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Phytoremediation Processes of Sasirangan Textile Industrial Wastewater Treatment using Water Hyacinth

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Abstract

The growth of the textile industry, including the Sasirangan textile industry, is increasing yearly, producing large amounts of liquid waste. Generally, this wastewater is discharged into the environment without treatment, becoming a source of environmental pollution. Therefore, it is crucial to reduce these pollutants. Various methods, not only physical and chemical but also biological methods, are available to remediate wastewater. Phytoremediation has provided an economical, environmentally friendly, and aesthetic solution to remediate wastewater. This study aimed to utilize the Water Hyacinth plant as a phytoremediator and determine its effect in reducing Total Suspended Solid and colors in the liquid waste of the Sasirangan textile industry. This research begins by preparing Water Hyacinth plants. Next, the characterization of Water Hyacinth roots using FTIR and SEM. Finaly, the acclimatization of water Hyacinth, followed by a phytoremediation process for 15 days. Based on the results of the characterization of Water Hyacinth roots with FTIR, it shows that Water Hyacinth roots contain functional groups O-H strain, C-H vibrations, C=O strain, C-H deformation, and C-O stretching. Observations with SEM showed that the roots of Water Hyacinth were extremely unstructured and had pores. However, it has cavities which are pores in cellulose. The significant decrease in Total Suspended Solid was at 9 days of phytoremediation, which was 54 mg/L (71.12% removal). The optimum color reduction within 9 days of phytoremediation was 81.5 PtCo (92.26% removal). The presence of these functional groups and pores, strengthened by the analysis of Total Suspended Solid and colors, showed that Water Hyacinth could reduce levels of Total Suspended Solids and colors in the Sasirangan textile wastewater.

Keywords: Sasirangan industry, wastewater, phytoremediation, total suspended solid, colors

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1. INTRODUCTION

The problem of water pollution in South Kalimantan has shown quite profound symptoms. The higher population growth rate and industrialization have caused a decrease in environmental quality, one of which is wastewater generated from the Sasirangan textile industry. Based on the initial analysis of wastewater from one of the Sasirangan textile industries in Cempaka Banjarbaru, the pH parameter is 13.11, the content of TSS is 204 mg/L, and the color of 12500 PtCo. According to the South Kalimantan Governor Regulation No. 36 2008th, the quality standards for pH and TSS of textile industry wastewater are 6-9, 50 mg/L, respectively. The minister of environment and forestry of the Republic of Indonesia Regulation No. P.16 2019th, the quality standard for wastewater for businesses and textile industry activities for color parameters is 200 Pt-Co. Based on this description, the wastewater of the Sasirangan textile industry does not meet the quality standards set by the Government. In addition, some people and industry players need more awareness and directly dispose of their waste into the environment without being processed. It motivated the author to think about how to solve this problem and not burden industrial players, especially the Small and Medium Industries of the Sasirangan textile industry, in processing their waste. This industrial wastewater treatment includes mechanisms and processes commonly used to treat water

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contaminated by industrial activities before being discharged into the environment. Wastewater treatment aims to reduce or even eliminate pollutant parameters in wastewater.

The production processes of Sasirangan require large amounts of water, resulting in a large amount of liquid waste. The liquid waste of the Sasirangan textile industry mainly comes from the dyeing and dyeing process. This liquid waste contains materials separated from the fiber and chemical residues added to the dyeing and coloring process. Various chemicals in the production process, such as dyes, caustic soda, and other materials, are auxiliary chemicals. Azo group dyes, as much as 60-70% are used by most of the textile industry in the dyeing process, and about 15-20% of the total dyes are discharged into the environment (Donkadokula *et al.*, 2020). These materials are the primary sources of pollution because only a small part is absorbed in textile products, while most of it is wasted with wastewater (liquid waste). Textile dyes are difficult to degrade because they have a complex molecular structure (Rigueto *et al.*, 2020)

One way to treat the wastewater is phytoremediation using the Water Hyacinth plant (*Eichhornia crassipes*) (Ilo *et al.*, 2020) as a biological agent in treating the waste through the exposure process. Phytoremediation is becoming popular to remediate various contaminants (Saber *et al.*, 2018), such as acids, bases, toxic organic and inorganic compounds, and colors (Pushpa *et al.*, 2015). Phytoremediation is environmentally friendly and cost-effective (Holkar *et al.*, 2016). Water Hyacinth is a member of monocot plants (Qin *et al.*, 2016) that live floating in tropical and subtropical areas (Tabinda *et al.*, 2019) containing cellulose and lignin (Gogoi *et al.*, 2017). Water Hyacinth was chosen as a plant for phytoremediation because it is relatively abundant in nature. Its growth is very high (Du et al., 2020), and it can thrive in extreme environmental conditions (Adelodun *et al.*, 2021). The amount of Water Hyacinth can be doubled within one week under suitable growing conditions (Sun *et al.*, 2018) and has been tested for its ability to reduce pollutants commonly found in industrial wastewater (Naaz *et al.*, 2013).

Water Hyacinth is suitable for controlling various types of waste water (Mahmood *et al.*, 2018) from the industry. It is also proven that among aquatic plants, Water Hyacinth is also suitable for absorbing nutrients and improving water quality. As part of a wastewater treatment system, Water Hyacinth has an even more critical and extraordinary effect on the environment by taking CO_2 from the atmosphere and collecting supplements for plants. Likewise, in terms of cost, this technology is cheaper (Jiang *et al.*, 2015) than other advanced technologies that require more costs to evacuate pollutants from wastewater (Rezania *et al.*, 2015). This environmentally friendly methodology (Ekambaram *et al.*, 2018) will positively assist the advancement of several new plant technologies in using Water Hyacinth to treat wastewater in the future. Phytoremediation research using Water Hyacinth can reduce color levels by up to 63.61% in tofu wastewater (Purwati *et al.*, 2021). In addition, phytoremediation research with Water Hyacinth can reduce Total Suspended Solid levels to 112.4 mg/L in wastewater domestic (Ryanita *et al.*, 2020).

Several researchers reported that phytoremediation for 28 days with Water Hyacinth applied to coffee wastewater resulted in a decrease in TSS of up to 90.2% and color of 45.4% (Ahmed *et al.*, 2021). However, research on Water Hyacinth phytoremediation applied to Sasirangan wastewater is lacking in the scientific literature. Therefore, to fill this research gap, this study aims to determine the potential of Water Hyacinth plants as phytoremediator agents in Sasirangan wastewater. FTIR analysis was carried out to determine what functional groups were present in the roots of the Water Hyacinth plant so that it could reduce contaminants in wastewater. SEM analysis was carried out to determine the surface morphology of the Water Hyacinth plant roots. In addition, this study aims to determine the effect of Water Hyacinth plants in reducing Total Suspended Solid and color in the liquid waste of the Sasirangan textile industry. Therefore, further research is needed to determine the ability of Water Hyacinth to remediate Sasirangan liquid waste. In this study, the phytoremediation process was carried out with several parameters like the weight of water hyacinth 0.5 kg, 1 kg, and 1.5 kg and contact time of 0, 3, 6, 9, 12, and 15 days, exposure of acclimated Water Hyacinth to Sasirangan wastewater. This study's results will benefit researchers and industry in designing alternative biotechnology to treat Sasirangan wastewater using wetland swamp plants.

2. MATERIALS AND METHODS

Materials

The main tools used are a phytoremediation reactor, thermometer, siever, beaker (Pyrex), measuring cup (Pyrex), spatula, mixer/blender (Philips HR 2116), analytical balance (OHAUS Galaxy TM 106), and Whatman filter paper No.42. While, the materials used are distilled water, Sasirangan wastewater from one of the Sasirangan industries in Cempaka Banjarbaru South Kalimantan, Water Hyacinth (*Eichhornia crassipes*) plants taken from swamps area in Martapura District, South Kalimantan. Plants used for phytoremediation are live plants with the characteristics of 3-6 leaves, roots, and plant height are relatively the same, leaf length is 3-6 cm, and the condition of the plant is relatively fresh.

Preparation of Water Hyacinth for FTIR and SEM Analysis

The material used for this analysis is water hyacinth root. Water hyacinth roots were cleaned with water and dried for 3 days at 25 ºC to 31 ºC. After drying, mash with a blender for 2 minutes. Afterward, the material was sieved with a mesh size of 60 and then analyzed by FTIR and SEM.

Characterization of Water Hyacinth Roots using FTIR and SEM

The functional group of Water Hyacinth root was determined by FT-IR Bio-rad, Digilab FTS-3500 at the wavelength range 4000-400 cm^{-1} with a scan rate of 8 cm^{-1}/s. The morphology and surface structure of water hyacinth roots was observed using SEM instrument (JEOL, JSM-6500 LV) at 5 kV with magnification of 2500 and 10000.

Water Hyacinth (*Eichhornia crassipes*) Acclimatization and Phytoremediation Method

At the acclimatization time, 1 liter of Sasirangan industrial wastewater dilution was mixed with 20 liters of distilled water and stirred until homogeneous. Acclimatization plants are finished by disposing waste liquid into a container and settling for four days for plants that did not wither or die. After that, the plants were neutralized with distilled water for 1 day before the experiment (Riyanti *et al.*, 2019). Samples of wastewater from the Sasirangan industry were accommodated in a reactor containing 1 liter of wastewater with 20 liters of distilled water (1:20 dilution ratio). Then the diluted waste is put into a reactor. Then put into reactors containing 0.5 kg, 1 kg, and 1.5 kg of Water Hyacinth plants (**Figure 1**). After that, pH, color, and total suspended solid were analyzed for each sample on days 0, 3, 6, 9, 12, and 15. pH analysis was carried out using a pH meter. TSS content analysis refers to ASTM D 5907-09 Standard Test Method for Filterable and Nonfilterable Matter in Water. Colors analysis refers to SNI 6989.80:2011.

Analysis of pH, TSS, and Colors

The pH analysis was carried out based on SNI 06-6989.11-2004 using a pH meter Ino Lab 7170. The initial pH analysis was carried out before the phytoremediation time, at 0 days. Then pH measurements were made during phytoremediation on days 3, 6, 9, 12, and 15 on each plant mass of 0.5, 1, and 1.5 kg. After that, the decrease in pH was calculated every 3 days for 15 days.

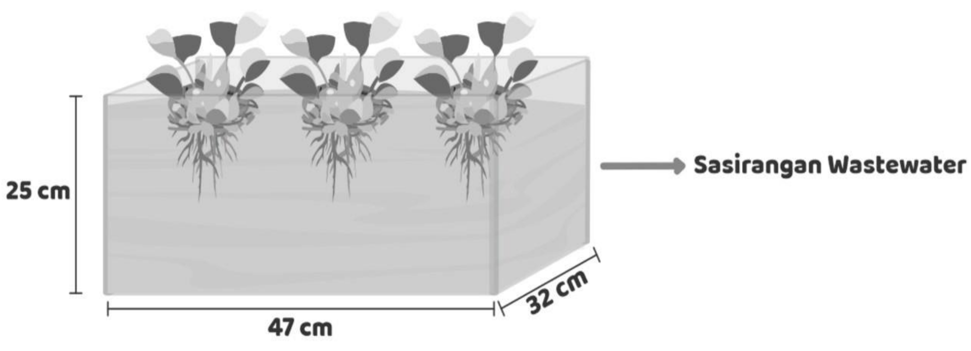


Figure 1. Set up of wastewater treatment phytoremediation processes with Water Hyacinth plant

TSS analysis was carried out using the gravimetric method concerning the ASTM D 5907-09 Standard Test Method for Filterable and Nonfilterable Matter in Water. A 50 mL sample was filtered with filter paper that had been weighed. The filter paper was put in the oven for 1 hour at 80 °C. The filter paper is cooled in a desiccator and weighed. The weight value obtained is recorded until it is constant. The TSS content is calculated using the equation 1:

$$\text{TSS (g/L)} = \frac{(A-B)x\ 1000\ mg}{sample\ volume\ (L)} \ldots\ldots\ldots\ldots\ldots (1)$$

Where, TSS is total suspended solid (mg/L), A is filter paper and dry residue (g) and B is filter paper weight (g)

Color analysis refers to SNI 6989.80:2011 with UV-Vis spectrophotometer. Initial color analysis was carried out 0 days before the phytoremediation took place. Then, the color analysis was carried out during phytoremediation on days 3, 6, 9, 12, and 15 on each plant dosage of 0.5, 1, and 1.5 kg. After that, the decrease in pH was calculated every 3 days for 15 days.

3. RESULTS AND DISCUSSION

Characteristic of Water Hyacinth Roots

FTIR is used for the identification of compounds, especially organic compounds. The analysis is determined by seeing the spectrum's shape, namely by the specific peaks that indicate the type of functional group possessed by the compound. FTIR analyzed the prepared water hyacinth roots to find out what functional groups were present in the roots so that they could remove the contaminant parameters in the Sasirangan wastewater.

Figure 2 shows the FTIR spectrum of Water Hyacinth roots. At the wavenumber of 3263.21 cm-1 associated with the O-H strain. The wavenumber of 2926.36 cm^{-1} is associated with C-H vibrations for alkanes. Water Hyacinth roots also showed a wavenumber of 1633.38 cm^{-1} associated with the C=O strain of the carboxylate. At 1370.63 cm^{-1}, wavenumber is associated with C-H deformation. Furthermore, the stretching of C-O is shown at a wave number of 1030.46 cm^{-1}, indicating an alcoholic hydroxyl group (Mukaratirwa-Muchanyereyi *et al.*, 2016). Thus, it can be said that the composition of the Water Hyacinth root is mainly composed of lignocellulose.

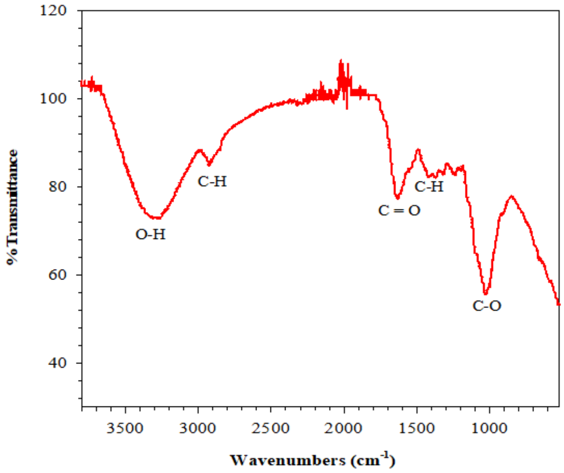
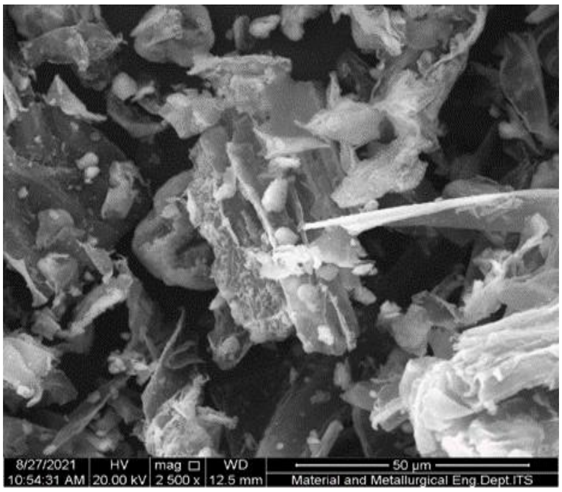


Figure 2. FTIR spectrum of Water Hyacinth roots

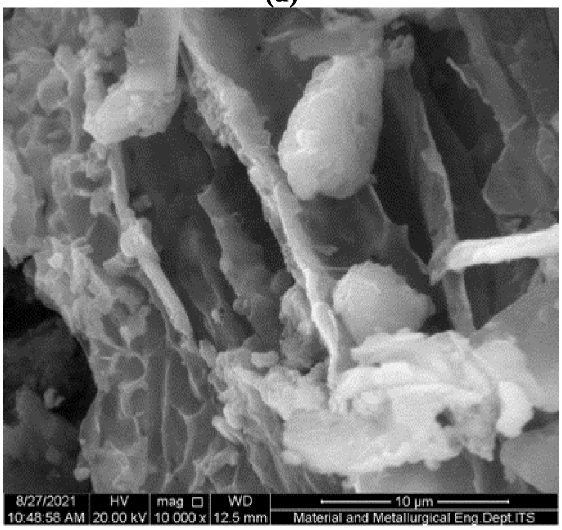
In addition, the shape of the Water Hyacinth roots is fibrous so that it can hold the solids present in the wastewater, reducing the levels of suspended solids. The hydroxyl (O–H) groups play a role in the adsorption of contaminants in wastewater so that it can reduce Total Suspended Solids in wastewater. The O–H group will be bound and interact with the adsorbate. Positively charged ions from the dye will bind to the O–H group, which is rich in electrons, so that it will attract harmful dyes contained in the Sasirangan liquid waste. Imron *et al.* (2021) reported that the functional groups that play a role in the absorption of dyes are the hydroxyl and carboxyl groups. In addition to the hydroxyl functional group, water hyacinth has a carboxyl functional group that promotes the adsorptive removal of pollutants from water through hydrogen bonds and electrostatic interactions (Madikizela, 2021).

The appearance of cellulose was confirmed through SEM, which shows the presence of cavities in cellulose pores. The cellulose in the plant's roots can absorb dyes. The clusters in the Sasirangan wastewater react with O-H substances in the cellulose to adsorb dyes in the Sasirangan wastewater. The hydroxyl group affects the adsorption process (Madikizela, 2021).

SEM analysis was carried out to observe the surface morphology of the material. In this case, the Water Hyacinth root, which will be used for the phytoremediation processes, was characterized using SEM to determine the root's surface structure so that it could absorb contaminants contained in the Sasirangan wastewater.



(a)



(b)

Figure 3. Characterization of Water Hyacinth roots using SEM with (a) 2500 and (b) 10000 of magnification

Figure 3 shows that the Water Hyacinth roots surface is very unstructured. However, it has cavities which are pores in cellulose. Mukaratirwa-Muchanyereyi *et al.* (2016) reported that Water Hyacinth does not have a thick epicuticular wax layer or structured surface. Besides, it consists of fibers and micropores (Muigai *et al.*, 2021). Cellulose has OH^- ions which can cause the adsorption process to occur. The N^+ of dye molecules in the wastewater is attracted to the OH^- in the cellulose molecules through hydrogen bonds. Electrostatic interactions also play a role in the adsorption process, where the N^+ in the dye molecules in the wastewater is attracted to the O^- in the cellulose molecules (Imron *et al.*, 2021).

Decrease in Total Suspended Solid and pH over a Period of Time

The pH decrease in phytoremediation correlates with a decrease in total suspended solids (TSS). For phytoremediation to be effective, suitable environmental conditions are needed to support the growth and development of Water Hyacinth. The higher plant weight does not necessarily affect the decrease in TSS. **Figure 4** shows the decrease in pH each day. A constant decrease is seen between TSS, and pH tends to be in equilibrium. The decrease in pH could be due to the greater concentration of hydrogen ions in the water. On days 0 to 3, the pH change was not significant. At the time, the Water Hyacinth plants are still adapting to the environment.

Meanwhile, on the 3rd to 15th day, there was a decrease almost close to neutral pH. The decrease tends to be constant because phytoremediation undergoes a phytostabilization processes mechanism, namely the attachment of specific contaminants to the roots that cannot be absorbed into the plant stem (Saleem *et al.*, 2020). Roots play a role in phytostabilization (Raza *et al.*, 2020). In this system, the respiration process may occur but does not exceed the photosynthesis process so that the carbondioxide can be taken up directly by plants through the air is released back into the water, and the pH will be lower but lead to regular and tend to be stable. The presence of H^+ ions caused by the decay of fallen plant parts can also cause a decrease in pH (Novi *et al.*, 2019).

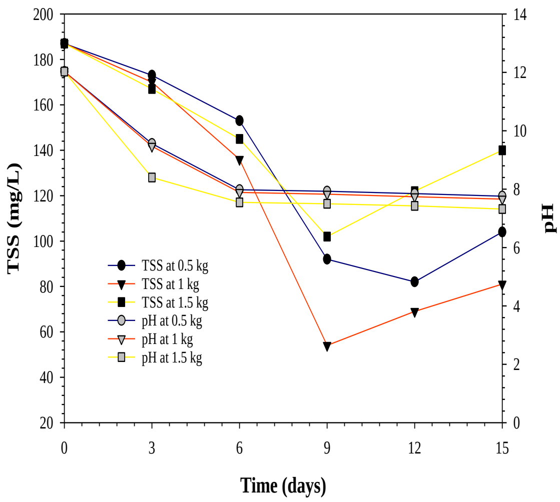


Figure 4. The relationship between the TSS to time and pH

This decrease in pH resulted in significantly reduced TSS for 0.5 kg, 1 kg, and 1.5 kg Water Hyacinth plants. TSS decrease is due to phytoremediation experiencing a rhizofiltration processes mechanism, which is a process of adsorption or deposition of contaminants by the roots by sticking to the roots (Saleem *et al.*, 2020). On days 12 to 15, there was an increase in the concentration of TSS again. It could be because the Water Hyacinth plants have experienced saturation in absorbing contaminants in the Sasirangan wastewater. The most significant decrease in Total Suspended Solid was at 9 days of phytoremediation, which was 54 mg/L or 71.12%. This decrease is more significant than the study of Abdul Aziz *et al.* (2020) phytoremediation using Lemna minor plants, one of which was applied for 8 days to sewage wastewater with a Total Suspended Solid reduction of 50.8%. This difference could be due to the root system of the Water Hyacinth plant being different from that of the Lemna minor plant. Lemna minor plants have smaller roots than Water Hyacinths so that water Hyacinths can filter more suspended solids. Therefore, the TSS reduction efficiency of Water Hyacinth plants were greater than that of Lemna minor plants.

Decrease in colors and pH over a Period of Time

The decrease in pH also correlates with a decrease in color concentration. **Figure 5** shows the color concentration that fluctuates from day to day. A significant decrease in colors occurred on day 3. This decrease was due to the rhizodegradation process by microorganisms in the root zone. Rhizodegradation is a process where plants' substrate stimulates microbial communities' growth in the rhizosphere to decompose organic pollutants. The rhizosphere provides a unique environment for microorganisms capable of breaking down harmful pollutants into harmless products through their metabolic activities. In rhizodegradation, the biodegradation process is produced from nutrients released by plants in the form of root exudates. The microbial population and activity in the rhizosphere can increase due to the presence of this exudate and can increase the degradation of organic pollutants (Chandra *et al.*, 2017). Dyes can be reduced, and the bond chain can be broken with the help of decomposing microorganisms. The first time, the process that occurs is to degrade the long-chain compounds that make up the dye into short chains, which can then be used as an energy source for plants to synthesize the components that make up new cells.

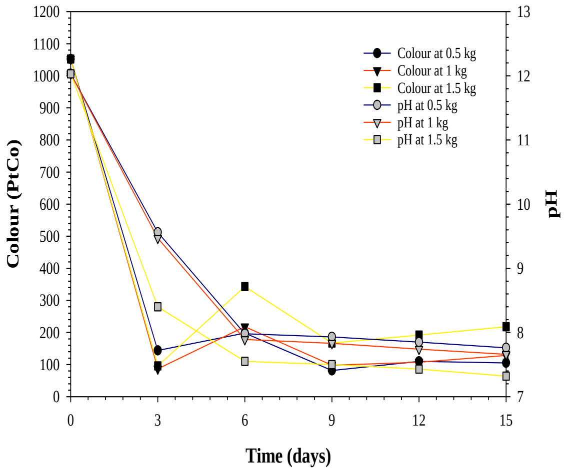


Figure 5. The relationship between the colors to time and pH

The increase in dye concentration occurred on day 6. It was probably caused by the number of plants that had not been proportional to the pollutant load in the wastewater, coupled with the possibility of decomposition of dead plants so that their concentrations increased. Many factors influence this decrease and increase, including the unpredictable weather every day, so it determines this phytoremediation process because it requires sunlight. In this study, the best color reduction at 9 days of phytoremediation was 81.5 PtCo or 92.26%. This result is slightly larger than that of (Ahila *et al.*, 2021). Using Pistia stratiotes as a phytoremediation agent can reduce the color content by 86% in dyeing waste. The root structure of the Water Hyacinth plant is more fiber than others. Plants with fibrous root tissue provide a larger surface for biofilm development, trapping and depositing particles that exhibit higher photosynthetic rates, thus showing better efficiency in pollutant removal. Aquatic plants have diverse microbial populations, acting individually or forming biofilms attached to substrates or plants (Chatterjee *et al.*, 2019). Biofilms are microbes consisting of various species that live in harmony in complex coordinated communities, providing resistance to harsh conditions or extreme chemical conditions. Biofilm can assist in the biomineralization of nutrients which plants then transport into the air through the epidermis of the root zone. Bacteria growing on biofilms produce exopolymers that help them adhere to surfaces, bind together, and protect them from the surrounding environment. The oxygen-rich root zone biofilm was dominated by Methanotrophs, Nitrosomonas, and Pseudomonas sp., which play a role in the aerobic degradation of pollutants (Rajan *et al.*, 2019).

The dominant dyes found in the textile industry are azo, with one or more nitrogen double bonds (Bharathiraja *et al.*, 2018). Water Hyacinth root contains cellulose. The presence of cellulose in plants generally can adsorb dyes. The molecular structure of cellulose contains hydroxyl (-OH) groups. The positive ions of contained dyes in the Sasirangan textile wastewater bind to the negative ions of cellulose so that there is an attractive force that causes adsorption to occur.

4. CONCLUSIONS

The Sasirangan textile wastewater treatment approach with the phytoremediation method using Water Hyacinth as plant adsorbent media showed good performance in reducing total suspended solids (TSS) and colors. Water Hyacinth roots were characterized using FTIR instrument analysis, showing that Water Hyacinth roots contain functional groups of O-H strain, C-H vibrations, C=O strain, C-H deformation, and C-O stretching. Observations with SEM showed that the roots of Water Hyacinth were unstructured and had pores that possibility for uptake phytoremediation process of TSS and colors. The effect of mass variation of Water Hyacinth showed a relatively small decrease. The pH decreases in phytoremediation correlated with a decrease in TSS and color. The significant decrease in TSS and colors of the phytoremediation process within 9 days was 54 mg/L (71.12% removal) with the optimum color reduction of 81.5 PtCo (92.26% removal). The presence of these functional groups and pores, strengthened by the analysis of TSS and colors, showed that Water Hyacinth could reduce TSS and color levels in the Sasirangan textile wastewater.

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