Adsorption Combined Phytoremediation System for Treatment of Laundry Wastewater

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Abstract. Laundry activities grow rapidly in Indonesia in the recent year, remaining the problem of environmental pollution because of the use of detergent. The purpose of the current study was to investigate the ability of sludge of drinking water treatment plant (DWTP) as adsorbent combined with phytoremediation system to remove chemical oxygen demand (COD), phosphate and surfactant in laundry wastewater. Batch and continuous blow studies were conducted on different variables such as adsorbent mass, contact time, and type of plant for phytoremediation system. The results of the current study show that adsorption combined phytoremediation system could remove COD, phosphate, and surfactant up to 77.5%, 54.3%, and 99.9%, respectively. Based on the results, it means that the adsorption combined phytoremediation system could be considered as an appropriate environmental technology for laundry wastewater treatment in the near future.

1 Introduction

In the recent year, environmental issues are becoming a public concern in developed and even under developing countries. The presence of contaminants is often causing some negative impacts on human being and environment. In a developing country, the home industry is commonly the main problem of environmental degradation. The rapid growth of laundry activity in many cities in Indonesia has been remaining environmental contamination due to the limit of wastewater treatment. Most laundry houses disposed their wastewater directly to the environment without any treatment, therefore the concentration of some pollutant such as COD, phosphate, and surfactant in some water bodies are frequently higher than the local and national standard. The concentration of COD and surfactant in laundry wastewater is up to 363.7 mg/L and 754.4 mg/L, respectively [1]. Types of detergent (powder and liquid) also influence the concentration of some contaminant in laundry wastewater [2]. The limit of technology and budget for laundry wastewater treatment are the most common reason for laundry problem in Indonesia and other developing countries, because the laundry activity is usually operated as a home scale industry.

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Many methods have been proposed in order to minimize water and soil contamination, i.e. bioremediation, adsorption, membrane technology, ion exchange, etc. [3]. Adsorption is one of the most common techniques that has been frequently employed for water and wastewater treatments. As an adsorbent, activated carbon has been often applied in many countries, however, this material is high cost [4]. Some researcher developed an alternative adsorbent material for removal of heavy metals and other contaminants from water such as adsorbent based on drinking water treatment plant sludge [5], adsorbent based on water hyacinth [6], adsorbent based on the ash of volcanic [7].

Phytoremediation, a method of contaminants treatment by using plants, is one of easy and cheap technology that can be applied in a developing country as like Indonesia. Phytoremediation system is recommended compared to a conventional system because it uses natural plants instead of a chemical reagent to remove some contaminants in water [8]. Many plants have been used in the phytoremediation system for treatment of pollutants i.e. water hyacinth for removal of organic and inorganic pollutants in wastewater [9], phytoremediation of contaminated soil by using Psoralea pinnata [10], removal of heavy metal Pb by using water hyacinth [11].

Powdery form adsorbent which is the most common type of adsorbent developed by many researchers has a high adsorption capacity due to the availability of surface area, however, an additional effort is required to separate the adsorbent from the solution after adsorption process, such as filtration, decantation [12]. Therefore, in the current study, the adsorbent based on drinking water treatment plant was encapsulated in alginate gel. The drinking water treatment sludge was utilized because it is largely available in Indonesia as solid waste material. The sludge is produced from sedimentation tank of drinking water treatment and usually disposed directly to the river without any adequate treatment.

Adsorption or phytoremediation system is usually employed as a single treatment method for removal of contaminants in water or soil. Therefore, its removal capacity is sometimes not effective and need additional treatment. Different from previous studies, in the current study, adsorption based on drinking water treatment sludge is combined with phytoremediation using Kiapu (Pistia stratiotes) to improve the quality of effluent.

2 Materials and methods

2.1 Preparation of adsorbent material and plant for phytoremediation

The sludge of drinking water treatment plant (DWTP), a solid waste material of city water treatment, was utilized as adsorbent material. The sludge was taken from one of city water company in Yogyakarta. Sludge was washed with tap and distilled water and then dried in the room temperature and oven on 100ºC for 2 hours. The dry sludge was crushed into a powdery form, sieve on 140 mesh and then encapsulated by using alginate gel following [12]. Kiapu (Pistia stratiotes) and water hyacinth (Eichhornia crassipes) were taken from Sleman to be employed as a plant for phytoremediation system. These plants were washed with tap water and put in the artificial environment for adaptation before used to remove some pollutant from laundry wastewater.

Laundry wastewater used in the current study was taken from some laundry houses near UII central campus at Kaliurang street. In order to get the real condition of laundry wastewater, some laundry wastewater was previously examined in the laboratory of Environmental Engineering Department, Islamic University of Indonesia (UII) Yogyakarta. The variables examined in the study were COD, phosphate, surfactant, and pH of laundry wastewater.

2.2 Batch and continuous system

First adsorption experiment was conducted in a batch system with some variable such as adsorbent mass, contact time and pH of the solution. Mass of adsorbent was varied from 0, 50, 100, 200, 300 and 400 mg and contact time was from 0, 30, 60, 90 and 120 minutes, respectively. A magnetic stirrer (200 rpm) was used for adsorption of 150 mL laundry wastewater placed in 250 mL of baker glass on 2 hours shaking time to determine optimum adsorbent mass. After knowing the optimum condition, the adsorption experiment then continued in a continuous system by using column glass. The combination of adsorption and phytoremediation system used in the current study is shown in Figure 1.

Fig. 1. The reactor of adsorption and phytoremediation system

3 Results and discussion

3.1 Characteristic of laundry waste

Laundry wastewater was analyzed in the laboratory in order to know its characteristics such as the concentration of COD, phosphate, surfactant, and pH. Furthermore, the characteristic of laundry wastewater utilized in the current study was compared to the standard of Indonesia (national standard) and also the standard of Yogyakarta province (local standard) as shown in Table 1.

Table 1. Characteristic of laundry wastewater

No.	Variable	Unit	Results	PP No. 82, 2001	Perda DIY No. 7, 2016
				standard	standard
1.	pH		6-9	6-9	6-9
2.	Temperature	^{0}C	27-29	± 3^{0}C	± 3^{0}C
3.	COD	mg/L	365-975	25	150
4.	Phosphate	mg/L	1-2	0.2	5
5.	Surfactant	Mg/L	9-27	0.2	5

n.a: not mentioned in the regulation

It was clear from Table 1 that the COD concentration of laundry wastewater was higher than both standards and the concentration of phosphate was higher than the national standard but lower than local standard. One of the main component in laundry wastewater is a surfactant. If the surfactant is discharged into water bodies, it can hinder aeration and treatment facility because of its high foaming and low oxygenation capacity [13].

3.2 Batch and continuous system

Batch adsorption study resulted in the adsorption capacity of drinking water treatment sludge for COD, phosphate, and surfactant as shown in Figure 2. It was clear that 50 mg of adsorbent mass has the highest adsorption capacity for COD, phosphate, and surfactant. However, the adsorption capacity of the surfactant and phosphate is less than 50%. The low capacity indicates that drinking water treatment sludge is not suitable for adsorption of phosphate and surfactant in laundry wastewater. Furthermore, for removal of COD, the data shows that the process of shaking is more dominant than the presence of the adsorbent because oxygen will be resulted by shaking and it could reduce COD by oxidation mechanism.

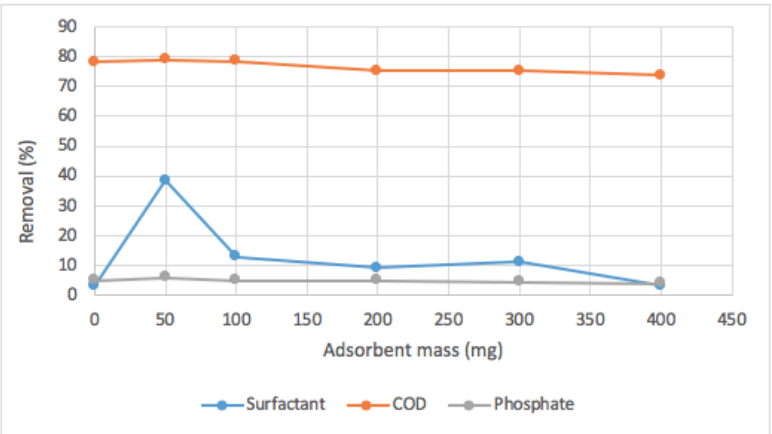

Fig. 2. Removal of Surfactant, COD, and Phosphate on adsorption

3.3 Continuous flow experiment

The continuous flow experiment for adsorption combined phytoremediation system was conducted up to 15 days based on a theory that phytoremediation process for some contaminant is in the range of 3-15 days. It was found from Fig. 3 that COD removal by using adsorption increase significantly until day-7 and then became stagnant until day-15. Similar to adsorption, the removal capacity of the adsorption combined phytoremediation system increase significantly up to day-7 and then increase slowly until day-15 (77.5%). It means that the saturation point is still not reached within 15 days.

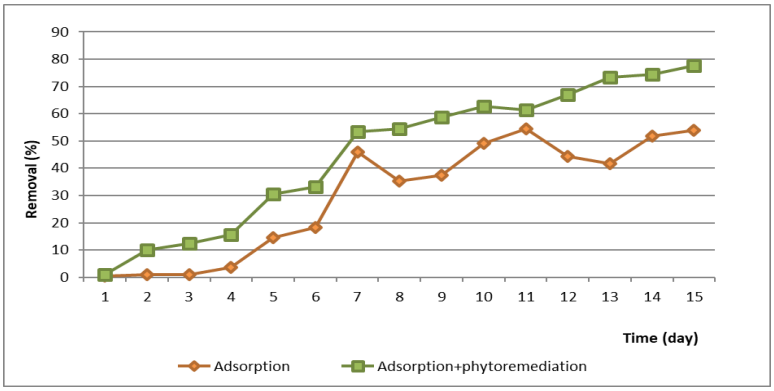

Fig. 3. Removal of COD by adsorption and phytoremediation system

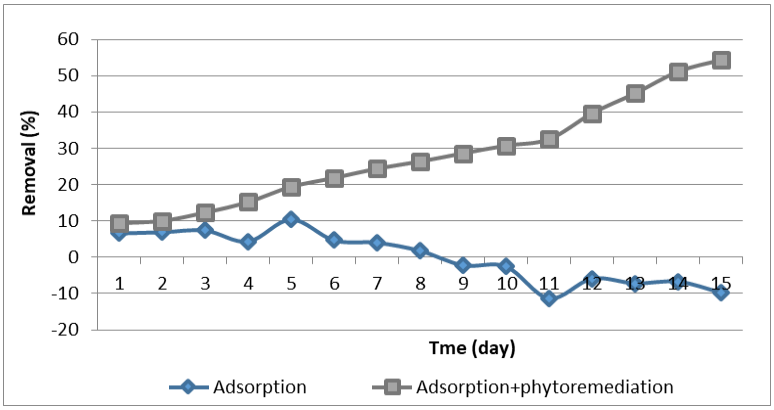

Fig. 4. Removal of Phosphate by adsorption and phytoremediation system

The removal of phosphate in the current study is shown in Fig. 4. Single adsorption system has low adsorption capacity and then reached a saturation point after day-5. However, the adsorption combined phytoremediation system shows its adsorption capacity increase significantly up to more than 50% until day-15.

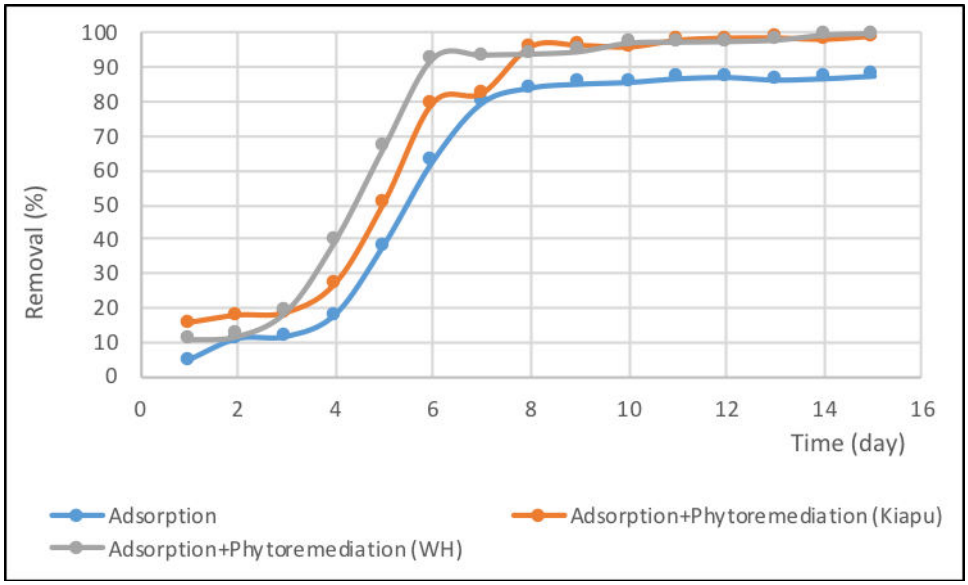

Fig. 5. Removal of Surfactant by adsorption and phytoremediation system

Different from the removal of COD and phosphate, the removal of surfactant by using adsorption or adsorption combined phytoremediation system was amazingly higher. Both methods show similar condition, which their performance in reducing surfactant reached the best result in the day-6 to 8 and then became constant until day-15.

In general, the phytoremediation system has five different mechanisms for pollutant removal, which are phytovolatilization, phytodegradation, phytoextraction, rhyzofiltration and phytostabilization [14] and [15]. In phytoremediation system, the mechanisms used are different, depending on pollutants to be remediated by plants [8]. In the current study, the phytodegradation and phytoextraction are suggested as the main mechanisms, because the target is organic pollutants.

4 Conclusion

Based on the results of the current study, it could be concluded that adsorption combined phytoremediation system could remove COD, phosphate, and surfactant up to 77.5%, 54.3%, and 99.9%, respectively. The phytodegradation and phytoextraction are suggested as the main mechanisms because the target is organic pollutants. It means that the adsorption combined phytoremediation system could be considered as an appropriate environmental technology for laundry wastewater treatment in the near future, especially for developing country such as Indonesia.

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