The effectiveness of filtration and phytoremediation with combination of aquatic plants in wastewater treatment of Sasirangan industry

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Abstract. Most of Sasirangan fabric industry in South Kalimantan have not carried out an optimal wastewater treatment effort. In order to improve the quality of the waste, a combination of filtration and phytoremediation using the symbiosis of water hyacinth and Jeringau plants were applied. This study aimed to analyze the effectiveness of the filtration and phytoremediation processes using a combination of the two aquatic plants. The method used in this study was an experimental method with the treatment of a comparison of water hyacinth and Jeringau, namely 1: 3, 1: 1, and 3: 1 (w/w). The research stages are the acclimatization of the two aquatic plants for ten days, filtration with sand, gravel, and coconut fibers, and phytoremediation. The parameters tested in this study were BOD, COD, and TSS. The results showed that the combination of filtration and phytoremediation with the combination of the two water plants was able to improve the quality of,sasirangan's effluent. The best treatment for BOD and TSS was the combination of water hyacinth and Jeringau 1:1 (w/w) with the effectiveness obtained was 75.57% for BOD; and 63.93% for TSS, and the combination of water hyacinth and Jeringau at 3:1 (w/w) for COD with the effectiveness of 87.20% for COD.

1. Introduction
Sasirangan is one of the most developed traditional textile industries in Tanah Laut Regency. Based on data from the Industry Office of South Kalimantan Province, in Tanah Laut Regency, 17 Sasirangan SMEs have been established spread over 6 different sub-districts. In practice, the production process of Sasirangan in South Kalimantan is still traditional so that the relatively high volumes of wastewater produced in, which is mainly sourced from the dyeing process and cloth washing, [1] has not been carried out processing efforts and directly disposed of into water bodies. Sasirangan industrial wastewater tends to have a potential hazard when discharged directly into the environment without prior treatment due to the use of chemical dyes during the coloring process. Sasirangan wastewater contains heavy metals chromium and cadmium as much as 0.51 mg/L and 0.1181 mg/L, respectively, Biological Oxygen Demand (BOD) levels are 168.80 mg/L, Chemical Oxygen Demand (COD) is 5329.40 mg/L, and Total Suspended Solid (TSS) is 232.00 mg/L. [2]. Most of the waste parameter values did not meet the Textile Industry Waste Quality Standards, South Kalimantan Governor Regulation No. 036 of 2008, so they cannot be discharged into the environment and require wastewater treatment first. There is an urgent need to study natural, simple and cost-effective techniques for control of pollution from industrial effluents in such a condition.
One of the potential wastewater treatment methods to be applied in Sasirangan SMEs is filtration and phytoremediation. Filtration is a separation method for separating solids from liquids using a porous device (filter). The use of the filtration method in waste treatment is expected to be more efficient if it is combined with the phytoremediation method. Phytoremediation was assumed to be very useful, as it is an innovative, eco-friendly, and efficient technology in which the natural properties of the plant are used in an engineered system to remediate hazardous wastes through physical, chemical, and biological processes from wastewater and sewage. Phytoremediation is the utilization of plants accumulation capabilities to remove contamination from water, soil, and air, the capacity of aquatic plants to remove pollutants from water is well documented [3]. In previous research, a combination process of filtration and phytoremediation has been carried out using the batch method where both processes were carried out in the same container/tub, using two different types of plants without any combination [2]. In a batch system like this, there is a drawback, namely the risk of falling plant parts during the phytoremediation process so that it inhibits the filtration process due to an increase in total dissolved solids [4]. In addition, the effectiveness of phytoremediation applications can also be increased by using a combination of plants with physiological characteristics that support each other's growth. One of the most widely used plants for phytoremediation is water hyacinth. Water hyacinth has a good heavy metal-binding ability, but it can only grow optimally at a pH close to neutral pH [5]. Thus, in the wastewater of the Sasirangan industry which has a high pH, it is necessary to combine it with plants that can lower the pH, such as Jeringau by nutrition absorption mechanism [6]. The specific purpose of this study was to analyze the effectiveness of the combination of aquatic plants (water hyacinth and Jeringau) in the treatment of continuous system Sasirangan wastewater through filtration and phytoremediation.

2. Research Method
This research uses a combination of filtration and phytoremediation methods to treat the wastewater from the textile industry, so the parameter levels were following the standard. The filtration step uses three filters media: coconut fibre, gravel, and sand, while the phytoremediation step utilize the combination of water hyacinth and Jeringau plants. The research were consisted of preparation, acclimatization, and running stages. The sample used was textile wastewater taken from IKM Fanesya Sasirangan. This research was carried out with variations in water hyacinth and Jeringau proportion to determine the most effective phytoremediation with the test of BOD, COD, and TSS. The method to determine the value of BOD, COD, and TSS respectively were 5 days incubation method (BOD), the reflux method, and gravimetric method. The variation of plants’ proportion for water hyacinth and Jeringau were 0:0 (K), 1:3 (A), 1:1 (B), 3:1 (C).

2.1. Preparation of Filtration and Phytoremediation Tank
The filtration and phytoremediation were conducted in a separate tank. The filtration process was done in an 80 l tank using three filter media: coconut fibre, gravels, and sand. The filtration tank was positioned higher than the phytoremediation tank so the outlet from the filtration stages could flow directly as an inlet in phytoremediation stages. The phytoremediation tank was conducted in four 80 l tank which would be filled with three variation of plants and the filtrated wastewater, with the last tank were only filled with filtrated wastewater as a control.

2.2. Acclimatization process
Acclimatization were conducted separately for water hyacinth and Jeringau. the plants were selected based on the number of the leaves, the uniformity size and the level of freshness. Both plants were grown in an acclimatization tank for 7 days. The acclimatization tank was filled with clean water in the first day and the water were replaced with 10%, 20%, 40%, 60%, 80%, and 100% of wastewater for each following day. After seven days the plants were selected for the phytoremediation process with the same basis of the number of the leaves, uniformity in size and level of freshness.
2.3. Filtration and Phytoremediation stages
The wastewater sample was put into a filtration tank. Furthermore, the filtrate from the filtration bath will become the influent in the phytoremediation bath. The acclimatized water hyacinth and Jeringau were placed in a 60 l of filtrate in the phytoremediation tank, with a ratio of 1:20 (w/v) of plant to wastewater, which is the best ratio from previous studies [7]. This process was carried out for 15 days after planting.

3. Results and Discussion
3.1. BOD
From Figure 1 the level of BOD was generally decreased over time with the exception for 25% Water Hyacinth and the control, which increased on the 15th day. The most prominent drop of BOD level was obtained in the 50% water hyacinth with BOD value of 7.5. This final BOD value were decreased by 75.57% from the initial BOD value. This drop was caused by decomposition process of organic compounds, the organic materials contained in wastewater which were absorbed by the plants. The plants absorbs the organic material and removing suspended particles by filtering them via their roots through mechanical and biological activity [8]. Microorganisms that break down the organic material compounds as a substrate for aerobic metabolism by both the microorganisms available at the wastewater activity and microorganisms that live on the plant’s root also caused the decrease of BOD levels [9]. In this case, the plants also acts as a growth medium of the bacteria, as well as an oxygen provider for their metabolism to degrade the organic matters. The oxygen produced by plants is moved to the root’s surface as a site of bacterial growth to support biodegradation of organic materials and therefore decreases BOD levels. The natural process of waste treatment is, therefore, a two-way combination of organic degradation by bacteria in suspended and attached (bio film) on plant root’s mat.

![Figure 1. Effect of Filtration and Phytoremediation on Level of BOD](image)

The results showed an increase in BOD levels caused by the rhizofiltration process, utilization of plant roots' ability to absorb, precipitate, and accumulate pollutants in wastewater, which occurred during the phytoremediation process. The increase of BOD levels is also caused by the addition of organic matter originating from decaying plant’s roots and decayed leaves which submerged in waste water, which then decomposed in the experimental tanks and releases the nutrients for growth of the plants, and decreases dissolved oxygen after certain amount of time [10,11]. The plant’s growth was stopped because of the dehydration of the wastewater due to the uptake by the plants and natural vaporization [12].
3.2. COD
From the Figure 2, the changes in the level of COD from all treatments were shown to follow similar pattern, in which the COD decreased from pre-filtration to filtration, but increased on the 5th day, and decreased from the 10th day to the 15th day. The best treatment to lower the value of COD were the 75% with COD value of 192,4 or decreased by 87,20% from the initial COD value. The increase of the concentration of COD is because at the initial exposure to sewage, plants experience stress conditions. Plants will generate exudate which will increase the biodegradable waste in the water so that the initially toxic waste will be transformed into biodegradable waste [2].

![Figure 2. Effect of Filtration and Phytoremediation on Level of COD (mg/L)](image)

Many factors can be attributed to the reduction in BOD and COD. The ability to transport oxygen from the aerial parts to the submerged ones is a unique feature of Aquatic plants. The oxygen transported will then significantly increase the water’s oxygen content. The oxygen transported into the root zone also plays an important role in supporting the aerobic bacteria’s growth which thrives in the root zone and the carbon in the wastewater will be degraded subsequently. Furthermore, the higher suspended solids in the effluent may acts as an additional substrate for microbial activity on the roots of aquatic plants [13].

3.3. TSS
Form the Figure 3, there were decreases in TSS in all treatments. Overall, the decrease were significantly occurred in 5th day, and then the rate of decrease would get lower and a slight increase of TSS in the 15th day. The largest drop of TSS were obtained at treatment 50% water hyacinth in which the TSS decreased to 36 or decreased by 63,93% from the initial condition. The removal of suspended solid involves the mechanism of rhizome-filtration and sedimentation of the suspended particles in the experiment tanks. The rhizome-filtration happened due to the attraction of opposite charges of colloidal particles; such as suspended solids; by the plant’s root which has electrical charges and cause them to adhere on the roots where they are digested and assimilated by plants and microorganisms [8]. The decrease of TSS levels are caused by the presence of media filters to precipitate the suspended solids materials. The longer the exposure time, the more soluble solid materials will be precipitated [9].
The increase in TSS levels in the 15th day was due to the increase in the number of plants which would cause competition between plants in obtaining nutrition. The impact of the competition was the disruption of plants’ growth, and the longer the competition, the roots would rot, and then withered or dead. The addition to the high concentration of waste solids from the plant’s roots, debris or rotting leaves and stems in water is the leading cause of the increase of TSS level [14]. Environmental factors also affect the value of TSS such as mosses growing in reactors. The mass of dead plants and lichens added to the mass of suspended substances in the reactor bath causing TSS values to rise. This is in accordance form the previous research which found that suspended solids can be formed from parts of plants that fall into the water [4].

4. Conclusions
The filtration and phytoremediation were proven effective in improving the quality of the wastewater form Sasirangan Industry. The best treatment for BOD and TSS was the combination of water hyacinth and Jeringau 1:1 (w/w) with the effectiveness obtained was 75.57% for BOD; and 63.93% for TSS, and the combination of water hyacinth and Jeringau at 3:1 (w/w) for COD with the effectiveness of 87.20% for COD

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