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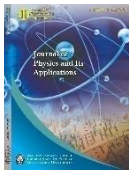

Development of Sasirangan Liquid Waste Treatment System Using Ozonization Method Using Composite Ceramic Filter Media Based on Water Chestnut (*Eleocharis Dulcis*)

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A B S T R A C T

Sasirangan Liquid Waste (SLW) contains heavy metals and chemicals with BOD and COD concentrations exceeding the waste water quality standards in accordance with the Minister of Environment and Forestry Regulation Number P.16 of 2019. The aim of this research is to design and develop a SLW processing system using filter media and composite ceramics made from water chestnut (Eleocharis dulcis). Based on previous research, using the filtration method; filtration and adsorption; filtration, adsorption, sedimentation and ozonization. Filtration method can remove solid particles and sediment from water, so the water appears clearer. The water purification process that involves a filtration method using slow sand filter (SSF), which additional processes are needed either before or after the SSF is carried out. Meanwhile, the use of water chestnut has been carried out by several researchers due to its high active carbon content, namely 50.68%. In this research, we combine several methods including filtration, sedimentation, and ozonization. Water chestnut has a bound carbon content of 84.53% after being activated with an H_2SO_4 activator, where the largest porosity is found in ceramics with activated charcoal composite materials with variations of the H_2SO_4 activator. Apart from that, chestnut also has a cellulose content of 35.32% so it has the potential to be effective as a ceramic composite material in sasirangan liquid waste processing filters, especially as an adsorbent. The benefits obtained from the results of this research can be a scientific reference for the use of water chestnut as a filter media and composite ceramic.

1. Introduction

Sasirangan is a typical South Kalimantan (Kalsel) cloth produced by most of the people of Banjarmasin city, especially in Kampung Sasirangan. Based on data from the South Kalimantan Province Industry and Trade Service, in 2017, there were 170 sasirangan industrial business units established in several cities/regencies in South Kalimantan [1]. The making of sasirangan cloth uses synthetic dyes, resulting in liquid waste that is deep colored and contains dangerous chemicals that pollute the environment [2]. The resulting Sasirangan liquid waste (SLW) is disposed directly into water bodies without prior processing, even though rivers are an important part of the lives of the people of Banjarmasin City [3]. The status of river water quality in South Kalimantan is classified as heavily polluted, especially for Martapura River and Barito River. The highest concentrations of BOD and COD in Martapura river water are 19.2 mg/l and 34.2 mg/l respectively, with a quality standard threshold of 2 mg/l [4].

If this pollution is not addressed as early as possible, the quality of water will continue to decline. One alternative to overcome this problem is to develop an SLW processing system using filter media and composite ceramic based on water chestnut (*Eleocharis dulcis*). South Kalimantan has swamp land covering an area of ±1,140,207 hectares, with one of its typical plants being water chestnut. This plant has hyperaccumulator properties, which have high absorption capacity, so that it can act as an adsorbent and reduce the level of pollutants. Water chestnut is a type of biomass that can be used as material for making active carbon because of its high carbon content. The physical properties and mechanical properties of water chestnut can also be used as a composite matrix material [5].

The utilization of natural materials in water treatment processes is garnering increasing attention due to its potential for sustainable and environmentally friendly solutions. Several studies have applied the use of "Water Chestnut" (Eleocharis dulcis) in treatment systems. Water Chestnut is employed as a layer in a slow sand filter. Slow sand filtration is a method used for water purification, renowned for its efficiency in removing impurities. With its unique structural and chemical properties, water chestnut presents an intriguing prospect for enhancing the filtration process. This research aims to investigate the feasibility of water chestnut as a filter medium, assess its performance in purifying water, and provide valuable insights into the field of eco-friendly water treatment. The exploration of natural materials like this holds the potential to advance sustainable practices in water management systems. The processing of liquid waste with SSF consisted of several layers of coarse aggregate and fine aggregate, and is combined with the use of water chestnut plants as an effort to reduce pollutant concentrations. The high-activated carbon content of purun tikus also proves effective as a composite material for ceramic filters. As the demand for efficient water treatment solutions continues to rise, exploring natural resources such as purun tikus for innovative applications in SLW treatment [5].

The treatment of Sasirangan textile waste involves a comprehensive series of processes, necessitating both primary and secondary treatment stages. Primary treatment serves as the initial step in mitigating the environmental impact, while secondary treatment further refines the effluent, ensuring that it meets the necessary quality standards before being released into water bodies. The complexity of the textile waste composition underscores the importance of a thorough and multi-step treatment process to safeguard the aquatic ecosystem and comply with environmental regulations. Related research has been carried out by several previous researchers, namely using the filtration method [6]; filtration and adsorption [7]; filtration, adsorption, and sedimentation [8]; and Ozonization [9]. The use of filtration can remove solid particles and sediment from the water, so the water appears clearer. The water purification process that involves a filtration method using sand is known as slow sand filter (SSF), a water treatment system that cannot stand alone in its purification, so additional processes are needed either before or after the SSF is carried out [8]. Advanced SLW processing can use the ozonization method which aims to meet the BOD and COD requirements of wastewater where the chemical properties of ozone is effectively working in an alkaline environment (pH>7). The color removal of liquid waste from the Sasirangan textile industry, in the ozonization process at pH 8 and a contact time of 60 minutes, achieved an efficiency level for reducing color parameters of 95.36%. This showed the effectiveness of ozonization in reducing color parameters and filtering heavy metals, so it is suitable to be applied to liquid waste from the Sasirangan industry [10].

Based on the Minister of Environment and Forestry Regulation Number P.16 of 2019 concerning Waste Water Quality Standards, including the parameters pH, color, COD, BOD, and TSS which are targets in SLW processing. This research aimed to analyze the effectiveness and capability of the SLW processing system with a combination of filtration, sedimentation, and ozonization methods as well as the use of water chestnut and activated carbon of water chestnut in SSF constituents.

2. Research Method

Tools and Materials

The tools and materials used in this research included water chestnut, distilled water, 1N H_2SO_4 grade, 72% H_2SO_4, KOH powder, kaolin powder, fine sand, aggregate, clay, PVC pipe, PVA glue, filter paper, gallon, label paper, beaker glass, latex gloves, ozone generator capacity 2000 mg/H, funnel, stir bar, digital balance, hotplate, furnace, oven, water bath, pH paper meters, printing equipment, hydraulic press, 100 mesh sieve.

3. Research Stages

Sampling of Water Chestnut and SLW

Water chestnut samples were taken in the Guntung Manggis area, Landasan Ulin District, Banjarbaru, South Kalimantan. 20 Liters SLW sample were taken by the industrial container at Kampung Sasirangan Industry, Jl. Sungai Jingah, North Banjarmasin District, Banjarmasin.

Preparation and Characterization of Water Chestnut and SLW

Water chestnuts were washed, then dried for ±7 days in sunlight and stored in a closed room. The water chestnuts used as a constituent layer of the filter was cut ±50 cm. Water chestnuts samples used for testing the characterization of cellulose and activated carbon content were cut ±3–4 cm, crushed, and sieved with a 100 mesh size.

Preparation and Characterization of Water Chestnut Cellulose Content

As much as 1 gram of water chestnut sample was added with distilled water and refluxed at 100°C using a water bath for 1 hour, filtered, and washed again with hot water, dried at 80°C for 45 minutes until the weight was constant. The residue was added with 1N H_2SO_4, then refluxed for 1 hour at a temperature of 100°C. The results were filtered until neutral using distilled water and dried at 80°C for 45 minutes. The dry residue was soaked in 72% H_2SO_4 at room temperature for 4 hours, then 1N H_2SO_4 was added and refluxed for 1 hour. The residue obtained was filtered and washed until neutral and then dried at 105°C for 30 minutes.

Preparation for Making Activated Carbon of Water Chestnut

Water chestnut powder was carbonized at 500°C for 15 minutes. The charcoal was sieved with a size of 100 mesh, then activated using 1N H_2SO_4 and 1N KOH by soaking for 18-24 hours. The charcoal was washed until the pH was neutral and dried at a temperature of 50°C-110°C.

SLW Sample Preparation and Characterization

The SLW samples were placed in a container and closed room that was not exposed to sunlight. SLW samples were characterized at the South Kalimantan Provincial Health Laboratory in Banjarmasin with the parameters of color, temperature, Total Suspended Solid (TSS), pH, Biological Oxygen Demand (BOD), and Chemical Oxygen Demand (COD).

Characterization Test of Water Chestnut Fiber and Activated Carbon of Water Chestnut
Calculation of the characteristics of the activated carbon contained in the water chestnut was in accordance with the provisions in Table 1.

Table 1. Requirements for Activated Carbon

Content	Quality Requirements	
Water Content	Max. 15 %	SNI 06 3730-1995 Activated Charcoal
Bound Carbon Content	Min. 65 %	
Ash Content	Max. 10%	
Volatile Content	Max. 25%	

Making of Composite Ceramics
The raw materials for making composite ceramics were water chestnut fiber or 20% activated charcoal, 45% clay, 5% PVA glue, and 30% kaolin. The ingredients were mixed with distilled water in a ratio of 2:3 and homogenized. The ceramic dough was dried using a hotplate with temperature steps up to 200°C. The dough was molded using a 4 ton pressure hydraulic press and dried at a temperature of 100°C for 30 minutes, then sintered at a temperature of 200°C for 10 minutes. Ceramics were made using a variety of matrices in the form of water chestnut fiber, water chestnut activated charcoal with KOH activator, and water chestnut activated charcoal with H_2SO_4 activator.

Ceramic Porosity Test
The porosity test followed the method carried out [10], by immersing the ceramic composite in water for 10 hours at room temperature and pressure. After immersion, the mass of the sample was weighed. The data obtained from the test was in the form of wet mass and dry mass, then porosity calculations were carried out.

$$porosity = \frac{\rho_2 - \rho_1}{\rho_1} \times 100\% \quad (1)$$

where ρ_1 is the density of the dry sample (g/cm^3) and ρ_2 is the density of the wet sample (g/cm^3).

Ozonization Treatment
Ozonization followed the method used [11], using a reactor in the form of an ozone generator. The equipment used was an ozone generator with a capacity of 2000 mg/hour. Ozonization has used a strong oxidant that can decompose numerous pollutants and colors from sasirangan wastewater. Studies by other research that has been carried out regarding the effectiveness of ozonization in reducing color parameter, has shown that O_3 in ozonization can decolorization for dye in textile wastewater approacing 87% reduced [12]. Based on that research ozonization was carried out with variations in contact time of 0, 30, and 60 minutes. The following is a picture of the ozone generator used in this research.

Fig 1. Ozone generator with a usage capacity of 2000 mg/H.

Construction of an SLW Processing System
Construction of the SLW processing system in the form of a series of systems consisting of filters for the filtration process with an SSF system followed by sedimentation and ozonization processes. The filter was made following the research conducted [5]. The layers consisted of dry water chestnut, fine sand, coarse aggregate, and ceramic composite. The next series was the sedimentation process in the sedimentation tank which aimed to settle particles that were not filtered during the filtration process and were carried to the sedimentation tank. The sasirangan liquid waste processing system was made with the design shown in Figure 2.

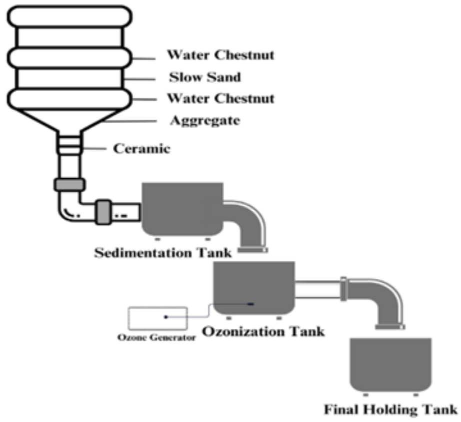

Fig 2. SLW processing system design (a) the first container for filtration uses a used gallon and all the materials arranged in the gallon with the volume of 19L are arranged with a thickness of around 5 cm per material. (b) the second container for sedimentation uses a used gallon that has been cut in half and connected to a pipe from the filtration container. (c) the third container uses a used gallon that has been cut in half and is connected to a pipe from the sedimentation container, the ozone generator is placed at the bottom of the container and the connecting hose is placed in the hole that has been made in the body of the container to facilitate the ozonization process. (d) the last container also uses a used gallon that has been cut in half and connected to a pipe from the ozonization container.

5. Results and Discussion

SLW Characterization

Testing on SLW aimed to determine the characteristics in the form of chemical and physical components of the waste. Physical components included temperature, color, and Total Suspended Solid (TSS). Chemical components were in the form of pH, Biological Oxygen Demand (BOD), and Chemical Oxygen Demand (COD).

Table 2. SLW quality before processing

No	Parameters	Unit	Research Result	Khair et al., (2021)	Wibawati et al., (2018)	Minister of Environment and Forestry Regulation No. P.16
1.	Color	TCU	770,0	4928	-	200
2.	TSS	Mg/L	108,5	-	578	50
3.	pH	-	11,28	11	9,5	6 – 9
4.	BOD_5	Mg/L	636,98	-	2.400	60
5.	COD	Mg/L	1356,9	5192	3.247,4	150

Based on the test results, it was found that the parameters exceeded the quality standards, such as Color, TSS, pH, BOD_5 and COD parameters when compared with previous research and in the Minister of Environment and Forestry Regulation no. p16 of 2019 concerning Wastewater Quality Standards for Textile Industry Businesses and/or Activities, the sasirangan waste taken as a sample for this research is included in high content concentration levels and can cause negative impacts on the environment and must be reduced so that in the future it does not harm the environment. The following is a picture of the SLW sample being tested.

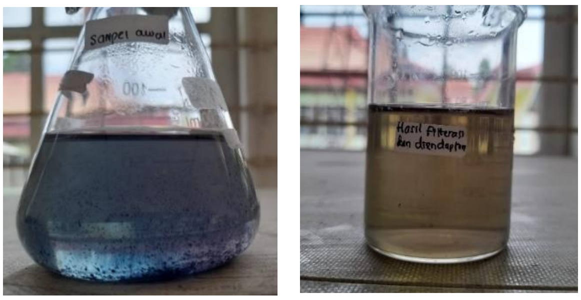

Fig 3. and 4. SLW initial sample before processing in the left and after processing in the right.

The high color content produced from liquid textile waste is caused by the presence of dissolved, suspended particles and colloidal compounds [13]. The TSS value in SLW is high due to the presence of solids in wastewater in the form of suspension or solution, as well as contaminants that make the water cloudy. The level of pollution can also be seen from the increasingly high BOD and COD values, which indicate that liquid waste contains a lot of synthetic organic materials originating from dyes and detergents in the process of sasirangan cloth production. This also causes the processed waste to become alkaline and the pH to become high [14].

Characterization of Water Chestnut Cellulose Content

This test was done to determine the cellulose content of water chestnut, so as to obtain the optimal composite material to be used as an adsorbent to reduce pollutant content in SLW. Based on the test results, the cellulose content was 35.32%. The higher the cellulose content obtained, the more efficient the material is to be used as activated charcoal in absorbing heavy metals [15]. This indicated that water chestnut is effective as a composite ceramic material and a constituent material for filters.

Test Results of Water Chestnut Fiber and Activated Carbon of Water Chestnut Characteristics

Water chestnut is a biomass that contains high levels of lignocellulosic compounds, so it can be used as raw material for activated carbon with a variety of activators because it has a high carbon content [16]. Making activated carbon of water chestnut requires a strong acid (H_2SO_4) and strong base (KOH) activator based on the SNI 06-3730-1995 method regarding technical activated charcoal.

Table 3. Test Results of Water Chestnut Characteristics

reatment	Activator Type	Water Content (%)	Ash Content (%)	Volatile Content (%)	Bound Carbon (%)
SNI 06-3730-1995	-	Max 25%	Max 10%	Max 15%	Min 65%
Water Chesnut Before Carbonization	-	4,41 %	21,78 %	18,97 %	74,61 %
Water Chesnut After Carbonization	KOH	4,71 %	7,55 %	10,74 %	81,71 %
Water Chesnut After Carbonization	H_2SO_4	4,46 %	9,49 %	5,98 %	84,53 %

Based on the tests carried out on 3 variations of treatment for Water Chestnut, including water chestnut, activated carbon of water chestnut using KOH, and activated carbon of water chestnut using H_2SO_4.The highest bound carbon content was found in the H_2SO_4 activator activated carbon variation, namely 84.53%. Acid activators are more capable of causing complex damage to H_2O and providing a dehydration effect, so the water content is smaller than when using base activators [16]. This was proven by the results of testing the water content of KOH activator activated carbon which had the highest value, namely 4.71%, compared to the water content of H_2SO_4 activated carbon, which was 4.46%. The ash content in the water chestnut before carbonization, namely 21.78%, was higher than the ash content of other variations after carbonization. The resulting high water content and ash content are related to the trapping of minerals and water into carbon pores [16].

According to research conducted by Negara et al. (2022), carbonization is intended to minimize volatile levels and convert raw materials into charcoal with a high bound carbon content. This was proven by the test results that the volatile levels before carbonization decreased after going through the carbonization process and the volatile levels were at the lowest value, namely 5.98%, with the H_2SO_4 activator. The value of bound carbon content before carbonization also increased, namely with a very high bound carbon content of 84.53% with the H_2SO_4 activator. The carbonization and activation processes can make organic molecules unstable, breaking the bonds between the molecules, causing the volatile matter in the material to become gas and liquid products, resulting in higher levels of bound carbon [16].

Test Results of Ceramic Porosity for Filters and Adsorbents

Porosity tests were carried out on ceramics to determine the percentage of the total pore volume that the ceramic has [17]. Tests were carried out on 3 types of ceramic samples as shown in Table 3.

Table. 4: Test Results of Ceramic Porosity

Ceramic type	Mass Before Immersion (M1)	Mass After Immersion (M2)	Porosity (%)
Water Chesnut Powder	6,24	8,47	35,88 %
Activated Carbon Activation KOH	6,46	10,31	59,74 %
Activated Carbon Activation H_2SO_4	6,67	9,55	43,07 %

Based on the test results obtained, ceramics using water chestnut fiber have a lower porosity level, namely 35.88%, when compared to ceramics using activated carbon of water chestnut, as in the tested ceramics in the following picture:

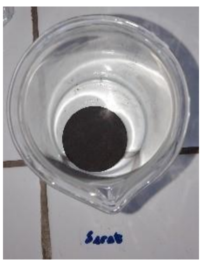

Fig. 5: Fiber-based Ceramics after porosity test.

Fig 6. Water Chestnut Activated Charcoal (KOH)-based ceramics after porosity test

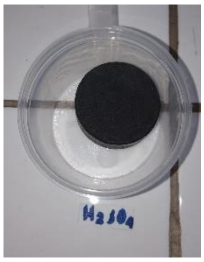

Fig 7. Water Chestnut Activated Charcoal (KOH)-based ceramics after porosity test

Fig 8. Water Result after Porosity Test for 10 hours

According to Negara et al. (2022), the activation process is needed to remove tar deposits, so that existing porosity can be increased. Tar deposits were removed during the porosity process and the opening of basic pores formed during pyrolysis. Development of new pores and widening of existing pores were done so that activated carbon with a high level of porosity will be produced. Based on porosity testing, the most optimal matrix for ceramic filters and adsorbents is activated carbon activator H_2SO_4. This is because the ceramic filter with a KOH activator activated carbon matrix has alkaline properties, so it is easily soluble in water and strong bases can be completely ionized.

Results of Ozonization Treatment

The ozonization process is a chemical water treatment process that involves ozone by utilizing an ozone generator. Ozonization is carried out as the final stage in the water treatment system [8]. Ozonization treatment was done using time variations of 0 minutes (0 mg/h), 30 minutes (1.000 mg/h) and 60 minutes (2.000 mg/h). The results of the ozonization process test can be seen in the following graph.

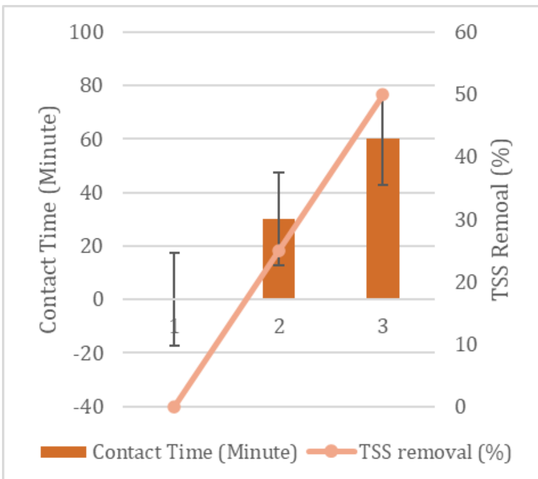

Fig 9. Allowance of TSS Value

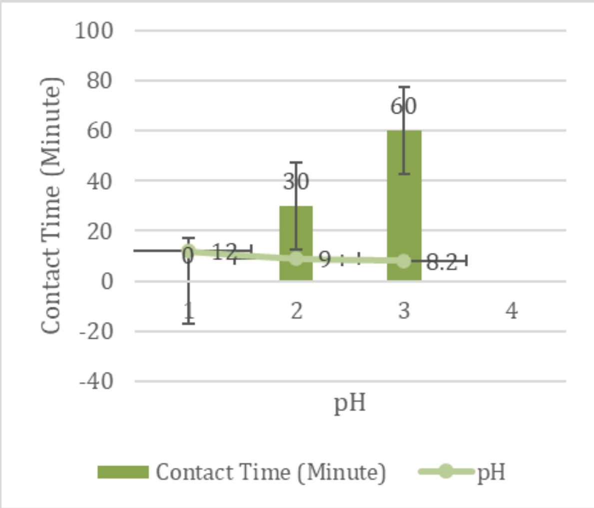

Fig 10. pH Reduction

TSS are suspended solids found in SLW. Based on research, waste processing using the ozonization method shows a reduction in TSS towards more efficient quality standards[9]. Waste processing using the ozonization method can reduce the pH value from pH 12 to pH 7. If the removal percentage is calculated, ozonization with a contact time of 30 minutes can remove TSS by 80% and a contact time of 60 minutes can remove TSS by 90%. Ozonization reduces Total Suspended Solids (TSS) by causing coagulation and flocculation of particles, making them easier to settle or filter out. It also oxidizes organic and inorganic substances, contributing to the breakdown of suspended solids. Regarding pH reduction, ozonization can lead to a decrease in pH due to the formation of acidic byproducts during the ozonization process. This may involve the conversion of organic matter into organic acids, leading to a lowering of the overall pH.

Final Analysis Results of SLW Processing Results

The final analysis of the SLW was carried out after the SLW had gone through a series of liquid waste processing systems using filtration, sedimentation, and ozonization methods. The analyzed parameters must comply with the quality standards contained in Minister of Environment and Forestry Regulation No. P.16 of 2019 [18], as seen in the table.

Table. 5: SLW Final Results after Processing with System

No.	Parameters	Unit	Result SLW Characteristic (Before)	Result SLW Characteristic (After)	Removal Efficiency
1.	Color	TCU	770,0	123,0	84,02%
2.	TSS	Mg/L	108,5	50,0	53,92%
3.	pH	-	11,28	8,27	26,68%
4.	BOD_5	Mg/L	636,98	122,9	80,71%
5.	COD	Mg/L	1356,9	269,6	80,13%

Based on research that has been conducted regarding the effectiveness of the SLW processing system, the combination method of filtration, sedimentation and ozonization processes with a contact time of 60 minutes has a color removal efficiency of 84,02%, a TSS removal efficiency of 53,92%, a BOD_5 removal efficiency of 80,71%, COD removal efficiency of 80.13% and pH reduction of 8,27.

Fig. 11: SLW after Filtration containing dissolved solid that causes the water has cloudy appearance.

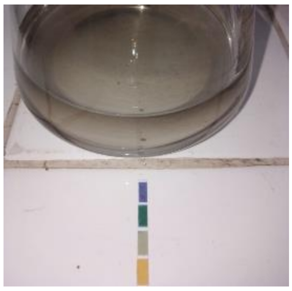

Fig. 12: SLW after filtration with the pH of 9

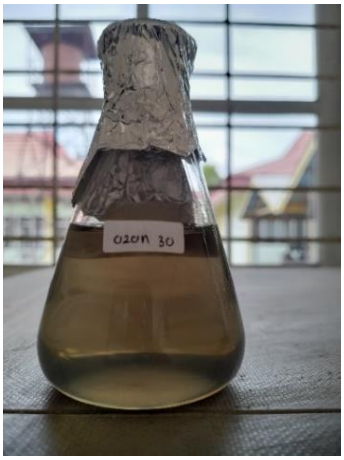

Fig. 13: SLW after 30 minutes ozonization with the pH of 8,5. The water still appears cloudy.

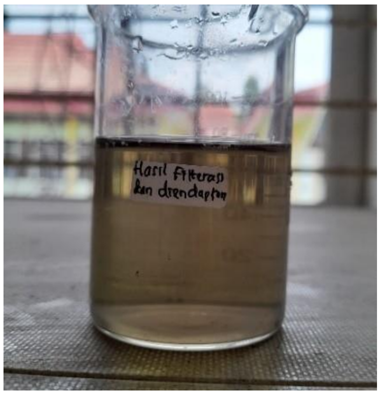

Fig.14: SLW after 1 hour ozonization with the pH of 8,27. The water appears clearer than before.

Fig. 15: Prototype of SLW processing system.

Based on the research that has been carried out regarding the effectiveness of the SLW processing system, the combination method of filtration, sedimentation, and ozonization processes with a contact time of 30 minutes had a TSS removal efficiency of 80% and a decrease in pH to 7. Treatment variations were also carried out by increasing the contact time in the ozonization process to 60 minutes and a TSS removal efficiency of 90% was obtained. This was because the longer the contact time for the ozonization process, the more O_3 that is formed, so the organic compounds that consumes dissolved oxygen will be less in quantity [11].

Conclusion

The results of this research show that LCS has a color of 123 TCU; has a TSS of 50 mg/L; has a pH of 8.27 or close to neutral; has BOD5 of 122.9 mg/L; has a COD of 269.6 mgL. The optimal conditions of the CSF processing system series were obtained after filtration (pH: 9) and settling for 3.5 hours (pH: 8.5) then ozonization was carried out for 60 minutes (pH: 8.27). The efficiency of combining filtration, sedimentation and ozonization methods for the five parameters is able to remove 84.02% color content: 53.92% TSS content; 26.68% pH level: 71% BOD_5 level; 80.13% COD content.

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