Proposal of an Integrated Treatment System for Colored Wastewater and Textile Sludge Derived from Textile Industry Activity

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Summary of Thesis

The role of textile industry in many developing countries is substantially important in terms of economic and social aspect. In the economic sector, textile industry becomes one of major export commodity particularly in the non-oil and gas sector. More than 50% of export income is coming from either textile or clothing in case of Cambodia, Sri Lanka, Pakistan and Bangladesh. Meanwhile in social aspect textile industry involves many workers, which are able to reduce the problem of unemployment. Apart from the key industry in country development textile industry has a negative impact on the environment especially in case of colored wastewater and sludge. When release to the environment the colored effluent not only become harmful for aquatic biota but also give bad impression from the aesthetic point of view. In addition, some types of dye on colored wastewater contain heavy metals like cobalt, chromium and copper, and resist to biodegradation under the conventional treatment. On the other hand, sludge, a residue from textile wastewater treatment, contains toxic and hazardous materials remaining from textile processing and after textile wastewater treatment. Thus, colored effluent and sludge problems are serious for textile industry management and a development of appropriate treatment system is desired. In this

research, I proposed and evaluated an integrated treatment system to solve both colored wastewater and sludge problems through waste utilization and recycling approaches.

Generally textile industry generates two types of wastewater: non-colored wastewater and colored wastewater. In case of a cotton textile processing, non-colored wastewater is coming from the process of desizing, bleaching, mercerizing, etc. while colored wastewater is deriving from dyeing and printing process. The conventional treatment composed of clarification process including coagulation, flocculation, sedimentation and activated sludge system is commonly applied for the treatment of textile wastewater. Unfortunately this process has a disadvantage of generating sludge as a residue, which requires a further treatment for handling.

Chapter I of this thesis described about the waste characteristics derived from textile industry activity as briefly aforementioned on the first and second paragraph.

In chapter II, I discussed about the utilization of textile sludge as a potential adsorbent. I hope the adsorbent can be used to solve the colored wastewater problem through adsorption treatment in the further. The main objective of this research is to investigate the applicability of textile sludge as a potential adsorbent and evaluating its adsorption capacity for color removal treatment. Firstly a simple process called carbonization was conducted to make adsorbents from the sludge. Carbonization is a process to form a carbonaceous material by heat treatment under absent of the oxygen. Textile sludge was heated in electric furnace for 2 hours at the various temperatures from 400 °C to 800 °C. This research demonstrated that the carbonized sludge at 600 °C creating larger specific surface area than other temperatures. Carbonized sludge at 600 °C has 138.9 m^2/g of specific surface area. TG-DTA analysis revealed that the organic matter was lost when the textile sludge was heated at 600 °C. Thus, heating over 600 °C was considered as a necessary condition for the production of adsorbent based textile sludge. In addition to improve the specific surface area activated carbon production was also carried out. Physical activation was conducted after carbonized sludge at 500 °C before. Physical activation by carbon dioxide (CO_2) at 900 °C for 30 minutes resulted in 179. 9 m^2/g of specific surface area. While physical activation by heat steam (H_2O) and nitrogen gas (N_2) at 800 °C for 1 hour created 172.1 m^2/g of specific surface area. This research showed that the adsorbent produced through physical activation creates larger specific surface area than only carbonization.

Thus, in order to investigate the performance of textile sludge-based adsorbent for color removal treatment, methylene blue as a representative of cationic dyes and procion brilliant red H-EGXL as a representative of anionic dyes was used in adsorption treatment. The result showed that the carbonized sludge at 600 °C was more suitable for cationic dyes than anionic dyes removal. It has an adsorption capacity of 60.30 mg/g for methylene blue removal and 21.41 mg/g for brilliant red removal. The alkaline pH of adsorbent was also thought to be a dominating factor of the adsorption capacity for the cationic dye. Although the adsorption test using textile sludge-based activated carbon was also performed, the adsorption capacity for both dyes gives no significant difference from that of carbonized sludge. The activated carbon had larger specific surface area, but the carbon content decreased as the result of second heat treatment. The low carbon content of the activated carbon was thought to result in insignificant difference of the adsorption capacity for dyes removal compared with that of the carbonized sludge.

In chapter III the typical gases release from textile sludge combustion were evaluated. This research will give information for the prediction of various gas emissions when textile companies incinerate textile sludge for the sludge treatment. In this research gas emissions were simulated with the MALT (Material Oriented Little Thermodynamic) software and the appropriate combustion temperature was searched to reduce the generation of sulfur oxide (SO_x) and nitrous oxide (NO_x). The component and the volume of textile sludge were modeled on the basis of heavy chemicals used in a dyeing process and a wastewater treatment process, and mass balance of wastewater. The data of heavy chemicals and the water balance were referenced to the case of an actual textile industry in Indonesia. The result showed that the combustion temperature should be carried out lesser than 800 °C to minimize and meet the Indonesian standard regulation for SO_x and NO_x. In this research I also simulated the effect of coagulant species for SO_x generation. The substitute of ferric chloride ($FeCl_3$) coagulant for aluminum sulfate ($Al_2(SO_4)_3$) could reduce 18% of SO_x emission at the combustion temperature of 850 °C.

The sludge ash resulted from the combustion treatment causes another problem for solid waste management. In order to tackle this problem, I demonstrated the applicability of textile sludge ash as a clay substitute for brick production in chapter IV. Basically previous researchers have already demonstrated the usability of textile sludge for brick production. However a high addition rate of textile sludge was not able to achieve the first quality standard for compressive strength and water absorption. Preliminary test showed that when the addition of textile sludge ash reached 10%, the brick quality was out from the first quality standard. Furthermore in order to enhance the addition rate of textile sludge on the brick formation without deteriorating the quality, I introduced another material of waste glass into the textile sludge ash-added brick production. The waste glass addition was able to improve the quality of brick. Brick formation with the composition of clay 60%, textile sludge ash 30% and waste glass 10% reached the optimum compressive strength of 73. 9 N/mm^2 and had 5.2 % of water absorption. According to the Japan Industrial Standard *JIS R1250 for common brick*, it achieved the first quality standard. An electron probe micro analyzer (EPMA) and a digital microscope showed that the melted waste glass clogged up the pore formed by sludge ash addition. In addition a leaching test showed that the heavy metal leaching from the brick was strongly inhibited and in the range of the standard regulation. It means that the textile sludge ash-added brick was acceptable in both quality and environmental aspects.

In Chapter V, I discussed the feasibility of textile sludge-based adsorbent for textile wastewater treatment. The mass balance of sludge produced from the textile wastewater treatment processes was estimated on the basis of chemical oxygen demand (COD). In addition, the performance of the sludge-based adsorbent in real wastewater was investigated. Basically the production rate of textile sludge-based adsorbent depends on the generation rate of sludge from the textile wastewater treatment processes. A real restaurant wastewater with 43.78 mg/L of methylene blue was used and treated by the activated sludge process before the adsorption treatment using the textile sludge-based adsorbent. The wastewater had 657 mg/L of total-COD. The activated sludge showed 85.57 % of removal efficiency for COD. According to the half reaction of McCarty the sludge production on this system reached 283.5 mg sludge/ L-wastewater. When the sludge was converted into adsorbent, the final production of adsorbent was estimated to reach 115.2 mg because 59.4% of weight loss was expected during the carbonization at 600 °C. The textile sludge-based adsorbent could remove dyes from the real wastewater, though slight interference by coexistent substances was observed. I found that the minimum solid/ liquid ratio of adsorbent mass to the volume of wastewater for complete color removal was 0.3 g/L, at which the dissolved-COD removal efficiency reached 40.3 %. Thus, according to the mass balance on this system the utilization of textile sludge-based adsorbent able to solve 38.4% of colored wastewater problem. In order to counter the lack material for colored removal problem, regeneration process of carbonized sludge could be applicable, though 13.8% of adsorption capacity was lost during second regeneration. In addition, a material adsorbent called synthetic talc has also introduced in this research. Synthetic talc showed a greater ability than carbonized sludge by faster in adsorption equilibrium time and four times higher of adsorption capacity than carbonized sludge for methylene blue removal.

The final conclusion of this research was summarized in chapter VI. An integrated treatment system was proposed for solving the colored wastewater and sludge problems in textile industry through recycling approach. A schematic scene was introduced by the utilization of textile sludge to counter the colored effluent and disposal problem. The conversion of textile sludge into adsorbent for color removal and recycling of textile sludge ash for brick manufacturing was successfully demonstrated and was thought to be a feasible countermeasure to the problems.