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Utilization of Nutgrass *(Cyperus Rotundus L.)* as a Phytoremediator in Reducing BOD and COD Levels of Batik Liquid Waste Using Constructed Wetlands in Sub-Surface Flow Type

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Abstract
The process of dyeing batik fabric is a significant source of water pollution due to synthetic dyes. Only 5% of this compound is used, while 95% will be disposed of as waste. This compound is relatively stable, so it is tough to degrade in nature and is dangerous for the environment because it can cause effects such as increasing COD (Chemical Oxygen Demand) and BOD (Biological Oxygen Demand). Constructed wetlands in sub-surface flow type is a wastewater treatment method that utilizes the role of plants and microorganisms found in the plant root area or rhizosphere. Nutgrass (Cyperus Rotundus L.) is rarely used and is considered a weed that causes harm to surrounding plants. On the other hand, nutgrass is a plant with good remediation and straightforward maintenance. In this research, the nutgrass plant was used as a phytoremediator with planting media in the form of sand and gravel to improve the performance of constructed wetlands in processing liquid batik waste. Based on the analysis of BOD and COD test parameters, the results showed that nutgrass could reduce BOD levels by up to 75% and COD levels by 73% so that wastewater produced from artificial wetlands flows more safely and can be used for irrigation and plants sanitation.

Keywords: batik, phytoremediator, nutgrass

INTRODUCTION

The increase in public interest in batik was accompanied by an increase in batik production and the development of the batik industry in various regions in Indonesia. The batik industry contributes to liquid waste with large volumes, dark colors, strong odors, alkaline properties, and high organic compound content (Tangahu & Ningsih, 2016). One of the Yogjakarta SMEs produces liquid waste of around 125 L/kg of batik (Yulianto, 2019), and in Pekalongan, around 100 L/kg of batik (Apriyani, 2018). This liquid waste was produced from remaining dyes, washing processes, and rinsing fabrics (Apriyani, 2017). The chemicals used in making batik include acid dyes, alkaline dyes, naphthol, indigosol, and rapide (Kurniawan et al., 2013). Only 5% of this compound is used in dyeing, while the other 95% is discarded as waste (Suprihatin, 2018). This compound is relatively stable, so it is tough to degrade in nature and is dangerous for the environment because it causes a cloudy color in waters, increases levels of COD (Chemical Oxygen Demand) and BOD (Biological Oxygen Demand) (Kiswanto et al., 2023).

The batik industry in the Semarang area produces liquid waste with a BOD content of 130.37 mg/L and a COD content of 1376 mg/L (Wahyu et al., 2010). This value shows that the BOD and COD parameters in the Semarang batik industry are still above the quality standards according to the Minister of Environment Regulation Number P.16 of 2019 concerning Textile Industry Wastewater Quality Standards, namely 60 mg/L for BOD and 150 mg/L for COD (Ministry of Environment and Forestry, 2019). The high levels of BOD and COD in batik liquid waste are due to the abundance of organic substrates and dyes in the wastewater. BOD measures microorganisms' activity in dissolved oxygen to degrade organic materials in the substrate. Meanwhile, COD shows the amount of chemical oxygen needed by microorganisms to oxidize organic materials in wastewater (Tangahu & Ningsih, 2016). High BOD and COD content can negatively impact the environment, such as decreasing water quality, reducing oxygen levels in the water, and causing a strong odor and germs that can harm human health (Pungus et al., 2019).

In processing batik liquid waste, the wastewater treatment plant (WTP) system applied to the batik industry usually uses physical, chemical, and biological processing. However, this processing system cannot significantly reduce the pollutant content (Indrayani & Triwiswara, 2018). Apart from that, WWTP also produces sludge, which requires further treatment (Triwiswara, 2019). Another problem is that the costs required for processing liquid batik waste are quite expensive, especially in small-scale or household batik industries (Wahyu et al., 2016). Therefore, an alternative effort is needed to process batik liquid waste economically and effectively so that it can be applied on a small scale to a medium industrial scale.

One method of processing liquid waste is phytoremediation (Kuswoyo & Ulimaz, 2022). Phytoremediation is a waste processing process involving the role of plants and liquid waste to reduce pollutant levels in waste (Kurnia et al., 2014). In this research, phytoremediation is a method of processing batik liquid waste using a constructed wetlands system in a sub-surface flow type. Constructed wetlands are a water treatment system using a new approach to improve water quality and reduce pollutants in batik liquid waste; this allows waste to enter rivers more safely (Erwin, Joko, and D, 2017). The sub-surface flow type constructed wetlands system utilizes the role of plants and microorganisms around the plant root area or rhizosphere (Indrayani and Triwiswara., 2018). Constructed wetlands have advantages, including simple equipment, energy saving, lower operational costs, more straightforward operation, reduced pollutants, and supply of oxygen well so that waste is safe to channel (Erwin, Joko, and D, 2017). Apart from that, constructed wetlands can be constructed in various shapes and sizes and only require a small amount of land, so this method can be applied to settlements with relatively high population densities (Indrayani & Triwiswara, 2018).

In this research, the nutgrass plant was used as a phytoremediator with planting media in the form of sand and gravel to improve the performance of constructed wetlands in processing liquid batik waste. So far, nutgrass has been considered a weed because its roots spread quickly when they enter the soil and are challenging to eradicate. On the other hand, nutgrass plants have a good ability to reduce pollutant levels such as BOD and COD, can live in polluted environments, are suitable for use for waste processing, and play a role in supplying oxygen, which helps the pollutant degradation process (Kurnia et al., 2014; Triwiswara, 2019).

Based on these problems, this research aims to reduce the levels of BOD and COD pollutants in batik liquid waste using nutgrass as a phytoremediator in constructed wetlands sub-surface flow type, so that the water output from constructed wetlands will be saved to flow and can be used for irrigation purposes and plant sanitation.

Literature Review

Batik Liquid Waste

According to Nurainun (2008), Indonesia's batik industry is a small and medium sector spread across several regions and islands. Coloring is one of the processes in making batik. In the dyeing process, the batik industry uses chemical dyes, which are easy to obtain and relatively low-priced (Nurdalia, 2006). Hidayat et al. (2021) add that much liquid waste is produced in the batik-making process. In dyeing and washing the batik industry, around 15 – 20 L/day of liquid waste is produced (Nurroisah, 2014).

Batik liquid waste contains high levels of phenol, sulfide, BOD, COD, TSS, and pH and has the characteristics of a sharp odor, deep color, thickness, and cloudiness (Fatiha et al., 2021). Acer batik waste also contains heavy metals that are difficult for microorganisms to decompose, such as Zn, Cd, Cr, Cu, Pb, suspended solids, and other organic substances (Oktavia et al., 2016). The coloring process in the batik industry uses synthetic dye chemicals (Erlita et al., 2022). Artisans prefer synthetic dyes to natural dyes because the colors produced by synthetic dyes are more stable and easy to obtain. It is more practical, but stable synthetic dyes take longer and are more difficult to decompose in the environment, so they can disrupt aquatic ecosystems (Erlita et al., 2022). Heavy metals and organic compounds in batik waste accumulate at high levels and enter the food chain cycle, causing disease in living creatures (Nurbidayah et al., 2014).

With the right technology in processing batik liquid waste, quality can be improved in compliance with quality standards following the Minister of Environment Regulation Number P.16 of 2019 concerning quality standards for textile industry wastewater, which is stated in table 1 as follows,

Table 1. Textile Industry Wastewater Quality Standards

Parameter	Unit	Maximum Level
pH	-	6 – 9
BOD_5	mg/L	60
COD	mg/L	150

(Ministry of Environment and Forestry, 2019)

BOD and COD

BOD (Biological Oxygen Demand) states the amount of dissolved oxygen needed by microorganisms to decompose or decompose organic matter under aerobic conditions (Metcalf & Eddy, 1991). Not only does it state the amount of oxygen, BOD also says the amount of biodegradable organic matter in the waters (Mays, 1996). Meanwhile, COD (Chemical Oxygen Demand) states the oxygen needed to decompose organic matter in water (Boyd, 1990). The total amount of organic matter in water is described in the COD value. The decrease in COD levels in wastewater is proportional to the reduction of the concentration of organic matter in the wastewater. According to Iskandar et al. (2019), high COD values will increase organic compounds in the waste and vice versa. We can compare the BOD and COD values to determine the number of more persistent organic compounds in water (Atima, 2015). Two parameters defining the quality standards for batik liquid wastewater are the BOD and COD parameters. The higher BOD and COD content in liquid waste disrupts the survival of living creatures in the waters due to a decrease in dissolved oxygen concentration (Suharto, 2011).

Nutgrass

Nutgrass (*Cyperus rotundus L.*) is better known as a weed because its presence often interferes with the growth of other plants. Nutgrass is classified as a wild plant that is difficult to eradicate because the tubers this plant produces regenerate very quickly (Roliya, 2021). In research conducted by Sobayar and Luth (2021), it is stated that nutgrass is a plant with potential as a phytoremediator with the highest relative dominance value (DR), namely 38.27%. The relative dominance value (DR) describes the level of land cover by understory plants such as nutgrass. Nutgrasses have a phytoremediation ability, a good one in the elimination rate of pollutants like BOD And COD so that batik liquid waste is more safely channeled into water bodies (Kurnia et al., 2014). Additionally, nutgrass can survive in polluted environments, is suitable for waste processing, and can help the pollutant degradation process with its oxygen supply (Triwiswara, 2019). This is what underlies the selection of nutgrass as a plant used for phytoremediation.

Constructed Wetlands

According to Fattayat (2022), constructed wetlands include waste processing, a process like in wetlands that cannot be separated from aquatic plants, which play an essential role in restoring water quality. Several advantages of the constructed wetlands method include cheaper processing costs, easy operation and maintenance, high efficiency, reduced levels of heavy metals, and the ability to support ecological functions (Azmi et al., 2011). Constructed wetlands are one way of engineering waste processing systems where the design involves aquatic plants, planting media, and a collection of related microbes (Suswati & Wibisono, 2013). The working principle of constructed wetlands is to utilize the reciprocity between aquatic plants and microorganisms in the media around the plant's root system (rhizosphere). Microbes will break down organic compounds in wastewater into simpler compounds and then use them as plant nutrients. At the same time, the oxygen produced in the root system is used as an energy source for the metabolism of these microorganisms (Sri Roliya, 2021). Plants in constructed wetlands aim to increase the surface area for the growth of microorganisms in the root area, provide oxygen levels around plant roots, and act as a medium to absorb metal content in wastewater (Sri Roliya, 2021; Nikho, 2020). The mechanism and efficiency of how constructed wetlands work depends on the type of planting medium, bioavailability, and the type of contaminant to be removed (Fattayat, 2022).

One type of constructed wetlands is sub-surface flow wetlands, which use macrophyte plants whose roots sink or are often called amphibious plants as the plant medium (Fattayat, 2022). Sub-surface flow consists of a channel or pond with a watertight bottom to support vegetation growth. It is filled with sand, stones, or other planting media (Cahyana & Aulia, 2019). The advantage of this method is that the efficiency of decomposing suspended solids and bacteria is more significant compared to other types (Khiatuddin, 2010).

METHODS

Types of research

The research used is applied research. Applied research is conducted to test and apply theories to solve concrete problems, develop and produce products, and obtain essential information for decision-making.

Research design

Figure 2. Research design

The research was designed with five stages, namely 1) Planning, there is a literature review so that the study can be based on existing literature or previous analysis of the same type. At this stage, the variables that will be addressed in the research are determined; 2) Preparation of tools and materials, at this stage, start preparing tools and materials for carrying out research; 3) Implementation, stage of preparing subsurface flow type constructed wetlands using nutgrass as a laboratory scale phytoremediator; 4) Data collection, data is collected by observation based on the results of testing BOD and COD levels in batik liquid waste; 5) Evaluation, evaluation is carried out to find out things that can be improved for further research; 6) The research was conducted in a chemical engineering laboratory from June to August 2023; 7) The independent variables are residence time 3, 6, 9, and 12 days, while the fixed variable is nutgrass with a total of 8 colonies, with the dependent variable being the decrease in BOD and COD levels; 8) Data collection in this research was carried out to collect primary data obtained from observations on the use of nutgrass as a phytoremediator in the processing of batik liquid waste using constructed wetlands of the subsurface flow type. From the data obtained, the efficiency of reducing BOD and COD levels in batik liquid waste and the optimum residence time will be known; 9) The procedure for creating subsurface flow-type constructed wetlands using nutgrass as a phytoremediator on a laboratory scale is based on research conducted by Damayanti, Fauzi, and Hajri (2013) and made several modifications. The research steps carried out are as follows:

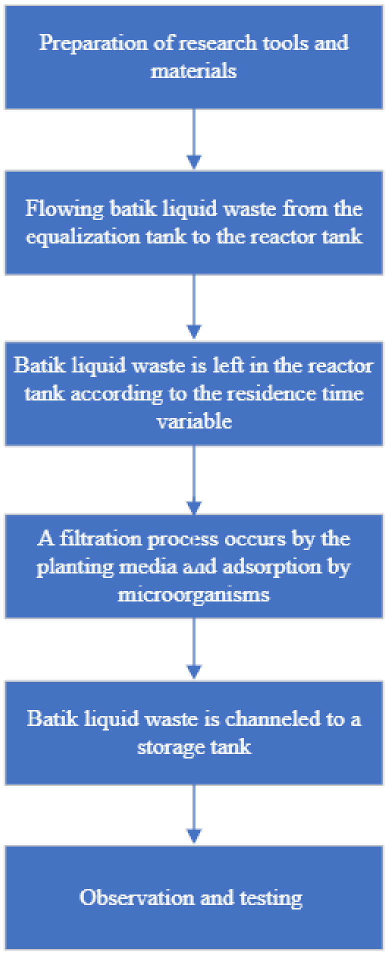

Figure 3. Research Steps

RESULTS AND DISCUSSION

Constructed Wetlands as a Batik Liquid Waste Processor

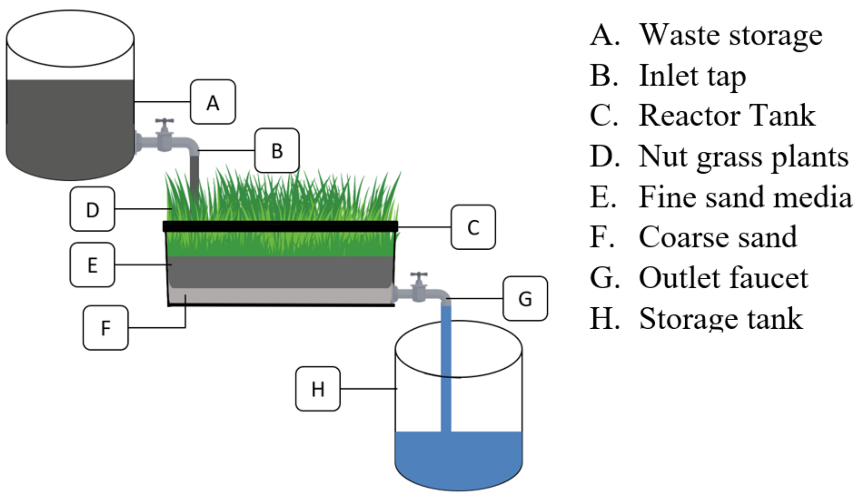

Figure 4. Constructed Wetlands Reactor Design

Wastewater treatment with constructed wetlands This type of constructed wetlands can be called an artificial swamp of constructed wetlands. As the name suggests, the system works by flowing waste water horizontally under the plants; these plants can adsorb pollutants in liquid waste using leaves, roots, and stems (Cahyadi, 2016). Thus, batik liquid waste containing BOD and COD levels will decrease along with the ability of nutgrass to absorb pollutants. According to Suswati and Wibisono (2013), constructed wetlands are the most suitable for the primary processing of waste because there is no direct contact with the water column and atmosphere, and this system is safe from a public health perspective because it reduces the opportunity for mosquitoes to develop.

The reactor tank was used to make a constructed wetlands laboratory scale, namely a glass aquarium with nutgrass planted on sand and gravel, to improve the performance of constructed wetlands (Suswati & Wibisono, 2013). The nutgrass used in the reactor tank is eight colonies with the same number of stems per colony, namely 2 stems per colony. Then, the plants will be moved into planting media in constructed wetlands and given healthy water for three days to adapt to the new environment (acclimatization) (Erwin et al., 2017).

Constructed wetlands for Batik Liquid Waste

The batik industry produces a significant amount of liquid waste from various processes, such as dyeing, washing, and removing wax. Around 80% of the water used in the batik-making process is disposed of as liquid waste (Suharto et al., 2013). Since batik is mainly produced by small and medium industries, many still require facilities to process their liquid waste (Triwiswara, 2019). Unfortunately, batik liquid waste is often disposed of directly into rivers or ditches without prior treatment (Subki & Rohasliney, 2011; Syuhadah et al., 2015).

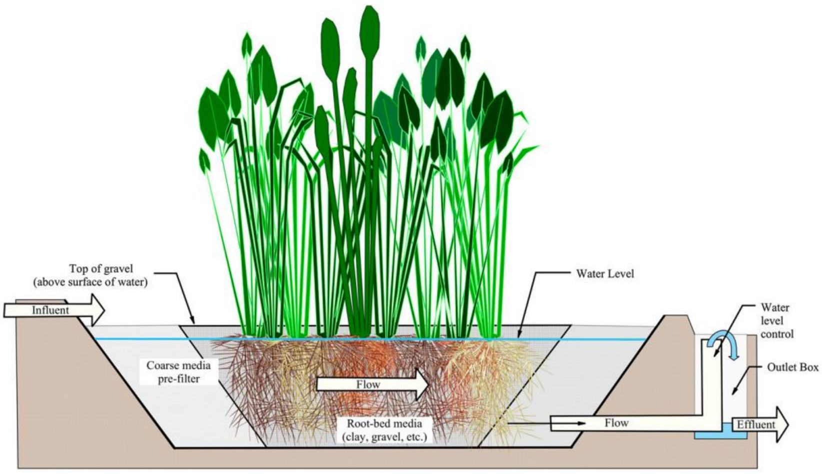

Figure 5. Constructed Wetlands Sub-surface Flow Type (White, 2014)

The internal process of constructing wetlands is almost similar to natural wetlands, but some parameters can be controlled better (Vymazal, 2014). Constructed wetlands are often categorized as biological processing because most of the process is the absorption of pollutants by plants and microorganisms. However, in constructed wetlands systems, there are other processes, such as sedimentation, filtration, adsorption, and precipitation, which can increase efficiency in reducing pollutant levels (Wahyudianto et al., 2019). In Figure 2.4, it can be seen that liquid batik waste will flow to the nutgrass plant and enter the planting medium, then there will be a filtration and absorption process by microorganisms, and then adsorption of pollutants will occur by the planting medium (Indrayani & Triwiswara, 2018).

Ability Nutgrass reduces BOD and COD

Figure 6. Constructed Wetlands Sub-surface Flow Type Bioreactor Prototype

Nutgrass is a plant that has many fibrous roots, so its ability to absorb nutrients is better than that of other plants. Nutgrass can grow anywhere, is easy to care for, is resistant to various external influences, and has a high level of microbial growth (Al snafi, 2016; Nurulita et al., 2020). High BOD levels indicate that the dissolved oxygen contained in the water is minimal. This condition will impact the death of aquatic organisms due to a lack of dissolved oxygen (anoxia). Meanwhile, high levels of COD will impact the environment, one of which is eutrophication (Daroini & Arisandi, 2020; Padmanabha et al., 2015).

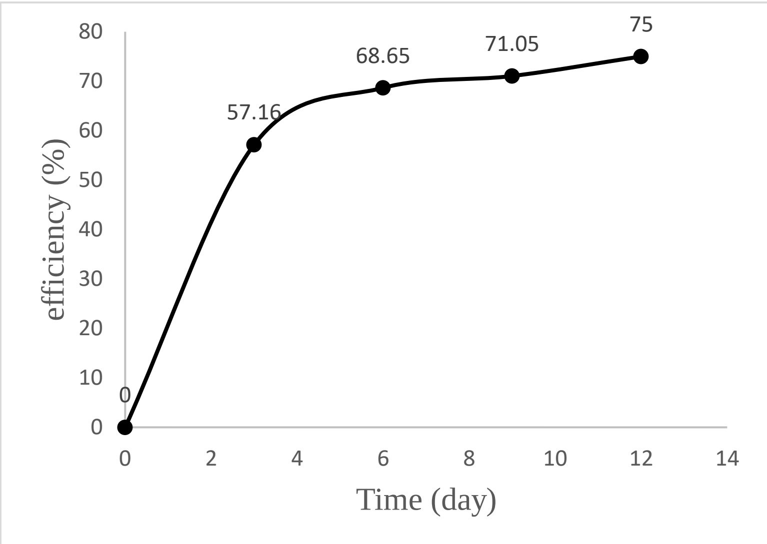

Figure 7. Relationship between BOD Reduction Efficiency with Time

Based on the Figure 7, it is known that reducing BOD levels can be done with nutgrass plants using the constructed wetlands type constructed wetlands method; the efficiency level increases quite significantly every day until the efficiency value reaches 75% on day 12. The quality of the batik liquid waste Initially, the BOD level reached 130.37 mg/L, which decreased to 31.3 mg/L on day 12. This figure was below the quality standard set by the government, namely 60 mg/L.

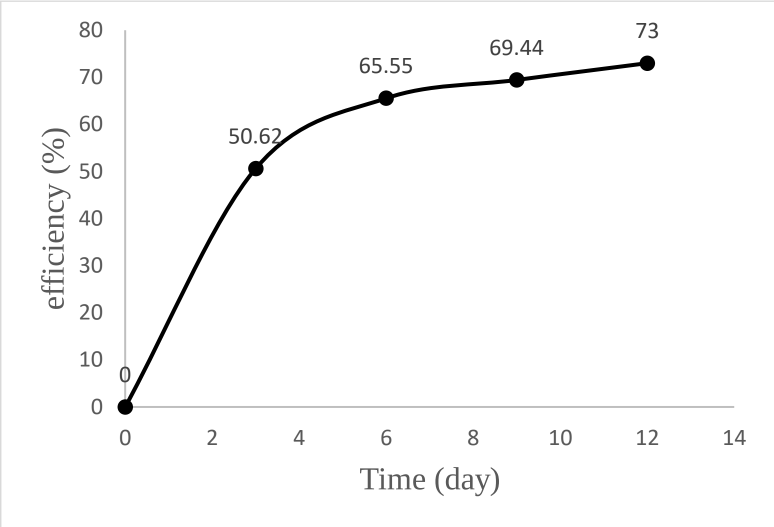

Figure 8. Relationship between COD Reduction Efficiency with Time

Furthermore, in Figure 8, it is known that the percentage of COD removal has increased significantly. On the third day, the efficiency value shows 50% and increases every day until, on the 12th day, it reaches 73%. Batik liquid waste, which initially had a COD content of 1376 mg/L, decreased to 372 mg/L. The decrease in COD levels occurs due to the adaptation process of nutgrass to provide oxygen supply to wastewater, thereby increasing dissolved oxygen and reducing COD values (Amalia et al., 2014).

Decreased efficiency BOD and COD are expressed in percentages to determine how much reduction has occurred. The efficiency of reducing concentration can vary due to environmental factors that influence the metabolism of nutgrass with the media (Amalia et al., 2014). The increased efficiency of reducing BOD and COD levels is caused by the roots of nutgrass plants, which have grown and spread well due to acclimatization (Kurnia et al., 2014).

Use of Nutgrass as a Phytoremediator in Previous Research

In previous research, nutgrass was used as a phytoremediator to reduce the BOD and COD content in batik liquid waste. However, no one has used nutgrass as a phytoremediator in liquid waste from the batik industry. However, in research conducted by Kurnia et al. (2014), nutgrass can effectively reduce BOD by up to 76% and COD by up to 73%. Other research conducted by Amalia et al. (2014) also stated that nutgrass plants with eight colonies could reduce BOD levels by up to 74% and COD levels by 65% on day 12, in line with research conducted by Octavia et al. (2021), where the stems of the Cyperus rotundus L. plant can reduce BOD and COD levels with an efficiency level of 59%.

Besides being used as a phytoremediator in domestic liquid waste or greywater, nutgrass has also been used as a phytoremediator in laundry waste. In research by Erwin, Joko, and D. (2017), 30 colony nutgrass can reduce BOD levels by up to 75% and 84% COD in laundry waste. Meanwhile, in research by Rolya (2021), nutgrass can reduce BOD and COD levels in laundry waste by 75% and 72%, respectively. In this way, nutgrass has the potential to be used as a phytoremediator in constructed wetlands to reduce BOD and COD levels in batik liquid waste.

CONCLUSION

Nutgrass is a plant that can be used as a phytoremediator in processing batik liquid waste using constructed wetlands. The nutgrass plant, which has only been considered a weed, has high efficiency in reducing BOD levels by up to 75% and COD levels by 73%, so it would be more beneficial if nutgrass were used as a phytoremediator because this plant can be found anywhere, is relatively easy to care for, is resistant against the weather, and easy to operate. Apart from that, by using nutgrass as a phytoremediator in constructed wetlands, it will be possible to reduce expenses for processing batik liquid waste. Further research is needed in nutgrass using the constructed wetlands method with variations in residence time, number of colonies, and number of nutgrass stems because the current data could be more extensive.

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