to the small size and high stability of oil droplets [4]. One technique for promoting oily wastewater separation is the increase of droplet size, which could result in more effective oil separation. In this work, coalescer was chosen for facilitating oil separation by enlarging oil droplets. Its working principle is to promote the coalescence of droplets in the emulsion that flows through a bed of hydrophobic media. Probability of droplet's aggregation is therefore increased resulting in larger oil droplets those can float to the surface faster than in the API, thus, higher separation efficiency can be achieved. Effects of flow velocity and bed height on the separation efficiency were investigated in the coalescer to find the optimal condition.

Methodology

Preparation of synthetic Oily Wastewater

The oily wastewater was synthesized at 0.5, 1 and 2 g/L concentrations by mixing palm oil (Refined, bleached and deodorized (RBD) palm oil), tap water and sodium dodecyl sulfate (SDS) under 800 rpm for 3 minutes. Oil concentration was analyzed in terms of COD and turbidity by the closed reflux method [5] and turbidimeter (Hach 2100P), respectively. Droplet diameter was measured by the Dino-Lite Digital Microscope after dyeing with oleate oil. Characteristics of the synthetic palm oil wastewater are summarized in Table 1. Both COD and turbidity were increased with the oil concentration, but no obvious difference of droplet sizes can be noticed.

Table 1 Characteristics of synthetic oily wastewater

Parameter	Oil concentration (g/L)		
	0.5	1	2
COD (mg/L)	840	1360	2046
Turbidity (NTU)	159	328	710
Oil droplet size (μm)	 12.5-125	 12.5-125	 12.5-125

Experimental setup

This research was divided into 3 parts by process configuration, including 1) vertical coalescer, 2) horizontal coalescer and 3) combined process. The experimental unit is shown in Figures 1 and 2. The synthetic oily wastewater was introduced from the preparation tank (1) to the reactor (2). It flows through the coalescer bed (vertically and/or horizontally) (3) before entering the decantation zone (4) and circulating (5) to the preparation tank. The effluent was collected every 15 minutes for 2 hours at the end of the decantation zone. After 2 hours, the effluent was discharged to the storage tank (6).

Coalescer bed

The media used in the experiments was polypropylene tubes [6] packed in stainless steel boxes with the lengths of 3, 5 and 10 cm as depicted in Figure 3.

Experimental conditions and parameters

The wastewater velocity (v) was varied from 6.1 to 18.9 m/h, while the bed lengths (l) of 3, 5 and 10 cm were used. The treatment efficiency was deduced from the percentage of COD removal as expressed in equation (1). The efficiency was also confirmed by turbidity results.

$$\text{Efficiency (\%)} = \frac{A - B}{A} \times 100 \qquad (1)$$

Where A is the COD_{inlet} (mg/L) and B is the COD_{outlet} (mg/L)

Result and Discussion

Effect of fluid velocity

1. Vertical coalescer

The effect of fluid velocity is shown in Figure 4a. As can be seen, when decreases the fluid velocity, the efficiency of the coalescer was increased. The highest efficiency of 78% can be achieved from the velocity of 6.1 m/h.

2. Horizontal coalescer

As can be seen in Figure 4b, the effect of fluid velocity in horizontal flow was similar as the vertical flow. In this work, the efficiency approximate values for the velocities of 6.1, 11.6 and 18.9 m/h were 72%, 67% and 61%, respectively.

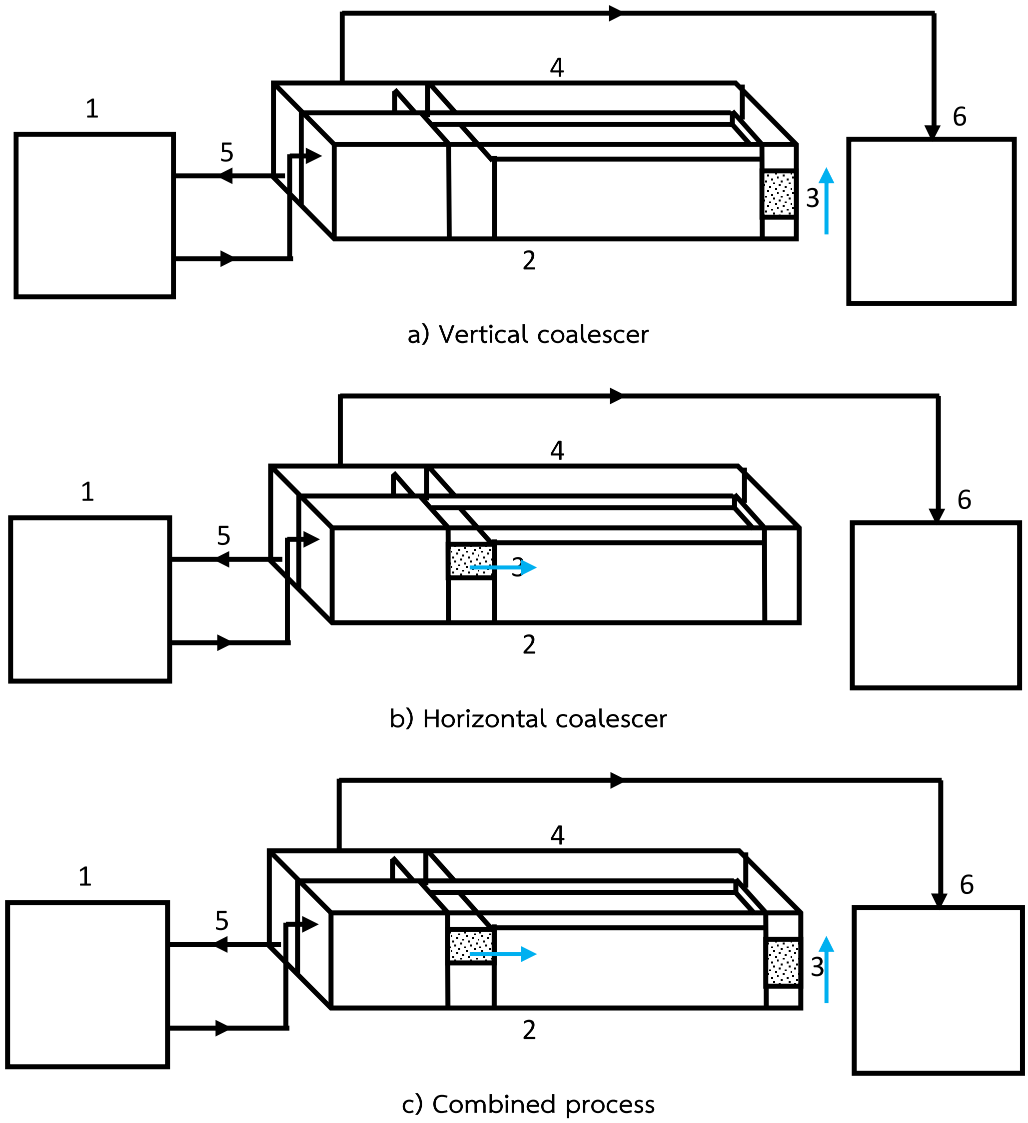


Figure 1 Schematic diagram of experimental setup for different operations

Figure 2 Coalescer reactor

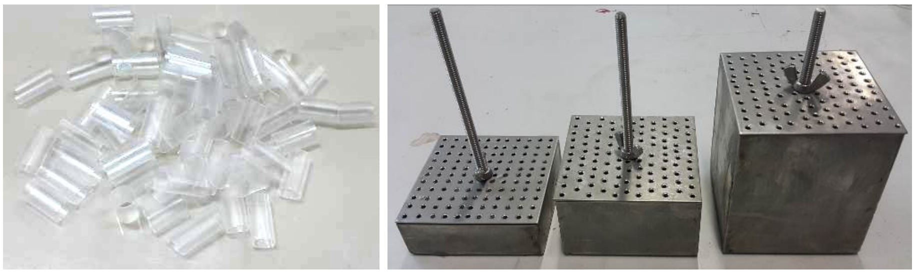
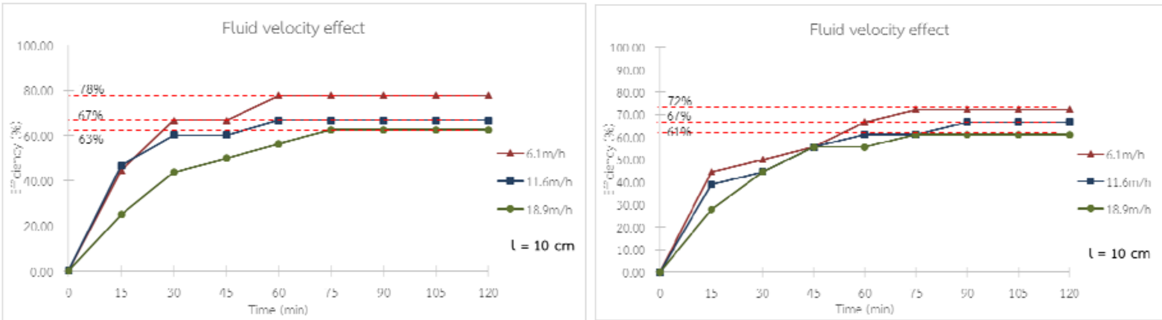


Figure 3 Coalescer media and boxes



a) Vertical coalescer b) Horizontal coalescer

Figure 4 Effect of fluid velocity on coalescer efficiency at 10 cm bed length with 1 g/L oil concentration

The decrease in the efficiency was owing to the fluid velocity increased. The increase of velocity resulted in shorter stay of oil droplets in the bed. Probability of droplet coalescence was lowered as a result. Effects of fluid velocity on the separation performance for both operation modes were similar. The highest efficiencies were attained from the lowest velocity of 6.1 m/h in both cases.

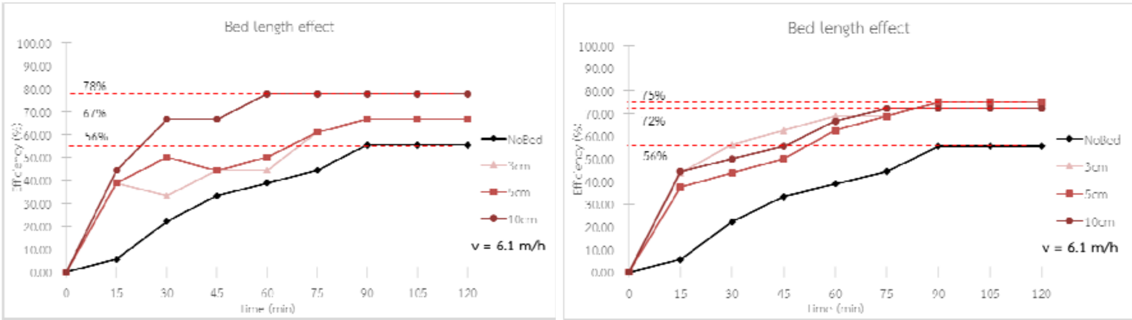
Effect of bed length

1. **Vertical coalescer process**

From Figure 5a, the efficiencies were increased with the bed length. The longest bed (10 cm) provided the highest efficiency of 78% at 6.1 m/h velocity. Moreover, the efficiencies obtained from other bed length were higher than that without coalescer bed (56%) under similar operation.

2. **Horizontal coalescer process**

Increasing the bed length only affected the efficiency of vertical coalescer as no obvious difference can be seen for the horizontal coalescer in Figure 5b. The efficiencies of the horizontal coalescer with different bed lengths were in the narrow range of 72-75%. Since the direction of the hydrodynamic force and Buoyancy force are perpendicular to each other, the flow velocity does not affect the efficiency of coalescer at different bed length significantly. However, the efficiency was still higher than that without coalescer bed, which confirmed the role of coalescer in the separation of oily wastewater. Thus, in the horizontal coalescer can be use the shortest bed length (3 cm) to reduce the cost of operations.



a) Vertical coalescer b) Horizontal coalescer

Figure 5 Effect of bed length on the coalescer efficiency at 6.1 m/h velocity with 1 g/L oil concentration

Efficiency of coalescer process

Figure 6 summarizes the treatment efficiency of the coalescer under the optimal condition for each configuration. The highest efficiencies of the vertical coalescer (10 cm bed length), the horizontal coalescer (3 cm bed length) and the combined coalescer (10 cm bed length of vertical coalescer and 3 cm bed length of horizontal coalescer) were 78%, 75% and 77%, respectively, which were higher than that without the coalescer bed of 56%. The results indicated that coalescer can improve the efficiency from conventional separation process, i.e. API separator.

From the results above, the combined process is most appropriate in this work. By using bed length of 10 cm in the vertical coalescer and 3 cm in the horizontal coalescer and using flow velocity of 6.1 m/h with 60 minutes of operation time. In addition, the combined coalescer process can shorten the treatment time as the efficiency as high as 59% can be achieved within 15 minutes, which is suitable for the case with limited operation time or area for the treatment facility.

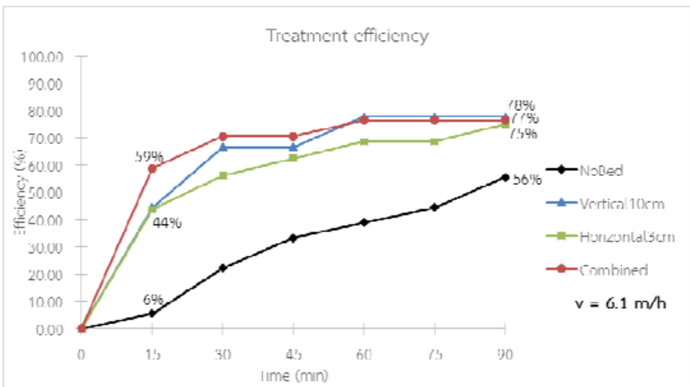


Figure 6 Coalescer efficiency of vertical coalescer, horizontal coalescer, combined process and without coalescer bed with 1 g/L oil concentration

Effect of oil concentration

The effect of oil concentration is exhibited in Figure 7. The oil concentration did not influence the efficiency of this process significantly. The efficiencies of both 1 g/L and 2 g/L oil concentrations were similar at 77%. However, lower efficiency was obtained from 0.5 g/L concentration due to less oil droplet number presented in the wastewater led to less coalescence probability. As can be seen in Figure 8, the lowest COD provided by the coalescer process was 320 g/L from both 0.5 g/L and 1 g/L oil concentrations.

Change in characteristics of oily wastewater

From Table 2, the reduction of oil concentration implied from COD and turbidity can be noticed. The initial COD of 840, 1,360 and 2,046 mg/L were decreased to 158, 320 and 472 mg/L in the effluent, respectively. The turbidities of 158, 328 and 710 NTU were also decreased with similar trend to 53, 70 and 120 NTU, respectively. In addition, oil droplet sizes were enlarged from 12.5-125 μm to 12.5-500 μm after passing the bed as can be seen in Figure 9. This affirmed the role of the coalescer to increase the size of oil droplets and enhance the separation efficiency. The coalescer process produced a good performance at high oil concentration and is suitable as a pretreatment. COD can be lowered but is still insufficient to pass the standard for industrial discharge [7]. Under the optimal condition, the effective separation of palm oil wastewater can be achieved without any chemical addition.

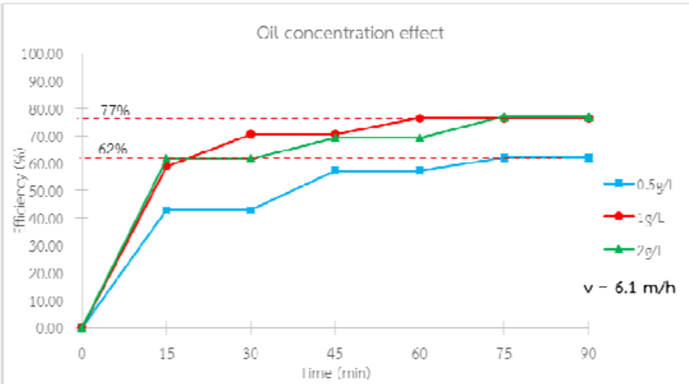


Figure 7 Effect of oil concentration on the coalescer efficiency

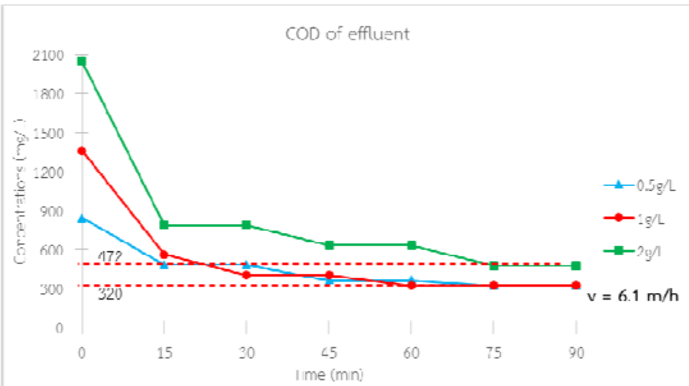
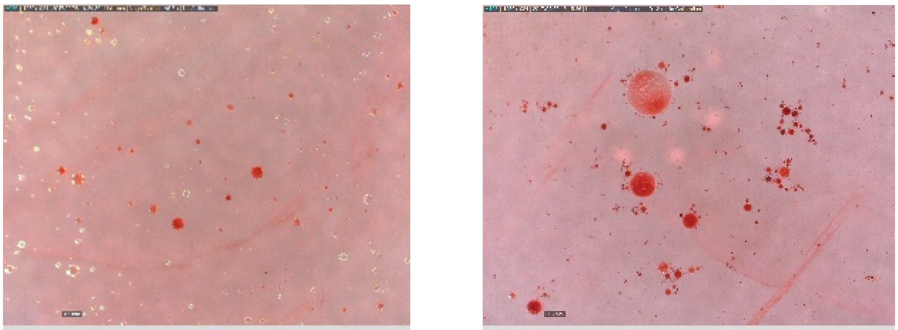


Figure 8 Residual COD of effluent after treatment

Table 2 Change in characteristics of oily wastewater from treatment

Parameter	Oil concentration (g/L)					
	0.5		1		2	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
COD (mg/L)	840	320	1,360	320	2,046	472
Turbidity (NTU)	158	53	328	70	710	120
Oil droplet size (μm)	12.5-125	- *	12.5-125	12.5-500	12.5-125	- *

* No Data



a) Inlet b) Outlet

Figure 9 Size of oil droplet

Conclusion

The results indicated the factors those affecting the efficiency of treatment were flow velocity and bed length. Low flow velocity and long bed provided the good coalescer performance in oil separation. The combined process, using the bed length of 10 cm in the vertical coalescer and 3 cm in the horizontal coalescer, was the optimal configuration in this work. The optimal flow velocity is 6.1 m/h with 60 minutes of operation time. The coalescer gave the treatment efficiency up to 78% with residual COD of effluent of 320 mg/L. However, the treatment efficiency was based on the characteristics of wastewater. The presence of surfactants and large amount of suspended solid can lower the treatment efficiency. The study on other processes for combining with coalescer for solving these problems and enhancing the treatment efficiency should be further carried out in the future.

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