Possibility study for water reutilization of the biodiesel refinery in Thailand

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Abstract

The specific characteristic of wastewater from the palm oil refinery is the oil contamination. The optimum condition of oil-water separation was studied under various operations. Increasing of the wastewater treatment system efficiency with the suitable operation of an oil scum skimmer regard to the suitable effluent quality for utilization. In recent times, water reutilization has applied for water management planning in various organization. The possibility of water reutilization planning was evaluated under various factors. Furthermore, the questionnaire was developed to survey the attitude about water reutilization. This is an important parameter for design the suitable water reutilization option. In this study, it was found that the oil-water separation should be operated under the pH 4.0-5.9 with retention time around 4-5 days. This was an optimum condition for oil scum skimmer pretreatment. The treated wastewater quality was calculated to find the alternative reutilize options. This was investigated with the user acceptance for water reutilization application. It was found that around 90 percent of respondent agreed with applying of water reutilization in the company. This would be investigated with water quality, water volume, and economic factor. The evaluated result presented that the treated water could be reutilized or reused for combine activity option. This option can be reduced 433.97 baht/day from the conventional cost of water supply operation in the company.

Keywords : Palm oil refinery, Oil-water separation, Oil scum skimmer, Treated water quality, Reused water attitude

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1. Introduction

The slowly disappearing part of the rainy season is presented that the climate changes. The reduction of rainfalls flows in the river is a significant issue of shortage water problem [1]. In 2015, the quantity of water flows in the main river of Thailand is a trend to reduce continuously. In the storage water in an open reservoir, water around 39 % is available in a major reservoir and 23 % is available water in a minor reservoir. This causes the seriously water management problem in Thailand [2]. The shortage water is one of the most troubling issue which challenges the water security management and the efficient utilization of storage water. The water insecurity affects from the household level forward to the nation level. Regarding the water management planning of the Thailand's government, the policy for shortage water was conducted to find out the suitable operation strategy of water management [3]. Inevitability on temporary water management, the water reserves is a short term strategy. On the other hands, the long-term water management in the form of water management planning and policy is necessary to complete the effective water management. As the efficient and secure utilization of water consideration, this encourages the sustainable water resource for the economic development of national level.

Another main factor in social and economic development is conducted by the energy section. Therefore, increasing of energy demand is resulted in rapid growing of pollution emission level [4]. The effectiveness of energy management is considered as the sustainable energy or alternative energy. This is used instead of the non-renewable energy. The biodiesel production from vegetable oil is one type of well know alternative energy [5]. The bio-diesel industry from palm oil in Thailand has been developed in a recent year. Since 1995, 49 palm oil refineries has been operated with the production capacity of 405,000 ton of crude palm oil per year. The crude palm oil and several types of chemical substance are also applied to the raw material for biodiesel production [6]. In addition, the biodiesel production process is generated a large volume of liquid waste with the pollution load. This is related to the contamination of the chemical substance and oil in wastewater. The general treatment technology for palm oil mill wastewater begins with the primary wastewater treatment as oil separation process [7]. The oil removal of oil scum skimmer or the oil separator pre-treatment is led to improve the wastewater quality and reduce the organic loading in the subsequent biological treatment system. An unsuitable operation condition of oil scum skimmer effects the ability of a micro-organism which is used for remove pollutant in wastewater. Improvement of the operational yield of pre-treatment is significant for effluent quality regarding the ability of water reutilization [8]. Before wastewater flow to wastewater treatment system, it would be benefited for the wastewater treatment system efficiency when the

oil separator pre-treatment is operated at the suitable condition. Therefore, the optimum operation condition of an oil separation in oil scum skimmer would be studied in the work. Furthermore, the treated water or effluent could be considered to evaluate the possibility of water reutilization. This was evaluated by the water quantity, water quality, economic factor, and acceptant of the consumer in the company. The aim of this paper is to suggest the suitable oil scum skimmer operations and a water reuse planning in palm oil industry.

2. Methodology

2.1 Study quantity and quality of the recycled water

The parameters, which were used for analysis quality, consist of physical, chemical and biological parameters. The physical parameters including temperature, Suspended Solids (SS), Total dissolved solid (TDS) and conductivity. The chemical parameters consist of pH, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), Hardness, Chlorine (Cl). Furthermore, heavy metal parameters are Ar, Ba, Cd, Cu, Fe, Pb, Mn, Ni, Se, Zn, Trivalent chromium, Hexavalent chromium, Mg, Hg and Cyanide. The biological parameter was E.coli

The result of this survey was used for set up the application options and the treatment technology for the water reutilization. These were considered based on the suitable condition of quality water for each utilization option in the company.

Meanwhile, water quantity data were collected such as volume of wastewater, treated water, evaporation, high conductivity water from process and water quantity demand for gardening, cooling tower, toilet flushing, firefighting, source for water supply, utilities and production process. It was conducted to calculate water balance and design water reuse option.

2.2 Oil scum skimmers study

In this work study, the optimal condition for oil scum skimmer operation was by observed the physical transfiguration at normal condition (without adding any chemical substance) within 12 days. After that, the transfiguration of wastewater in oil scum skimmer was operated by controlled pH condition. Acid-base condition were studied within 3 ranges: acid range (pH 1.0-6.9), normal rang (pH 7.0-9.9) and normal range (pH 10.0-14.0). NaOH is used for increase pH range and HCl is used for reduce pH range. Daily COD was also considered together.

2.3 Evaluating the possibility of reuse the treated-wastewater

2.3.1 Questionnaires

Respondents

Number of the respondents was calculated by using Eq.1 [9]:

$$n = \frac{N}{1+N(e)^2} \quad (1)$$

Where n is the sample size; N is the population size and *e* is the level of precision.

Procedure and measures

The questionnaire was applied to measure the attitude of the treated-wastewater. The details of the questionnaire consist of 5 parts including:

I) General information of respondents were assessed such as gender, age, job position,

II) Knowledge toward the reutilization of treated wastewater in aspect of wastewater definition, wastewater category, wastewater treatment system and knowledge about water conservation.

III) The respondents 'attitude toward to the reutilization of treated wastewater were assessed with the terms of water resources replacement, environment, human health, production process, and economic.

IV) An agreement about the reutilization of treated wastewater in the company.

V) Problem which was concerned in the treated wastewater such as pathogen, color, odor of water.

The attitude ratings scales are strongly agree, agree, neutral, disagree, and strongly disagree.

2.3.2 Cost analysis

Cost analysis of water reutilization was calculated by using the operating cost of each utilized options. The technologies that were selected to improve water quality are an activated carbon, an ultrafiltration system, and an UV disinfection system. The operating cost of activated carbon was estimated by the average cost of activated carbon system in the palm oil refinery [10]. Meanwhile, the operating cost of ultrafiltration was generally estimated by UF membrane filtration facility O&M costs from the composite Civil Works Construction Cost Index published by the U.S. Army Corps of Engineers [11]. Lastly, the operating cost of UV disinfection was computed by the estimated average cost function for UV in Eq.2.

$$A = 0.2653x^{-0.6003} \quad (2)$$

Where A is the average cost and x is the capacity in cubic meters per day

3. Results and Discussion

3.1 Wastewater balance

In order to study the optimum condition of oil scum skimmers and evaluate possibility of the treated-waste water reutilization, the wastewater balance was developed as shown in Fig 1.

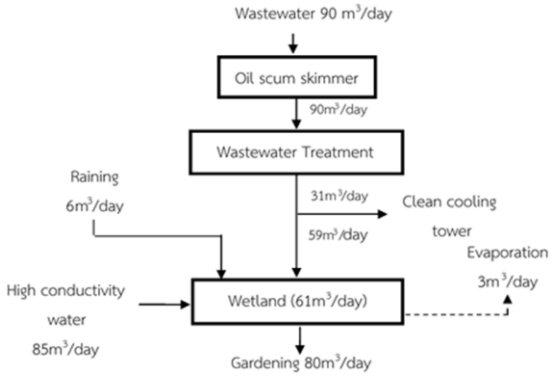

Fig. 1. Wastewater balance in the palm oil refinery

The total wastewater is approximately 90 m^3/day that is pumped to oil scum skimmers and sent to the wastewater treatment system. Then the treated water is discharged into 2 routes. First route, the treated water is returned to the clean cooling tower. Another is pumped to the constructed wetland. It should to note that there are 3 main streams of water that send to the wetland including 85m^3/day of high conductivity water, 59 m^3/day treated water and 6 m^3/day of rain water. Normally, the treated-wastewater is used for gardening around 80 m^3/day. In this calculation, the natural evaporation is constant at 3m^3/day. So, the remained water in the natural wetland is about 61 m^3/day. This is considered to evaluate the possibility of the treated-wastewater reutilization. After calculation, it was found that 39.3% of water in wetland come from oil scum skimmers. The wastewater had to be storage in these skimmers until the oil scum is compacted. After removed the compacted oil scum on the surface, the wastewater is sent to the treatment plant. Therefore, the operating condition of oil scum skimmers is directly influenced to the efficiency of wastewater treatment system in the terms of quality and quantity of effluent.

3.2 Optimum operating condition of oil scum skimmers

The optimum operating condition was conducted by varied the pH of wastewater. This is impacted to the thickness of the compacted oil scum layer, COD concentration, and oil scum skimmers retention time. Noted that the HCl and NaOH were used for adjusted the pH value of wastewater. The results from this experiment are summarized in Fig. 2. It represented about the thickness of the compacted oil scum layer at different pH condition within 7 days. The pH of original wastewater is between 4-6. When it was added some NaOH to adjust the pH to 6.0-7.9, the highest COD is occurred. If the pH of the wastewater is higher than 7.9, the oil contamination in the wastewater, becomes to soap via saponification reactions.

On the other hands, when the pH condition of wastewater is changed to range 2.0-5.9, it was found that the COD is reduced. This behavior is also found in the 5 days and the 6 days retention times.

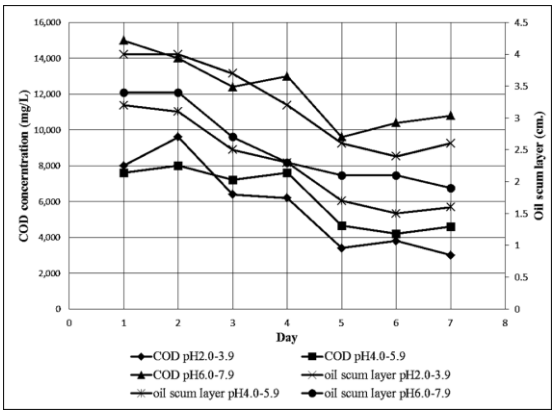

Fig. 2. Seven days of COD concentration and oil scum layer compaction at different pH condition in oil scum skimmer.

While study the compaction of the oil scum layers, the wastewater properties in each pH range are:

1) pH 2.0-3.9, the ability of oil scum compaction is minimized because the oil contamination could be broken down to small particles and results in solid sedimentation.

2) pH 4.0-5.6, the sedimentation process would be gradually subsided and hardened with 4-5 days. This is the optimal time to oil scum compaction.

3) pH 7.0-8.0, the ability of oil scum compaction is similar to the above condition. However, the last experiment indicated that changing the COD in pH 7.0-8.0 condition is not appropriate for the oil scum skimmer. So this condition is eliminated from consideration.

The experimental to study conditions that suitable for oil scum working with the acidity - alkalinity condition and observe compaction of oil scum. This study concludes that changing pH of wastewater to 4.0-5.9 within 4-5 days for sedimentation is the optimum condition for oil scum skimmers. This is also benefited for reducing the COD concentration before entering to plant and good sweeping the oil scum at the top surface of the wastewater.

After investigate the optimum oil scum skimmer operating condition, the feasibility of the treated-water reutilization is assessed in 3 aspects which are the attitude about water reutilization, water quality, water quantity. These are advantaged for design options of water reutilization.

3.3 Attitude about water reutilization

In a part of questionnaires, they were survey about attitude of water reutilization and option to reuse or recycle water as shown in Fig 3. It presents the attitudes about water reuse applications toward the water resource, environment, human health, production process and economic issue. It could be seen that respondents have the positive attitude to water resource, environment, and economic issue.

Firstly, the respondent's attitude toward water reutilization since this encourages the water conservation and water saving. From all of analysis, It could be interpreted that around 61% of respondents have a positive attitude to water reutilization that toward to water resources and water conservation issue, which are significant at the best level of score. The percent positive results are between 50-80% .This is mean moderate satisfaction or acceptance [13]. Meanwhile, the attitude to environment issue is trend to not bad attitude because of the respondent didn't want to concern about the quality of the treated water when it is applied for gardening or agriculture. In the part of attitude to economic issue, the 31.8 % of respondents are strongly agreed.

The analyzed result is the representation of respondent who was thought that water reuse application is the alternative way to reduce the existing cost of water supply production. On the contrary, the respondents have a negative attitude about human health and production process for water reuse application. They might aware of the quality of the

treated wastewater which could negatively affect to their health and the quality of the product.

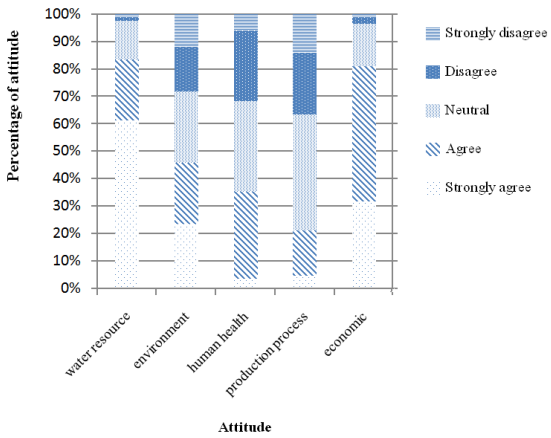

Fig. 3. Attitude of respondents about water reutilization

3.4 Opinion to water reuse in each activity

From questionnaire result in part of opinion to water reuse application in each activity shown in Fig. 4. Respondents want to utilize the treated water in gardening and/or utility activity, firefighting, toilet flushing, and the source of water supply in production process, respectively.

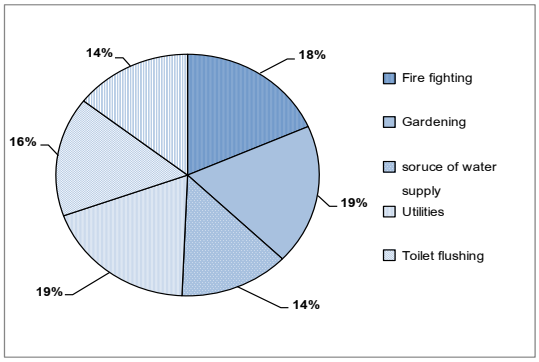

Fig. 4. Options for water reuse in palm oil refinery

Addition, this study survey about the problems that respondents concern about the treated wastewater reutilization. The survey results presented that there are six main problems as taste, odor, color, precipitated, disease and chemical substance. The chemical substance contamination and pathogen are the first two consideration from respondents. They aware of chemical substances will be effected to their health. These lead to determine the water quality.

3.5 Water quality analysis

The treated wastewater quality was analyzed by determined 4 parameters which are an odor, precipitate, pathogen and chemical substance. After that, the treated wastewater quality would be compared with the relevant legislation and other water utilization criteria such as water supply standard and water quality standard for agricultural or the production process. The results show the treated wastewater quality is not required to any quality improvements. It could be used directly for gardening and utility (such as clean road, floor). However, it should be improved TDS and conductivity parameters before use in the production process. In term of the biological parameters, the treated wastewater is not more than the standard but it should be concerned about disinfection system. This is because of the survey results indicated that the most respondent is the mindfulness about the treated wastewater would effect to their health when applied or exposure.

After water quality analysis, the additional technology to improve water quality is investigated. One of interested option is adding an ultrafiltration as a pretreatment [14]. Ultrafiltration (UF) is an extensive alternative for wastewater treatment. Various water quality are suitable for treatment, easier operating conditions, able to apply with other methods both chemical and biological treatment. Moreover, it is easier to control of the treatment system with Ultrafiltration (UF) [15]. Reducing the TDS and conductivity parameters with UF is importance before utilizing in the production processes such as softener and reverse osmosis unit [16]. Adding the UV disinfection system is necessary to ensure that the treated-water without pathogen and good confidence for using [17]. The high doses of Ultraviolet (UV) enable to inhibit the Total Coliforms in only 3-4 log. Total inhibit of both Fecal Coliforms and E.coli was toward under the highest UV dose of 330 mJ/cm^2 [18].

Next, the treated wastewater reutilization options will be designed to match with the surveyed attitude about water quantity, water quality, technology and estimated cost analysis for the wastewater reutilization implementation.

3.6 Design option for water reutilization implementation and cost analysis

There are 5 options for water reutilization implementation which are designed is this study as shown in Figs. 5-9.

Firstly, the treated water is reused without the additional improving quality technology. The flow diagram of this option is shown in Fig. 5.

This is available in only utility activities. It can reduce the water supply cost around 33 baht/day. However, the water is still discharged to wetland about 67 m^3/day. A flow diagram of the second option is shown in Fig 6, the treated wastewater is totally replaced underground water for softener unit and utility activities.

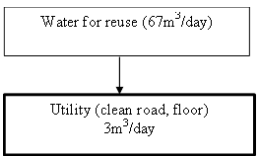

Fig. 5. Flow diagram of the treated water reutilization without the additional pretreatment technology.

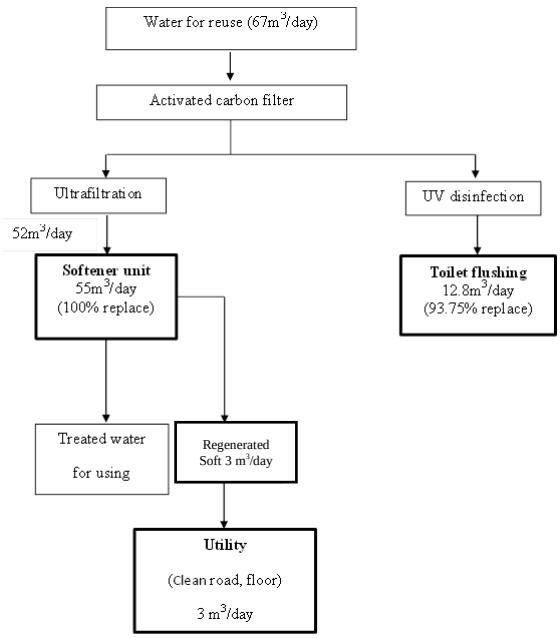

Fig. 6. Flow diagram of the treated water to replace 100% underground water for softener

Moreover, none of water is released water to the wetland. Finally, the treated water is reused in the clean cooling tower. However, it could replace 26.48% of required water supply in this unit. The cost was reduced around 310.21 baht/day. In summary, after the preparation of wastewater, the oil scum skimmer should be maintained at the suitable condition at pH 4.0-5.9 with retention time around 4-5 days. The high efficiency of oil scum skimmer treatment results in lower percentage of oil loss into wastewater treatment plant. Moreover, the retention time of wastewater in oil scum skimmers could indicate the daily volume of wastewater flow into wastewater treatment system and natural wetland as a result to define water quantity and quality for water reuse in the company.

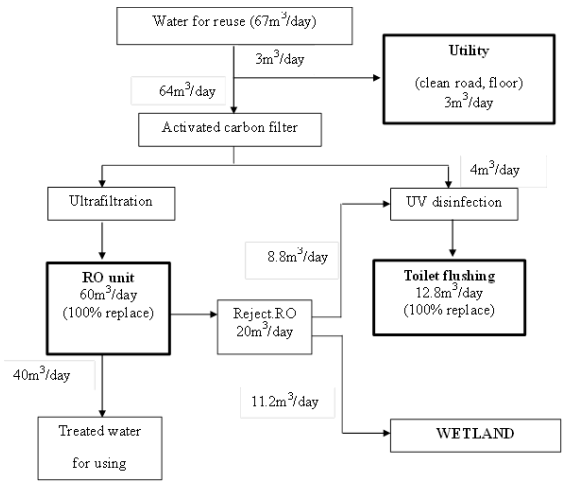

Fig. 7. Flow diagram of the treated water to replace 100% underground water for RO unit

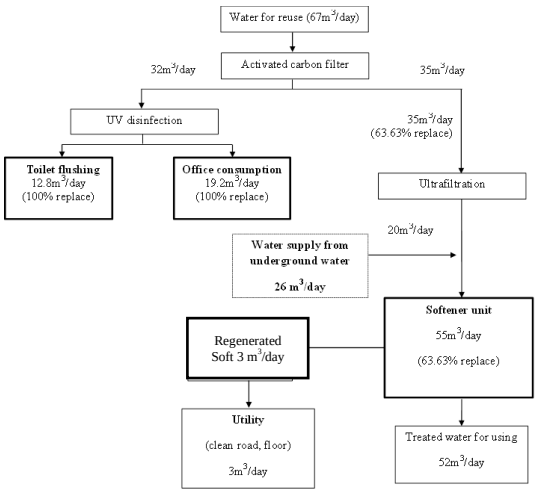

Fig. 8. Flow diagram of the treated water for combine activities

4. Conclusion and Suggestion

Based on the above analysis and discussion, we provide the following conclusions: study optimum operation for oil scum skimmer and feasibility of water reuse show that

1. For study oil scum skimmer operation, according to the experiment setups, at a different range of pH (1.0-6.9, 7.0-12.9, and 13.0-14.0) in 12 days was found that the oil scum skimmer that operated at pH 4.0-5.9 with retention time around 4-5 days was an optimum condition to reduce COD and increase the compatibility of the oil scum. Moreover, the strong alkalinity condition in oil scum skimmer should be avoided because it could be encouraged a saponification reaction. On the others hand, a strong acid condition affects to oil scum content dissolve to water and reduce a compatibility rate of oil scum. However, avoiding the liquid oil loss into oil scum

skimmers can be encourage the work efficiency of oil skimmer. Because liquid oil can cover on the top layer in order to reduce evaporation rate of water and compatibility rate of oil scum.

2. For feasibility of water reutilization, the water reuse in combine activity option is a suitable option in term of water quality, water quantity, cost analysis and user acceptance. The treated water quality is under the effluent and reuse standard. The water quantity can be cover replaced as water supply in all activities in this option without rejected the water to a constructed wetland.

This is benefited for encourage the zero discharge policy. The water supply cost is also reduced about 433.97 baht/day from the conventional cost of water supply operation in the company. Most of user in the company are accepted the water reutilization option which added the new activated carbon filters as a pretreatment to reduce the pollutant before sent the treated water to UV disinfection and ultrafiltration. This can be ensured that the treated water is suitable good quality for reutilization and increase user confident when the treated water exposed to their body.

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