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A Design of "SWAFT" Technology for Separation of Fe, Pb, and Cu Metal Waste in Deli River Water Medan (Based on Coagulation-Adsorption Using Activated Carbon from Rice Husks and Aloe Vera Coagulant)

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ABSTRACT

The increase in population has influenced the rising water demand, and one way to meet this demand is by utilizing river water. Deli River is one of the rivers that flow through the city of Medan. The development of industries and settlements along the Deli River has affected its water quality due to heavy metal waste, specifically Fe, Pb, and Cu. This is evident from the deterioration of water quality characterized by changes in color and odor. One solution to address this issue is by using rice husk-activated carbon as an adsorbent and aloe vera as a bio-coagulant. Rice husk contains cellulose which can be converted into carbon and has a carbon content of 48.9%, while aloe vera contains mucilage which is an active coagulant used for water clarification. The principle used in this product is coagulation, which involves mixing chemicals, such as coagulants, with Deli River water followed by the adsorption process, where metal particles accumulate on the surface of the adsorbent. The results obtained showed a decrease in the parameters of Fe, Pb, and Cu metal content successively by 0.0092 mg/liter; 0.0081 mg/liter, and 0.0072 mg/liter. Thus, the filtered water meets the clean water quality standards set by Government Regulation No. 82 of 2001. Based on the existing problems and potentials, this product becomes a smart solution to assist the community, especially those in riverside areas, in water treatment and also addresses the challenges in preparing human resources that are actualized in facing the era 5.0 revolution.

Keywords: Activated Carbon, Aloe Vera, Bio-coagulant, Deli River Water, Metals, Rice Husk

I. INTRODUCTION

The increase in population directly correlates with the escalating demand for clean water for daily needs, including sanitation requirements that generate wastewater. Human activities stemming from agriculture, industry, and household endeavors contribute to the degradation of river water quality. Consequently, land use changes and the increasingly diverse urban lifestyle patterns result in a growing volume of domestic waste over time. The decline in water quality occurs due to uncontrolled waste disposal from development activities along the river, thus exceeding the river's carrying capacity.

Deli River originates from Karo Regency, passes through Deli Serdang Regency, and traverses Medan City with a length of 73 km. The Deli River basin is one of the critical areas in North Sumatra requiring prioritized intervention as a target for rehabilitation. The designation of the Deli River basin as critical is due to nearly half of its total area being classified as critical land, significantly impacting the conservation of land and water resources.

This is primarily due to the dominant land use for residential, office, and industrial purposes (Harahap, 2018)

The Deli River has been contaminated by hazardous heavy metals due to several industries in its basin utilizing materials containing heavy metals in their production processes, such as metal goods manufacturing, plastics, and rubber industries. The polluted river conditions result in stunted and withered vegetation along its banks, and aquatic animals like fish struggle to survive. Moreover, consuming fish from the river poses health risks to humans due to the accumulation of metal pollutants in their flesh (Rini, 2016).

One of the alternative methods for treating the poor water quality of the Deli River is by utilizing two methods: coagulation and adsorption. Coagulation is a chemical process used in surface water treatment. It involves mixing a chemical coagulant with raw water to form a homogeneous mixture. The main goal of coagulation is to evenly distribute the coagulant to form flocs, which are clumps of suspended solids generated during the coagulation process. Once flocs are formed, they are separated from the coagulated water. On the other hand, adsorption is the accumulation of particles on a surface. The particles accumulated and absorbed on the surface are called adsorbate, and the material where adsorption occurs is called adsorbent or substrate. In this study, a filter is created using rice husk waste material transformed into activated carbon using a heating method at specific activation temperatures. Additionally, aloe vera is used as a raw material, which is transformed into gel.

Activated carbon, also known as activated charcoal, is a type of carbon that has been treated with steam and heat until it develops a strong affinity for absorbing various substances. Activated carbon possesses a remarkably large surface area, ranging from 300 to 2500 m^2/g, and can be used to adsorb nearly all types of organic solvents at temperatures around 35 °C. Activation is a treatment applied to charcoal aimed at enlarging its pores by breaking hydrocarbon bonds or oxidizing surface molecules, resulting in a change in its properties, both physical and chemical, such as an increase in surface area, which significantly affects its adsorption capacity (Legiso, 2019).

The rice husk is the outermost layer of rice grains, which is a byproduct obtained during the rice milling process. About 20% of the weight of rice is rice husk, and approximately 15% of the composition of rice husk is rice husk ash, which is consistently produced each time the rice husk is burned. Rice husk is composed of cellulose fiber tissues containing a high amount of silica in the form of very hard fibers (Rohmah, 2014). The composition and quantity of rice husk content can be seen in Table 1.

Table 1. Composition of Rice Husk Content and Quantity

No.	Component	Composition (%)
1	Water	9.02
2	Crude protein	3.27
3	Fat	1.18
4	Carbohydrate	33.71
5	Crude Fiber	35.68
6	Ash	17.71

Rice is an essential food crop crucial for sustenance as it is a primary producer of rice, the staple food in Indonesia. Rice serves as a staple food source experiencing an annual increase in demand due to the continuous population growth. The data on rice production in North Sumatra can be observed in Table 2.

Table 2. Rice Production Quantity in North Sumatra from 2018-2021 according to the Central Statistics Agency (BPS)

No.	Year	Ton

1	2018	2,108,284
2	2019	2,078,901
3	2020	2,040,500
4	2021	2,074,855

The coagulation method is a chemical process used in surface water treatment. Coagulation involves mixing a chemical coagulant with raw water to form a homogeneous mixture. The primary objective of coagulation is to evenly distribute the coagulant to form flocs. Flocs are clumps of mud generated during the coagulation process. Once flocs are formed, they are separated from the coagulated water. In the coagulation-flocculation process, synthetic coagulants and flocculants are commonly used. The usual coagulant employed is alum. However, the use of alum still has drawbacks as its process is too complex and requires high costs. Moreover, water treatment using synthetic substances impacts human health. The use of natural coagulants is expected to reduce treatment costs and minimize environmental impacts caused by the use of synthetic substances that produce side effects during their application. Aloe vera is one of the alternatives to synthetic coagulants. This is because aloe vera contains mucilage or gel, similar to cactus plants, which have been proven to clarify water. The selection of aloe vera as a bio-coagulant is due to its low cost compared to synthetic coagulants. Additionally, the relatively small-scale production of aloe vera allows for further development, potentially yielding other benefits aside from its medicinal properties (Mujariah, 2016).

Table 3. The amount of Aloe Vera Production in North Sumatra from 2017-2020 according to the Central Statistics Agency (BPS)

No.	Year	Kg
1	2017	928
2	2018	958
3	2019	4,437
4	2020	1,940

II. METHODS

Equipment and Materials Used

The main raw materials used are rice husks obtained from the rice milling process in North Sumatra and aloe vera obtained from plant cultivation. Additionally, the raw materials used include distilled water (H_2O), KOH solution, salicylic acid, and samples of Deli River water collected from Medan City, North Sumatra. The equipment used includes a furnace, oven, digital scale, filter paper, water sample container, blender, magnetic stirrer, measuring glass, beaker glass, and Erlenmeyer flask.

Experimental Method

Water Sampling

In this study, samples of Deli River water were collected from a location near Letjen Suprapto Street. The sampling location is situated not far from the bridge. The coordinates of the sampling location are 3°34'49.1" N 98°40'51.0" E. Sampling was conducted at one point on the surface of the water, manually. Manual sampling is suitable for instantaneous sampling at specific points and for a small number of samples. The water sampling process adheres to the Indonesian National Standard (SNI) 03-7016-2004 regarding procedures for water quality sampling in a river basin.

Preparation of Rice Husk-Activated Carbon

The process of making activated carbon using rice husks as raw material is as follows:

1. Cleaned rice husks are dried and finely ground using a blender, then weighed to 150 grams.
2. The raw material is soaked in a 10% KOH concentration for 2 hours at a temperature of 100 °C on a magnetic stirrer.
3. After soaking in the KOH solution, the sample is placed and heated in a furnace at a temperature of 600 °C for the optimal time of 90 minutes.
4. The resulting activated carbon is then cooled to room temperature.
5. The activated carbon is washed with boiling distilled water until reaching a pH of 6-7.

Preparation of Aloe Vera Bio-coagulant

The raw material used is aloe vera, harvested and stored at room temperature for 2-3 days. Then, the aloe vera is washed with water to remove any attached impurities. Next, the outer skin of the aloe vera is peeled off, and the inner flesh is cut into smaller pieces. The inner flesh of the aloe vera is blended into a pulp using a blender. The pulp is then strained to obtain aloe vera gel. Subsequently, the obtained aloe vera gel is mixed with salicylic acid preservative and stored in a clean, dry container.

Explain the chronology of research, including research methods, research design, research procedures (in the form of algorithms, flow charts, storyboards, or others), time and place of research (if the article is based on field research), population, research sample, data collection techniques, data analysis techniques, state the hypothesis if your article contains one (optional). The description of the research process should be supported by references so that the explanation can be accepted scientifically.

Metal Content Separation Process from Deli River Water

In the first stage, 2 liters of Deli River water samples are placed into four Erlenmeyer flasks. Then, 0.3 ml of aloe vera gel is added to each water sample. The addition of 0.3 ml of aloe vera is determined to be the optimal amount. Subsequently, the aloe vera and Deli River water samples are stirred using a magnetic stirrer at a speed of 120 rpm for 1 minute, then the speed is reduced to 30 rpm for 20 minutes. The mixture is left to stand for approximately 30 minutes. After flocs are formed and settle at the bottom, the Deli River water sample is separated from the flocs. The process then proceeds to the second stage, which involves separating the metal content using activated carbon. To separate the metal content, a container containing activated carbon is used to filter the Deli River water sample, resulting in a decrease in metal content in the water sample.

III. RESULTS AND DISCUSSION

SWAFT Filter Mechanism

The SWAFT technology utilizes two methods to separate metal content in Deli River water: coagulation and adsorption. In the coagulation method, Deli River water samples are treated with aloe vera gel and stirred at a specific speed to form flocs. Flocs are clumps of mud generated during the coagulation process. A magnetic stirrer is used for stirring as the technology is still in the laboratory testing phase. Once flocs are formed, they are separated from the coagulated water. The second stage involves separation using activated carbon made from rice husks through the adsorption method. In the adsorption method, the coagulated Deli River water sample is passed directly through a container filled with activated carbon. In this condition, the coagulated water passes through the pores of the rice husk-based activated carbon filter material. Rice husks possess dehydration properties (releasing H_2O molecules) that selectively adsorb metal elements. The purpose of using two separation stages is to separate soluble and insoluble metal content in Deli River water samples. The container used for the SWAFT filter mechanism in the research scale can be seen in Figure 1.

Figure 1. The SWAFT Filter Container Used in Research Scale

Characteristics of Rice Husk Activated Carbon with KOH Activation

The characterization of activated carbon is conducted to understand and analyze activated carbon with KOH activation. In the production of rice husk-activated carbon, carbonization is performed in a furnace at 600 °C for 90 minutes. Testing to determine the characteristics of activated carbon is carried out based on the Indonesian National Standard (SNI) No. 06-3730-1995 for powder quality. The SNI standard for activated carbon along with the test results can be seen in Table 4.

Table 4. SNI for Activated Carbon Along with Quality Requirements

No.	Description	Quality Requirements
1	Water Content (%)	Max 15
2	Ash Content (%)	Max 10
3	Absorption Capacity of I_2 (mg/g)	Max 750
4	Volatile Substance Level (%)	Max 25

Based on the experiments conducted by the author, testing was carried out according to SNI No. 06-3730-1995, and the activated carbon from rice husks met its quality requirements. The results indicate that the rice husk-activated carbon meets the standard quality criteria. The test results obtained by the author can be seen in Table 5.

Table 5. Results of Activated Carbon Testing and Its Quality Requirements Based on SNI No. 06-3730-1995

No.	Description	Quality Requirements
1	Water Content (%)	10.32
2	Ash Content (%)	3.45
3	Absorption Capacity of I_2 (mg/g)	508.66
4	Volatile Substance Level (%)	19.74

Figure 2. Rice Husk Activated Carbon

Characteristics of Aloe Vera Bio-coagulant

Aloe vera, as a natural plant, contains mucilage, making it suitable for use as a natural coagulant. The mucilage present in aloe vera contains polygalacturonic acid, which acts as a coagulant substance. Its coagulation mechanism involves binding particles that do not come into contact with each other but are bound to polygalacturonic acid compounds, resulting in the formation of flocs from particles in the water. The natural pH of aloe vera is between 3.5 and 5.0. Adding dissolved H^+ ions in an acid will push the equilibrium to the left (OH^- ions will bind to H^+ to form water), resulting in an excess of hydrogen ions and an increase in acid concentration. The higher the concentration of added coagulant, the more hydrolysis processes occur in the water, leading to a greater amount of H^+ ions ionizing in the water and thus lowering the pH. In the aloe vera bio-coagulant, a preservative substance, salicylic acid, is added to produce a long-lasting bio-coagulant with a bright green color. The addition of this preservative substance allows the bio-coagulant to last for about 14 days. The image of aloe vera bio-coagulant can be seen in Figure 3 and Figure 4.

Figure 3. Aloe Vera Gel with the Addition of Salicylic Acid

Figure 4. Aloe Vera Gel without the Addition of Salicylic Acid

Results of Deli River Water Testing

Characterization of Deli River water was conducted to determine the extent of heavy metal contaminant reduction in Deli River water before and after treatment using the coagulation and adsorption methods with aloe vera coagulant and rice husk waste. The results were then compared with water quality standards. The water quality standards used comply with the river class based on Government Regulation No. 82 of 2001 concerning water quality management and pollution control. The parameters of metal content in Deli River water can be seen in Table 6.

Table 6. Results of Activated Carbon Testing and Its Quality Requirements Based on SNI No. 06-3730-1995

No	Content Parameters	Test results (mg/liter)		Testing Standards (mg/liter)
		Before	After	
1	BOD	6.0	1.8	3.0
2	COD	219.51	53	25
3	TSS	58.00	4.0	50
4	Fe	0.1618	0.0092	0.3
5	Pb	0.0362	0.0081	0.03
6	Cu	0.0274	0.0072	0.02

Table 6 shows the content of several metals found in Deli River water. After determining the content of several metals in Deli River water, such as Fe, Pb, and Cu, filtration was performed through coagulation and adsorption to reduce the levels of these metals. The quality of Deli River water after filtration showed a significant decrease. For Fe, there was a decrease of 5.68% from 0.1618 mg/liter to 0.0092 mg/liter. For Pb, there was a decrease of 22.37% from 0.0362 mg/liter to 0.0081 mg/liter. Meanwhile, for Cu, there was a decrease of 26.27% from 0.0274 mg/liter to 0.0072 mg/liter. This reduction occurred because the working principle of activated carbon in filtering metals is through adsorption, causing the clumping of soluble substances in river water (adsorbate) onto the surface of the absorbing material or substance (adsorbent). The mechanism involved is that adsorbent molecules move from the bulk phase to the interfacial surface of the adsorbent, molecules of adsorbent move from the interfacial surface to the outer surface, and molecules of adsorbate move from the outer surface of the adsorbent to the pores of the adsorbent.

Sustainable Development

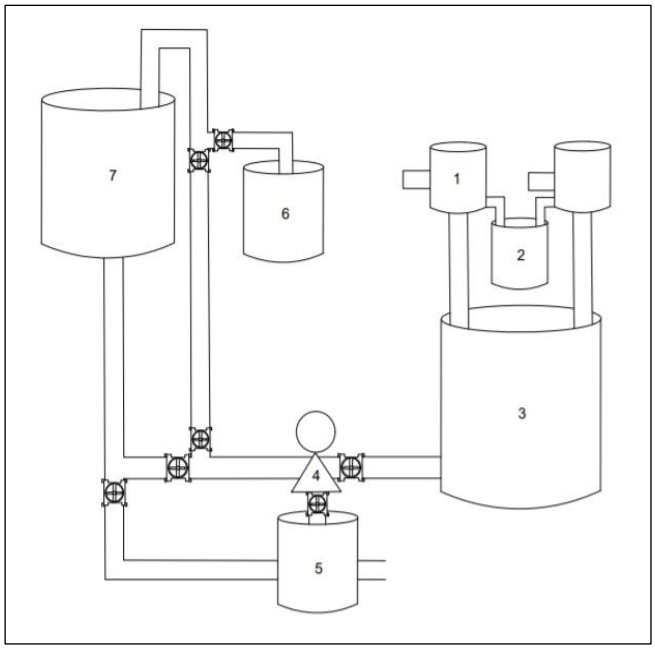

Figure 5. Application of SWAFT Filter in Batch System

Explanation:

1. Coagulant tank
2. Coagulant waste storage tank
3. Coagulant product storage tank
4. Pump
5. Clean water storage tank
6. Activated carbon waste tank
7. Activated carbon tank

The author also applied this filter in batch form, which is expected to be developed further in the future. This system will use multiple tanks to filter Deli River water, allowing for a larger quantity of clean water to be obtained. In this system, the contaminated water will be contacted with aloe vera coagulant in a tank and undergo the coagulation-flocculation process. Subsequently, the water that has undergone the coagulation-flocculation process will be collected and pumped into activated carbon tanks. The clean Deli River water will be stored in a storage tank. However, if the water is still not collected, recycling or re-cleaning will be carried out in the activated carbon tank. This system also includes tanks to collect exhausted activated carbon waste or when it cannot filter Deli River water. The application of this system is illustrated in Figure 5.

In facing the challenges of Industry 4.0, innovative solutions are required to address the issues. To meet these challenges, this product will be enhanced in the future through the sale of equipment that can be integrated well with both its coagulant and activated carbon. Additionally, this equipment will also utilize Artificial Intelligence technology connected through computers or smartphones.

IV. CONCLUSION

From the conducted experiments, activated carbon from rice husk was obtained by carbonization at a temperature of 600 °C for 90 minutes. The obtained activated carbon met the SNI No. 06-3730-1995 standard with a moisture content of 10.32%, ash content of 3.45%, iodine adsorption capacity of 508.66 mg/g, and volatile matter content of 19.74%. Additionally, aloe vera bio-coagulant was obtained with a pH of 3.5-5 and a shelf life of 14 days with the

addition of salicylic acid. The addition of salicylic acid serves as a preservative and imparts a bright green color to the bio-coagulant.

Deli River water filtered using rice husk activated carbon and aloe vera bio-coagulant has met the clean water quality standards of Government Regulation No. 82 of 2001 for parameters: BOD at 1.8 mg/liter, COD at 53 mg/liter, TSS at 4 mg/liter, Fe at 0.0092 mg/liter, Pb at 0.0081 mg/liter, and Cu at 0.0072 mg/liter.

This technology has great potential for large-scale development utilizing rice husk waste as activated carbon and aloe vera as a bio-coagulant. The implementation of large-scale operations will be done using a batch system, where multiple tanks will be used to filter Deli River water to obtain a large quantity of filtered water. The "SWAFT" innovation, which utilizes rice husk waste and aloe vera bio-coagulant as filter materials for Deli River water, is expected to address the challenges of Industry 4.0 in improving public health, especially for communities around the Deli River area.

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