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Original Paper

Effectiveness of Sugarcane Bagasse Adsorbent Combined with Aquaponics System as an Innovation for Absorbing Contaminants in Sugar Industry Wastewater

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***Abstract*— The sugar industry in its production produces by-products in the form of bagasse and liquid waste, both of which, if allowed to exist, can damage the ecosystem and the life of aquatic biota. Sugarcane bagasse contains cellulose which can be an adsorbent to reduce pollution in rivers. Apart from that, kale plants have the ability to release H ions which can reduce pollution by attracting heavy metal ions. The aim of this research is to determine the effectiveness of adsorbents from sugar cane bagasse in combination with aquaponics to reduce river pollution from liquid waste from the sugar industry. The research method used in this study was a completely randomized design with 2 factorials, namely the amount of absorbent and the length of contact time of the adsorbent. The results of the research that has been carried out are obtained, the pH value is 6, the ammonia value is 0 mg/L, the TSS value is 150 mg/L, the DO value is 4.9 ppm, the BOD value is 336 mg/L and the COD value is 254 mg/L. The conclusion of this research is that the combination of sugarcane bagasse adsorbent and aquaponic system has been proven to reduce the concentration of pollutants in river water pollution caused by sugar industry wastewater.**

Keywords—adsorbent, sugar wastewater, bagasse, aquaponics

I. Introduction

Based on data from the Central Statistics Agency, the amount of sugar cane production in Indonesia will reach 2.42 million tons in 2021. This production amount has increased by 13.5% compared to the previous year which was 2.13 million tons. The main sugar cane production centers are in 5 (five) provinces, namely East Java, Central Java, Lampung, West Java and DI Yogyakarta [1]. The province that produces the most sugar cane is East Java which is in first place with a contribution of 69.57% to national sugar, while other provinces contribute less than 20% [2]. Increasing sugar production will increase the liquid waste produced by the sugar industry. The production process not only produces liquid waste, discarded bagasse from palm juice presses becomes solid organic waste, if it accumulates it will cause environmental pollution and be a source of disease.

Sugar industry wastewater comes from milling unit machines, sap leaks, ash water from boiler units and wet *scrubber* and condenser falling water where the waste contains carbon monoxide, sulfur dioxide, zinc (Zn), copper (Cu), lead (Pb) and other toxic substances which have great potential to inhibit the growth of microorganisms in high quantities [3, 31]. Increasing the solubility of pollutants from reasonable limits can cause biomagnification events in various aquatic biota, so it is very important to treat wastewater to reduce pollutants in the environment [4]. There are several methods for wastewater treatment, such as precipitation, coagulation and ion exchange, solvent extraction, electrolysis extraction, evaporation, osmosis, ion exchange and adsorption [5], but some methods are relatively expensive. To consider wastewater treatment costs that are more economical and easier to implement, you can use materials from nature as pollutant absorbers. Adsorbents combined with phytoremediation methods can be used for wastewater treatment.

Sugarcane bagasse is a material that has the potential to be developed because of its abundant availability and has not been utilized optimally, causing problems for the sugar industry and the environment because it is considered waste [6]. This solid waste can be used as a basic ingredient in making adsorbents. The chemical composition of bagasse includes 3.82% ash, 3.01% SiO_2, 22.09% lignin, 37.65% cellulose and 27.97% pentosan [7]. The presence of cellulose and lignin makes bagasse a potential carbon source that can be utilized in the adsorption process. The cellulose in sugarcane bagasse is coated with lignin which makes the structure of the cellulose strong. The presence of lignin can interfere with cellulose from binding with metal ions. Chemical activation treatment with NaOH solution can damage the lignin structure and increase the adsorbent absorption base [8]. The cellulose contained in bagasse determines the adsorption capacity, where cellulose contains carboxyl (-COO-) and hydroxyl (-OH) groups [9].

According to research results [6], that sugarcane bagasse can adsorb 94.3% of Cu (II) metal at pH 6.5. A study conducted by Fitri *et al.* [10], showed that 0.1 g of activated carbon from sugar cane bagasse produced an effective absorption of dyes from the songket industry of 76.3%.

Phytoremediation is a technology for handling waste by removing or reducing dangerous pollutants in water or soil using the help of plants. This method is more economical because the plants used are easy to find and grow widely in the environment [11]. The research results of Dewi *et al.* [12], show that water treatment resulting from suwung wastewater treatment with taro plants *(Colocasia esculenta)* resulted in COD absorption effectiveness of 78.19% and BOD of 84.29%. Another study shows that processing domestic liquid wastewater with water hyacinth plants (*Eichornia Crassipes*) produces water with a pH of 7 and BOD levels of 80.85 mg/L, while according to the results of research by Novita *et al.* [11], states that water spinach plants have value the efficiency of reducing pollutants was highest compared to water jasmine and water hyacinth plants with the percentage efficiency value for reducing turbidity parameters, TSS, TDS and COD respectively, namely 91.2%; 81.8%; 44%; and 64.2%.

So far, several studies have been carried out using various types of adsorbents and phytoremediation methods applied to various types of wastewater treatment, both domestic waste and agricultural industrial waste. Based on this, the combination of sugarcane bagasse adsorbent with a water spinach aquaponic system as phytoremediation in sugar industry wastewater treatment as a technology that is economical and easy to apply is an innovation in improving water quality based on water quality standards for the test parameters TSS, Ammonia, DO, COD, and BOD according to Kep.08/MenLH/2009 is 100 mg/L, 0.3 mg/L, >5 mg/L, 30 mg/L, and 20 mg/L. This research aims to determine the concentration of sugar cane bagasse adsorbent, optimal processing time and the effectiveness of the absorption capacity of a combination of sugar industry wastewater treatment technologies.

II. Research Methodology

A. Time and Place

This research was carried out from July 2023 to October 2023. The research was carried out in several laboratories, namely the Agro-Industry Technology and Management Laboratory, Faculty of Agricultural Technology, Jember University, and the Agricultural Instrumentation and Environmental Control Laboratory, Faculty of Agricultural Technology, Jember University.

B. Tools and Materials

The equipment used is an oven, beaker glass, 40 mesh sieve, 40 mesh sieve, pH meter, filter paper whatman Microfiber No.41, water test speed, ammonia test speed, volume pipette, analytical balance, incubator, Winkler bottle, Erlenmeyer, titration equipment, UV-Vis spectrophotometer, knife, mortal, pestle, stopwatch, desiccator, mask, chemical and latex gloves, label paper, jerry cans and stationery. The research materials used were bagasse, kale seeds, net pot, *rockwool*, 3 cm thick cork, cable ties, tea bags, H solution$_2SO_4$, distilled water, $MnSO_4$, sodium thiosulfate, COD *high range reagent*, NH_3 *reagent*, alkali iodide azide, starch indicator, aluminum foil, plastic box, 1 inch Viva pipe, 1 inch L pipe.

C. Research Design

The method used in this research is a laboratory experimental method using quantitative analysis data. The experimental design provides variations in density and contact time. The research formula was determined using a Completely Randomized Design (CRD) with 2 factors, namely the difference in adsorbent density and the contact time of the absorbent with wastewater which can be seen in Table 1.

TABLE I. Research Design

Sample Code	T1	T2	T3	T4
M1	M1T1	M1T2	M1T3	M1T4
M2	M2T1	M2T2	M2T3	M2T4
M3	M3T1	M3T2	M3T3	M3T4

Information:

M1 = 1% adsorbent mass to wastewater volume
M2 = 3% adsorbent mass to wastewater volume
M3 = 5% adsorbent mass to wastewater volume
T1 = 6 hours contact time
T2 = 12 hours contact time
T3 = 24 hours contact time
T4 = 48 hours contact time

D. Research Stages

1. Wastewater Quality Analysis before treatment

Testing the quality of wastewater from the sugar industry with the main parameters including pH, TSS, Ammonia, DO, BOD and COD. The results obtained are initial data that will be compared with the water quality standards of the 2014 Minister of Environment Regulation concerning wastewater quality standards.

2. Making Sugarcane Bagasse Adsorbent

An 8 kg bagasse sample was dried in the sun for 2 days, then carbonized using the pyrolysis method. This tool uses fire as a heating medium. This composition was carried out at a temperature of 300-400°C for 2 hours and followed by standing for 3 hours. Next, the charcoal was sorted, sieved with 40 mesh and activated using 1 N NaOH (1:1) for 24 hours. The results were filtered and neutralized using distilled water until the pH was neutral. Activated charcoal powder is dried using an oven at 150^{O}C for 3 hours. The absorbent which has become powdered activated carbon is put into a bag as a medium for absorbing wastewater pollutants. The concept of adsorbent placement can be seen in Fig. 1.

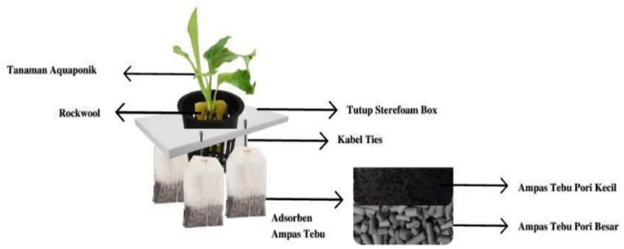

Fig. 1. Adsorbent Design

3. Making Aquaponics

Making aquaponics uses 3 cm thick cork as a floating medium and attached to a net pot which will be filled with kale plants. Start by soaking the kale seeds then placing them in rockwool as a planting medium. Next, the seeds and rockwool are put into the net pot which has been arranged in each sponge hole. Planting kale in aquaponic media functions as an adsorbent for pollutants found in wastewater through plant roots. The two materials that absorb waste water pollutants are expected to improve water quality in accordance with water quality standards. The concept of wastewater treatment can be seen in Fig. 2.

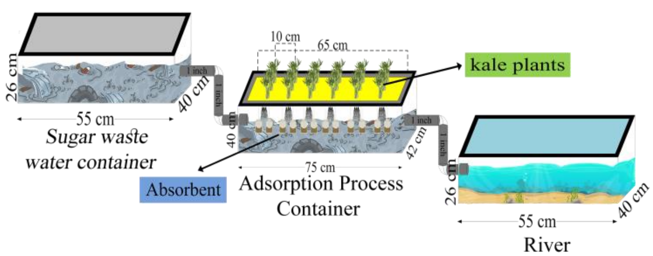

Fig. 2. Making Aquaponics

4. Wastewater Quality Analysis after treatment

Processing simulations were carried out in accordance with the research design. The mass of sugarcane bagasse adsorbent used is 1%, 2%, 3% while the water processing time is 6 hours, 12 hours, 24 hours and 48 hours. This treatment aims to determine the effect of mass and the effectiveness limit of the adsorbent. The processing results are tested for pH, TSS, Ammonia, DO, BOD and COD parameters to determine the water quality standards.

E. *Observation Parameters*

Parameter testing is used to determine and determine an effective formula for making adsorbents from sugarcane bagasse. This parameter is carried out by 6 supporting tests, namely testing pH, TSS, ammonia (NH_3), DO, BOD, and COD. These guidelines are carried out by considering the Minister of Environment Regulation Number 5 of 2014 and the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.68/Menlhk-Setjen/2016 concerning Separate Domestic Wastewater Quality Standards.

F. *Data analysis*

In this study, variations in the density composition of the adsorbent were given using test parameters, namely pH, TSS, ammonia (NH_3), DO, BOD, and COD. The test results were then carried out a One Sample T-Test statistical analysis with a Completely Randomized Design (CRD) at a confidence level of 95%, then the Duncan Advanced test was carried out to find out how big the detailed differences were between the sample data generated using IBM SPSS Statistics 25 software.

III. Discussion

A. *pH*

The pH parameter is an indicator of whether water is acidic or alkaline. The results of pH measurements for each treatment show an increasing trend approaching the water pH quality standard based on the 2014 Minister of Environment Regulation concerning wastewater quality standards, namely 6-9. This unstable pH value is due to the mechanism of wastewater reacting with OH^-. Test results data can be seen at Fig. 3.

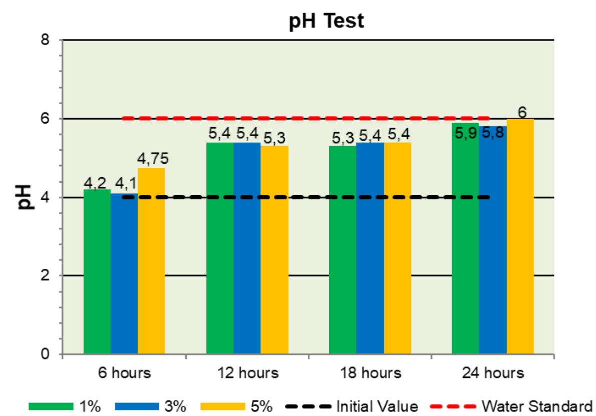

Fig. 3. pH Test Results

The research data shows that the greater the amount of adsorbent concentration, the pH of wastewater increases, this is directly proportional to the length of processing contact time which results in a pH value that increases as the wastewater treatment process takes longer. The best treatment obtained from processing sugar industrial wastewater is 48 hours of processing time with a 5% concentration of bagasse adsorbent, while the lowest treatment is 6 hours of processing time with a 1% sugarcane bagasse adsorbent concentration.

According to the research results of Sahendra *et al*. [13], the optimum absorption results from cow dung and sugar cane bagasse adsorbent occurred at a contact time of 3 hours with an adsorbent mass of 3% resulting in a pH value of 6 which is in accordance with the sugar industry wastewater quality standards based on the Minister of Environment Regulation. 2014 concerning wastewater quality standards and the lowest effectiveness value when the contact time is 1 hour with an adsorbent concentration of 1%. A study conducted by Annisa *et al.* [14] showed that an adsorbent from sugarcane bagasse with a mass of 4 grams and a processing time of 120 minutes produced the best treatment among other treatments with a pollutant absorption capacity of 99.81%. Activation of activated charcoal using 15% NaOH produces the best absorption capacity compared to $CaCl_2$ and H_3PO_4 [15].

The aquaponics system of kale plants can help produce oxygen in the water which is produced from the plant's photosynthesis process. Supported by sugarcane bagasse adsorbent which is able to absorb pollutants in wastewater so that the availability of oxygen in the water increases which will have an impact on increasing the pH value in the water. This is as stated by Novita *et al.* [11], that the increase in pH in waters can be caused by dissolved oxygen levels in the water.

B. *Ammonia*

Ammonia is a chemical compound that is a factor in environmental pollution because its smell is very strong. The pungent odor of ammonia comes from microbial activity, waste processing and so on. Ammonia is easily soluble in water and is an organic compound that is important for the bacterial nitrification process in waters, namely ionized ammonia and non-ionized ammonia. Unionized ammonia is highly toxic so it can irritate the nerves of fish, while ionized ammonia has low toxic levels. The toxic power of ammonia in water will increase when oxygen solubility is low [16]. Ammonia test results on Fig. 4.

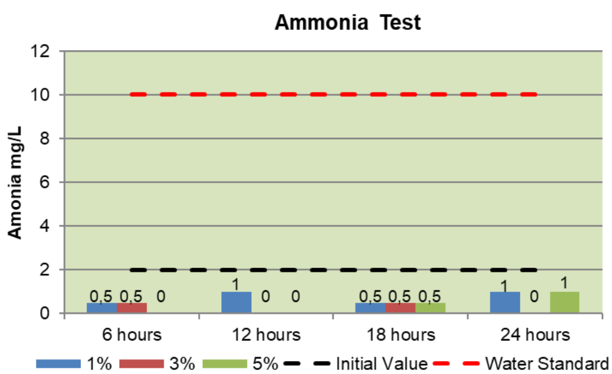

Fig. 4. Ammonia Test Result

The value of ammonia levels in sugar industrial waste is 2 mg/L, which indicates that sugar industrial waste meets the maximum ammonia limit so that nitrate contamination in it is relatively low. The best treatment results were with a processing time of 6 hours with an adsorbent concentration of 5% with an absorption efficiency of 100%. Meanwhile, the worst treatment was 48 hours with an adsorbent concentration of 5% with an absorption efficiency of 50%. According to Christiana *et al.* [17] ammonia content generally increases if it is contaminated with domestic and agricultural waste because ammonia is found in urea fertilizers and detergents. However, the ammonia content can decrease if a body of water contains a high dissolved oxygen (DO) content. So, ammonia content is usually not found in bodies of water that have an adequate supply of oxygen in the water.

C. TSS *(Total Suspended Solid)*

TSS is a water quality parameter to determine suspended solids in wastewater. The influence of variations in adsorbent mass and contact time for processing sugar industrial wastewater can be seen in Fig. 5.

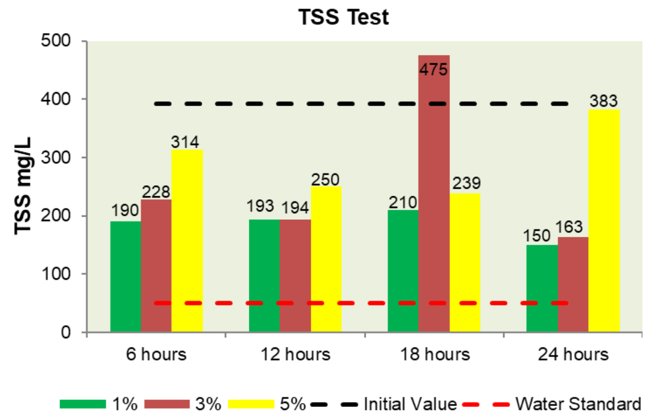

Fig. 5. TSS Test Results

The parameter test results for the TSS value in sugar industry wastewater were 392 mg/L. After processing wastewater with variations in adsorbent mass and processing contact time, it was able to reduce TSS levels. The best treatment results were obtained at a contact time of 48 hours with an adsorbent concentration of 1% with an absorption efficiency of 61.75%, while a contact time of 24 hours with an adsorbent concentration of 3% resulted in the lowest absorption efficiency, namely 17.47%. The TSS value in each wastewater always varies depending on the amount and quality of organic and inorganic materials in the form of sedimented particles, floating particles and colloidal suspended components [3].

Based on the 2014 Minister of Environment Regulation concerning wastewater quality standards, the maximum TSS value is 50 mg/L. The research results show that the resulting value is still outside the maximum limit that has been determined. The research results of Sahendra *et al.* [13] show that the adsorbent of cow dung and sugar cane bagasse with a ratio of 2% and 3% within a contact time of 4 hours produces a TSS content that does not comply with quality standards, this is because the adsorbent has not undergone complete deposition. So, there are materials that can be added to filter paper which can increase the TSS value. There is a possibility that the adsorbent used will experience a saturation period so that the suspended solids that have been absorbed can be released again [18].

The results are not in accordance with wastewater quality standards because the contact time for wastewater treatment is not long enough so that the absorption process does not take place optimally. This is supported by research by Ahmad and Adiningsih [19] showing that the TSS value before processing was 2,924.3 mg/L, after 1 week of contact time using the phytoremediation method with kale plants was able to reduce the TSS level to 114.8 mg/L. L with an absorption efficiency of 96%, but the TSS levels are still not in accordance with the 2014 Minister of Environment Regulation.

D. DO *(Dissolved Oxygen)*

Dissolved Oxygen is a parameter to determine the amount of dissolved oxygen in water originating from photosynthesis and atmospheric/air absorption. The greater the amount of DO, the better the water quality. DO concentrations below 5 ppm were found at station 2 with a DO value of 4.91 mg/L. The low DO value is due to the photosynthesis process by phytoplankton in the river bed being very low so that the dissolved oxygen levels in the water are low. This can affect the performance and survival of biological communities [20]. DO test results on sugar factory waste in Fig. 6.

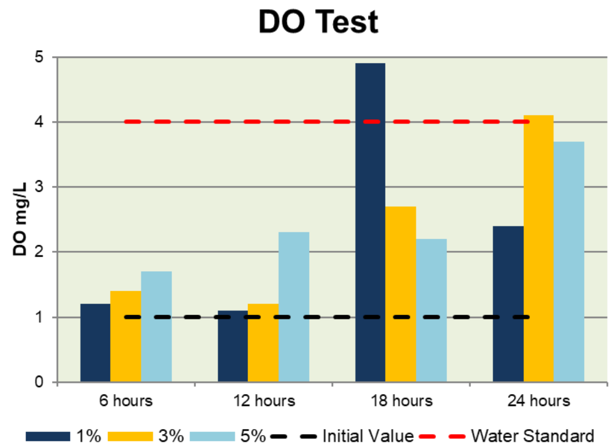

Fig. 6. *Dissolved Oxygen* Test Results

The resulting DO parameter values varied; the best results were obtained at 5% adsorbent mass with a contact time of 48 hours of 4.9 ppm with a DO increase efficiency of 39%. According to PP No. 82. of 2001 concerning water quality management and water pollution control, the best processing results fall into water quality category II which can be used for water recreation, preserving fresh fish, animal husbandry, water for irrigation, and other purposes that require high quality. The same. The lowest DO level is a 1% adsorbent mass formula with a contact time of 6 hours which produces a value of 2.01 ppm and is only able to increase the DO value by 10.1%, this value is included in water quality category IV which can be used for irrigation and other uses. which requires the same quality. Sugarcane bagasse adsorbent is able to reduce pollutant levels in sugar industry wastewater, by reducing contaminants it can increase DO levels in the water. The research results of [21] showed that the COD level in sugar wastewater before processing was 139671 mg/L, after processing with bagasse it resulted in an absorption efficiency of 75%.

According to the research results Effendi *et al.* [22], processing catfish farming wastewater using the phytoremediation method using water spinach produces DO levels of 3.19, at this concentration fish and plants can still live because the oxygen concentration is good for plants, namely 2.5 ppm. The existence of plants has an important role in providing oxygen by the photosynthesis process of plants. The oxygen produced will flow to the plant roots through the stem after diffusing through the leaf pores so that a rhizosphere zone rich in oxygen will be formed on the root surface. The release of oxygen in plant roots by this phytoremediation agent causes the water or media around the root hairs to have a higher dissolved oxygen content, thus creating a micro-habitat for anaerobic microorganisms to carry out the decomposition process [23].

E. COD (Chemical Oxygen Demand)

Chemical Oxygen Demand (COD) is the amount of oxygen (O_2) needed to oxidize organic substances in 1 liter of water, where oxidizing organic substances are in 1 liter of water. In measuring COD, the organic material is deliberately decomposed chemically using a strong oxidizer, potassium bichromate under acidic and hot conditions with a silver sulfate catalyst so that all types of organic material that are easily decomposed will be oxidized. COD test results with processing time and adsorbent concentration at Fig. 7.

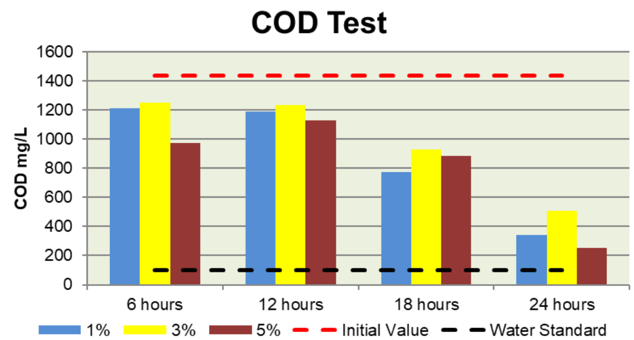

Fig. 7. Chemical Oxygen Demand Test Results

The results of parameter testing for the COD value in sugar industry wastewater were 1400 mg/L. Based on water quality standards in the 2014 Minister of Environment Regulation, the maximum COD value is 100 mg/L. After processing wastewater with variations in adsorbent mass and processing contact time, it was able to reduce COD levels. The best treatment results were obtained within 48 hours with a variation in adsorbent mass concentration of 5% with a value of 254 mg/L with an absorption efficiency of 81%. Meanwhile, the worst value results were at 6 hours with an adsorbent mass concentration of 3% with a value of 1254.5 mg/L with an absorption efficiency of 10%. The resulting research results are still above the standards of the 2014 Minister of Environment Regulation.

The research results by Halim *et al.* [24] show that variations in adsorbent concentration and length of contact time can increase the efficiency of absorbing pollutants in wastewater, 0.5 g mass of rice husk adsorbent with a contact time of 180 minutes produces a Cu metal absorption efficiency of 90.44% and when the adsorbent mass is increased to 2 gr with the same contact time it can increase the absorption efficiency to 96.46%. This is because the active side of adsorption increases along with increasing adsorbent mass. The absorption results are still not in accordance with the sugar wastewater quality standards, because the more absorbent used, the longer it will take to reach an equilibrium state.

This data is supported by the research results of Widiyanti *et al.* [25] that processing liquid wastewater from fish marketing depots using the phytoremediation method from water spinach plants within a contact time of 6 days produces a COD value of 64 mg/L with an absorption efficiency of 95.5%. The high reduction in dissolved substances is caused by the ability of the fibrous roots of the water spinach plant to retain particles and organic materials in the waste. The decrease in COD levels is directly proportional to the decrease in BOD levels, which indicates that the organic material contained in waste water is mostly organic material. Water spinach has a high growth rate, and its ability to directly absorb pollutants directly in wastewater. The roots become a place for filtration and adsorption of suspended solids and microbial growth that removes pollutants in sugar industry wastewater, so that COD levels in wastewater decrease [26].

F. BOD (Biological Oxygen Demand)

BOD is the amount of oxygen needed by microorganisms to degrade waste materials contained in waste water. The greater the BOD value indicates greater waste water pollution. The results of the BOD value test can be seen at Fig. 8

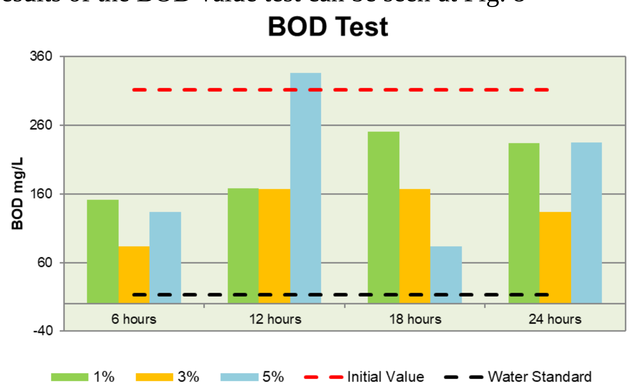

Fig. 8. Test Results Biological Oxygen Demand

BOD parameter test data shows that an adsorbent mass concentration of 3% with contact time for 6 hours produces the best BOD value, namely 83 mg/L with an absorption efficiency of 78.98% and this value is still not in accordance with the 2014 Minister of Environment Regulation on wastewater quality standards. The highest BOD value occurred at 5% adsorbent mass with a contact time of 12 hours, namely 336 mg/L. The adsorbent experienced saturation starting at 12 hours. The data showed that the BOD absorption value was getting weaker. BOD does not indicate the actual amount of organic material but only measures the relative amount of oxygen needed so that if the BOD value is large, it can be a reference that the pollution in the wastewater is also large.

The research results by Sahendra *et al.* [13] show that the adsorbent mass of cow dung and sugar cane bagasse as much as 2% with a contact time of 4 hours can increase the BOD value in wastewater, the saturation point of the adsorbent occurs when it enters a contact time of 1 hour and the absorption results are not suitable with the Minister of Environment Regulation of 2014 concerning waste water quality standards. This is supported by the research results of Dayani *et al.* [27] that adsorbents from tofu dregs have the best effectiveness in reducing iron and manganese levels at a contact time of 60 minutes, after reaching a contact time of 90 minutes it decreases due to the re-release of the adsorbate (desorption). In another study, it was stated that a saturated adsorbate surface can cause desorption, where the contact time no longer has an effect because the adsorption rate decreases in the saturated state [28].

The presence of water spinach plants helps in the process of absorbing pollutants in sugar industry wastewater. The research results by Wahyuningsih *et al.* [29] showed that 200 grams of water kale was able to reduce BOD levels to 146.08 mg/L within a contact time of 16 days with an efficiency level of 81.13%. Sugar industry wastewater contains a lot of biodegradable organic material which is a source of nutrition for microbes which are then converted into simpler compounds. The presence of rhizosphere microbes in plant roots breaks down organic substances, this is high BOD5. The process of reducing pollutants in liquid waste using aquatic plants is a collaboration between plants and microbes that reside in these plants [30].

The decrease in BOD content in kale plants occurs because the microorganisms in the roots absorb organic pollutants. The more microorganisms there are in the roots, the better the plant's ability to absorb and adapt to the surrounding environment [11].

IV. CONCLUSION

Based on the research that has been carried out, it can be concluded that the concentration of sugar cane bagasse adsorbent, the deposition time of the adsorbent in sugar industry wastewater and the effectiveness of absorbing pollutants by the aquaponic system can have an impact in the form of reducing the existing parameters of pH, TSS, Ammonia, DO, COD and BOD. in sugar wastewater, so it can be concluded that the use of sugarcane bagasse adsorbent in combination with an aquaponic system can be effective in reducing wastewater pollution.

V. SUGGESTION

Based on the conclusions obtained, suggestions can be given for further research is increasing the deposition time of adsorbents in liquid waste from the sugar industry with the aim of finding out the optimal time for adsorbents to reduce pollution caused by sugar wastewater.

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