



Utilization of Gondorukem Industrial Solid Waste Into Activated Carbon as Adsorbent to Improve the Quality of Gondorukem Color

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Abstract. The production process in the gondorukem industry produces solid waste in the form of litter, twigs, and pine tree leaves. In this study, solid waste from the gondorukem industry was processed into activated carbon as an adsorbent to improve the color quality of the gondorukem. The workings of this research include carbonizing solid waste in a combustion tube until it becomes charcoal, then the charcoal is ground and sieved using a -16 + 28 mesh sieve. Furthermore, activation was carried out based on the type of activator, namely sodium hydroxide (NaOH) and hydrochloric acid (HCl), with concentrations according to the independent variables, namely 0.3 M, 0.6 M, 0.9 M, 1.2 M, and 1.5 M for 24 hours. After that, assays were carried out on activated carbon samples which included; water content assay, ash content assay, and iodine number assay. The results of the best solid waste activated carbon using an hydrochloric acid (HCl) activator with a concentration of 0.3 M, which has been compared with SNI 06-3730-1995, produces 3% water content, 17% ash content, and 3046.32 mg/g iodine number. The result of the gondorukem color that has been treated and batch distilled produces a color value of 10.6, which is physically brownish red and still, does not meet gondorukem color standards.

Keywords: Adsorbent, Activated Carbon, Gondorukem Solid Waste.

1 Introduction

Gondorukem industry in the pine resin production process, which is processed into gondorukem, produces a lot of solid waste precisely in the Resin Treatment Plant process. This solid waste is litter, pine bark, leaves, and other solid objects. This solid waste will be placed into sacks and usually taken by residents as fuel for small industries. In addition, there is no other utilization of this solid waste. Therefore, as an alternative to solid waste treatment, it will be further processed into activated carbon under

SNI 06-3730-1995, which acts as an adsorbent to improve the color quality of gondorukem.

Activated carbon is made from solid waste gondorukem industry, motivated by utilization is less than the maximum, so it is expected from the research conducted can increase the benefits of solid waste. Then, this study refers to several previous researchers who have researched Activated Carbon and gondorukem. Among them are HCl activators used for carbon activation proposed by Hafidoh (2021) [1]. Oktari (2014) conducted a study by activating carbon for 24 hours using HCl, NaOH, and NaCl activators and producing activated carbon according to SNI [2]. The research conducted by Hidayat et al. (2021) regarding improving the quality of gondorukem and turpentine by adding chelating agents in the form of EDTA and zeolite adsorbents produce colors of gondorukem 8+ (nancy) [3]. The three research guidelines become guidelines in conducting research, especially from Hidayat et al. These will later become guidelines on the stages of application of activated carbon made from solid waste to be applied to gondorukem products to improve the quality of the color.

The scope of the problem in this study is gondorukem industrial solid waste which is currently only used by the surrounding community to be used as fuel for small industries without any further processing. Another alternative is used to develop the potential of solid waste by processing it into activated carbon according to SNI standards. It can be used as an adsorbent to improve the quality of gondorukem color. This research uses a variable type of activator and concentration of activator in manufacturing activated carbon. This research is expected to increase the benefits and selling value of the solid waste gondorukem and turpentine industry.

This study aimed to determine the effect of activator type and activator concentration on the quality of activated carbon produced from gondorukem industrial solid waste and identify the characteristics of activated carbon from gondorukem industrial solid waste based on SNI 06-3730-1995 standards. In addition, it also compares the characteristics of activated carbon from gondorukem industrial solid waste with zeolite and EDTA as adsorbents to improve the color quality of gondorukem and to determine the yield produced of activated carbon from gondorukem industrial solid waste.

2 Literature Review

2.1 Processing of pine resin into Gondorukem

There are several stages in the process of processing pine resin into gondorukem and turpentine, including [4]:

- Acceptance and quality testing of pine resin
- Dilution
- Precipitation and filtration
- Heating or cooking
- Testing and packaging

In general, the processing of pine resin into gondorukem and turpentine consists of 2 stages: pine resin purification and distillation process to separate turpentine from gondorukem. The Pine resin purification process consists of 3 steps, namely the dilution of resin by adding turpentine 40% and the process of filtering the resin. The distillation process to separate gondorukem and turpentine consists of 2 stages: direct heating and indirect heating [5]. The processing of pine resin in the purification process includes dilution, precipitation, and filtration to produce Oleo Pine Resin (OPR), where OPR is the main ingredient that will go into the distillation process and the following process.

2.2 Gondorukem Industrial Solid Waste

Solid waste is produced from the gondorukem production process in the form of litter, Pine twigs, pine leaves, and shavings obtained from melter tanks in the dilution stage of pine resin. Based on research conducted by Komarayati et al. (2004) found that litter and pine bark have a bound carbon content of more than 50%, which is 53.6% and 71.93%, respectively [6]. For the processing process, solid waste from the melter tank is moved into a container; then, this waste will be inserted into the sack and weighed. Usually, this solid waste will be taken by the surrounding community to be used as fuel in small industries such as the tofu and limestone industries.

2.3 Adsorbent

Adsorbents that function as absorbents of unwanted substances or play an essential role in adsorption have properties. The adsorbent properties in question, such as composition and pore structure related to the surface area. To increase the adsorbent's adsorption capacity by increasing the surface area, reducing the pore size, and so the volume of the adsorbent pores. In addition to these properties, particle size also affects the adsorbent to absorb unwanted substances. The particle size referred to here is the reduction in particle size, and the separation of particles of the desired or appropriate size will accelerate the adsorption process [7].

2.4 Activated Carbon

Activated carbon is charcoal through the activation process by chemicals that are either acidic or alkaline. Activated carbon is a raw material that can help or as an industrial helper. Activated carbon can be an adsorbent, which will have adsorption properties that depend on the porosity of the surface. However, if in the field of Activated Carbon Industry will be more focused on the adsorption properties rather than the pore structure. The Shape of activated carbon pores varies greatly, namely in the form of cylinders, rectangles, and other irregular shapes. Here is a table of Activated Carbon quality requirements under SNI [8].

Table 1. Activated Carbon Quality Requirements

No.	Types	Of Parameter Requirements
1.	Water content	Maximum 15%
2.	Ash content	Maximum 10%
3.	The content of the substance evaporates.	Maximum 25%
4.	The bound carbon content	at least 65%
5.	The absorbability of iodine	at least 750 mg/g
6.	The absorbability of benzene	at least 25%

2.5 Manufacture Of Activated Carbon

According to Wardani (2020), the process of making activated carbon consists of 3 stages, which are as follows [9] :

- *Dehydration Process*
The dehydration process removes or reduces the raw material's water content by heating it to 105oC-170oC.
- *Carbonization Process*
The carbonization process breaks down organic matter into carbon: the temperature to produce CO, CO2, and acetic acid ranges above the temperature of 170°C. Then there is decomposition that produces tar, methanol, and other by-products, which occurs at a temperature of 275°C. Almost 80% of elemental carbon is obtained at a temperature of 400-600°C.
- *Activation Process*
The carbonization process breaks down organic matter into carbon: the temperature to produce CO, CO2, and acetic acid ranges above the temperature of 170°C. Then there is decomposition that produces tar, methanol, and other by-products, which occurs at a temperature of 275°C. Almost 80% of elemental carbon is obtained at a temperature of 400-600°C. *Activator*
Activating carbon into activated carbon can be done in 2 ways, namely, chemically and physically.
- *Activation Chemically*
Chemical activation is done by mixing carbon materials with chemicals or activating reagents, and then the mixture is dried and heated [11].
- *Activation Physically*
Physical activation is the process of breaking carbon chains from organic compounds with the help of heat, steam, and CO2. Physical activation uses water vapor, carbon dioxide, oxygen, and nitrogen. These gases serve to develop the existing cavity structure in charcoal to expand its surface, remove volatile constituents, and dispose of the production of tar or hydrocarbon impurities in charcoal [10].

3 Research Methodology

The research method used in data collection or analysis and research results of each Activated Carbon treatment is a quantitative method. In addition, it is also supported by qualitative methods of the process and results of the interpretation of research that has been carried out in the following research procedures.

3.1 Stages Of Manufacture Of Activated Carbon

- *Preparation:* Prepare solid waste that has been cleaned, drying solid waste with sunlight for two weeks, weighing dry solid waste (W0).
- *Carbonization:* Put 650 grams of solid waste into the combustion tube, and then the combustion process at a temperature of 400°C for 40 minutes. Then Cool the solid waste charcoal to a temperature of 30°C. Crush the charcoal to a powder. Sifting charcoal using size -16 + 28 mesh. Weighing the sifted charcoal (W1).
- *Activation:* Weigh ten charcoal samples of 15 grams of solid waste charcoal for each activator. Immerse each charcoal sample in a solution of NaOH and HCl concentration according to the independent variable for 24 hours. Filter the charcoal using filter paper and then wash the charcoal with aquades. Drying charcoal using oven temperature of 105°C for 4 hours, and then analyzing each sample of activated carbon. Compare the results of sample analysis with SNI quality requirements. Determined one sample of Activated Carbon is best.

3.2 Application of Activated Carbon as adsorbent

- *OPR Treatment Process:* Preparing OPR of 1318 grams. Add activated carbon of 2.2% and stir in a hot plate Stirrer for 15 minutes. It is stirring the solution on the hot plate Stirrer with a temperature of 60°C for 30 minutes. Leave the solution to cool, and the activated carbon settles, then filter the solution. Hold the resin solution in the container that has been provided. Weigh and record the resin solution produced and then test the resin solution's color. Record the results of testing the resin solution.
- *Batch Distillation Process:* Weigh the results of the OPR treatment. Put the OPR into a 2 L round flask. Install the batch distillation apparatus and make sure there are no leaks. After that, turn on the circulation of cooling water and nitrogen gas. Set the heater temperature to 120oC by pressing the button on the control panel to evaporate the remaining water. Raise the heating temperature by 5oC gradually until it reaches a temperature of 175oC so that the round flask does not burst. Wait until the resin is cooked (total distillation time is ± 3 hours). Separate the distillate and the product, then test the color quality of the resin distillation results.

3.3 Analysis Process

- The Technical quality assay is applied using the quality standard of activated carbon SNI 06-3730-1995, which includes::
- *Water content assay*: Put activated carbon weighing 1 gram into the oven with a temperature of 105°C for 1 hour. Cool the activated carbon into the desiccator. Weigh activated carbon and calculate the water content in activated carbon using the following formula.

$$\text{water content (\%)} = \frac{a-b}{a} \times 100\% \quad (1)$$

Description:

a = initial activated carbon weight (grams)

b = weight of Activated Carbon after drying (grams)

- *Ash content assay*: Put the activated carbon weighing 1 gram into the furnace with a temperature of 800°C for 2 hours. Cool the activated carbon into the desiccator. Weigh activated carbon and calculate the ash content in activated carbon using the following formula.

$$\text{Ash content (\%)} = \frac{\text{ash weight}}{\text{sample weight}} \times 100\% \quad (2)$$

- *Iodine number assay*: Weigh activated carbon by 0.15 grams. Add 15 ml of 0.1 N Iodine solution. Stir the solution for 15 minutes. Filter the solution with filter paper to separate it from the residue. Take 5 ml of the solution and titrate it using 0.1 N sodium thiosulfate. Adding 1% amylum solution as an indicator when the yellow color of the titrated solution begins to fade. Re-titrate the solution until it changes color to clear, then calculate the iodine number using the following formula.

$$\text{Iodine absorption} \left(\frac{\text{mg}}{\text{g}} \right) = \frac{\left(A - \frac{B \times N_{\text{Na}_2\text{S}_2\text{O}_3}}{N_{\text{iodine}}} \right) \times 126,93 \times fp}{a} \quad (3)$$

Description:

A = volume of iodine solution (mL)

B = volume of Na₂S₂O₃ used (mL)

fp = dilution factor

a = weight of activated carbon (g)

N (Na₂S₂O₃) = Na₂S₂O₃ concentration (N)

N (iodine) = iodine concentration (N)

126.93 = appropriate amount of iodine 1 mL of na₂s₂o₃ solution

- *Gardner Color assay*: Weigh a sample of 3 grams. Dissolve the sample with 3 grams of xylene in a glass beaker. Stir the solution until completely dissolved. Reweigh the solution as a reference for the addition of evaporated xylene. Insert the solution up into the Gardner tube. Matching the sample to Gardner's standard color.

4 Result and Discussion

The quality of the gondorukem is influenced by the color produced gondorukem itself after going through the pine resin's production stages. Gondorukem color is getting brighter, or gardner and lico color numbers are getting smaller when the color test is done, then the quality of gondorukem is improving. Improving the quality of gondorukem requires the addition of materials that are adsorbing. This study uses activated carbon as an adsorbent to improve the quality of gondorukem color. Activated carbon is activated carbon derived from the utilization of solid waste Gondorukem industry.

4.1 Yield charcoal and Activated Carbon

Table 2. Result of The Carbonization Process

Wet Waste Mass (g)	Wet Waste Mass (g)	Temperature (°C)	Period (minute)	Charcoal Mass (g)	Yield (%)	Charcoal Size (mesh)
705	650	400	40	123,9	19,06	-16+28

This carbonization process results in charcoal, which originally carbonized solid waste of as much as 650 grams into charcoal of as much as 123.9 grams. Therefore, yield charcoal yield was obtained by 19.06%. This yield has been calculated under the formula used. The resulting charcoal yield value can be said to be low. That is, under Komarayati and Hendra (1994), the yield is getting lower because the water content is also increasing [12]. In addition, according to the opinion of Komarayati, Gusmailina, and Pari (2011), the high and low yield is also influenced by the carbonization process, specific gravity, density, and chemical composition of the material [13]. In addition to the charcoal yield, the size of the charcoal obtained is -16 + 28 mesh, where most of this charcoal escapes in 16 mesh and is trapped in 28 mesh.

The yield of activated carbon that has been activated using HCL and NaOH activators obtained results where the greater the concentration of HCL and NaOH activators, cause the smaller the carbon yield. According to Subhadra, Setiaji, and Tahir (2005), it is relatively difficult to evaporate organic compounds and substances in activated carbon [14]. Meanwhile, according to Sianipar et al. (2016), where the activation process uses HCl as an activator, the yield decreases due to the removal of adsorbent weight. Here is a graph showing the relationship of activator concentration to yield.

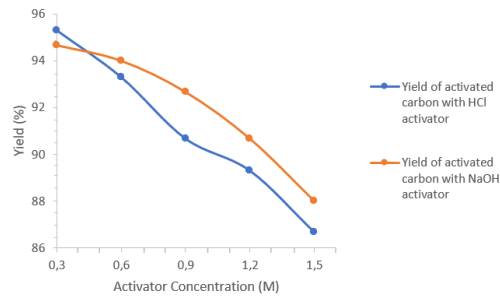


Fig. 1. Graph of activator concentration to *yield*.

4.2 Activated Carbon Analysis Based On Water Content

The method used in determining the water content of Activated Carbon is a gravimetric method of chemical analysis based on weighing the difference in weight between the Activated Carbon before the water content is evaporated and after the evaporation of activated carbon. In the water content test results, we can see that the amount of water evaporated so that the water bound to the Activated Carbon does not close the carbon pores. The loss of water molecules in Activated Carbon will cause the carbon pores to get bigger and the surface area to increase. This increases activated carbon's adsorption ability [16].

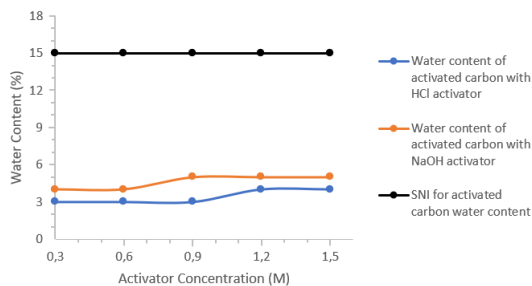


Fig. 2. Graph of activator concentration to water content

The low water content of activated carbon indicates the success of the activator agent in binding the water molecules contained in the material and releasing the free water content and bound water contained in the raw material during the carbonization process [11]. The water content resulting from the activation using HCl according to the concentration of the independent variable is stretched 3-4 %, while the value of the water content of the NaOH activator is 4-5%. This figure shows that this Activated Carbon has met the quality requirements of Activated Carbon at a water content parameter of 15%.

4.3 Activated Carbon Analysis Based On Ash Content

Ash content test on Activated Carbon is done to determine the content of metal oxides in activated carbon. Ash content is very influential on the quality of activated carbon. The presence of excessive ash can cause blockage of activated carbon pores so that the surface area of Activated Carbon is reduced [17].

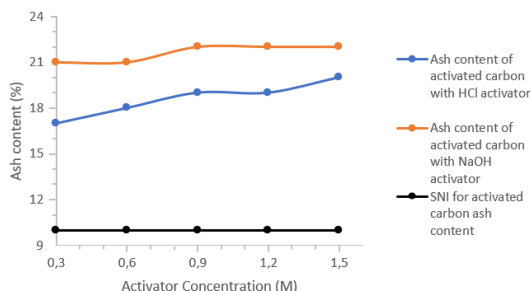


Fig. 3. Graph of Activator concentration to ash content

The ash content produced from the two activators exceeds the quality standard of ash content, where the quality standard is a maximum of 10%. The ash content produced by activating HCl is 17-20%, and NaOH is 21-22%. This phenomenon can occur because the higher the concentration of HCl and NaOH, the water content decreases, so the minerals formed into mineral salts are partially insoluble. They attach to the pores of the activated carbon [18].

This can also be caused by using a semi-continuous furnace during the solid waste carbonization process. There is direct contact between the fire and the raw material so that a lot of carbon becomes ash before the fire is turned off, and there is still a lot of ash attached to the surface of the charcoal. On the other hand, the washing process is still not optimal and can also cause an increase in the ash content so that the remaining mineral activation is still not completely removed. Because the more significant the concentration of HCl and NaOH given, the more minerals are left in the activated carbon. Although activated carbon is washed, it is impossible to confirm that the activator's remnants and other minerals are entirely lost [20]. The resulting graph shows that the ash content tends to increase and, in this study, is relatively high and does not meet the standard of SNI 06-3730-1995; the maximum ash content is 10%.

4.4 Activated Carbon Analysis Based On Iodine Number

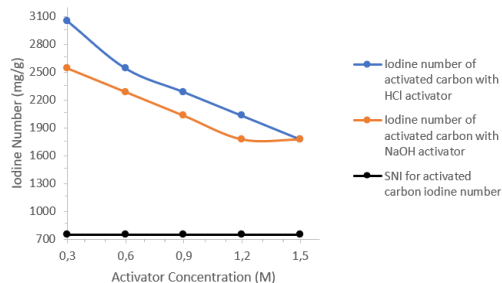


Fig. 4. Graph of Activator concentration to Iodine number

Determination of the absorbency of Activated Carbon to iodine aims to determine the ability of Activated Carbon to absorb colored solutions. One method used in analyzing activated carbon adsorption power to iodine solution is the iodometric titration method. The addition of iodine solution serves as an adsorbate that activated carbon will absorb as an adsorbent. Absorption of iodine solution is indicated by a reduction in the concentration of Iodine solution [11].

It can be seen if there is a significant decline in graph 4. The iodine number indicates that the HCl and NaOH concentration affects the activated carbon pores opening at the activation time. The higher the HCl concentration, the more pores are formed, so the higher the concentration of the HCL activator, the higher the absorption of iodine. However, the concentration of HCl that is too high can cause the pores of activated carbon formed to be damaged. This result is similar to research from Mujizah (2010) [21]. The results of ash content analysis also influence the high and low absorption of iodine. The ash content value and the iodine number are inversely proportional. The increase in iodine absorption affects the lower ash content produced because excessive ash can cause blockage of activated carbon pores, reducing the surface area of Activated Carbon [17]. The overall iodine absorption of activated carbon produced in this study has met the standards of SNI 06-3730-1995 because all the values of activated carbon iodine number obtained were more than 750 mg/g.

4.5 Application Of Activated Carbon As Adsorbent To Improve The Color Of Gondorukem

After analyzing the quality of 10 samples of Activated Carbon with the variable type of activator and concentration of activator, the best results were obtained in the activated carbon sample with HCL 0.3 M activator with a water content value of 3% and an iodine value of 3046.32 mg/g, an ash content of 17 % and 95.3% yield.

The results of the application of Activated Carbon with the activation of 0.3 M HCl as an adsorbent is the OPR treatment process by adding activated carbon as much as 2.2% of the initial mass of OPR; this condition is adapted to the best conditions of Hidayat et al. (2021) research [3]. The purpose of the OPR treatment is to use activated

carbon to absorb impurities in the OPR and maximize the color of the gondorukem, which later becomes a better color quality from the research of Hidayat et al. (2021) [3]. After the treatment process, filter the results of the OPR twice to separate it from the activated carbon that has been added. This filtering is carried out twice because, in the first filtration, the activated carbon is still included.

After filtering, the OPR treatment results before entering the distillation stage produced OPR with gardner color 6+ which is converted to lico color to 5+; this means that activated carbon successfully adsorbs impurities contained in OPR to produce a brighter OPR color.

After treatment OPR, then do batch distillation to separate gondorukem and turpentine. However, gardner color levels decrease gardner in gondorukem after going through the distillation process. Gondorukem produced after the distillation process has a very low color level. Here is the gondorukem result of the batch distillation process.

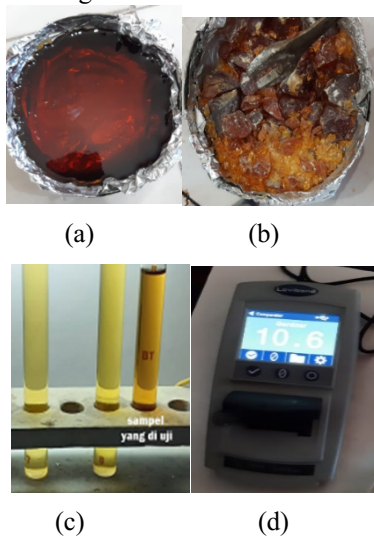


Fig. 5. Gondorukem: (a) and (b) gondorukem, (c) gardner color gondorukem, and (d) gardner color gondorukem digital

The higher the resulting number, the darker the color of the gondorukem. Can see In Figure 5 that the distillate gondorukem has a brownish color; when testing the color using the gardner color in Figure 5 (c), it can be seen that the sample being tested has a darker color than the standard color of gardner 8 so can say that the result of the gardner color test is more than eight while using digital Gardner color the number is 10.6. Based on the gardner color assay results, a number more than 8 or 10.6 means that the color quality of the gondorukem product is still not good, namely brownish red, which is in stark contrast to the results of OPR before distillation. OPR color reduction is possible because activated carbon particles are still present during filtration, and this causes the OPR color after distillation or gondorukem to be darker. In addition, a decrease in the color quality of gondorukem can occur due to the high ash content of the activated carbon used as an adsorbent. Ash content is very influential on the quality of activated

carbon. The presence of excessive ash can clog the pores of the activated carbon so that the surface area of the activated carbon is reduced [17].

Activated carbon from the solid waste of the gondorukem industry, which is used as an adsorbent in this study, is said to improve the color quality of the gondorukem. However, in this study, it is still not optimal. Because it produces colors above 8, which are different from the results of Hidayat et al. (2021), which used a mixed zeolite-EDTA adsorbent with a concentration ratio of 1: 1.2% and produced gondorukem with a color test of 8 (WG window glass) with a description of the second color quality, namely brownish yellow [3].

5 Conclusion

Based on research data and discussions that have been presented about the use of solid waste Gondorukem Industry into Activated Carbon which is applied into an adsorbent to improve the quality of gondorukem color, can be concluded as follows:

- 1) Activator type and activator concentration on the quality of activated carbon produced from solid waste, namely activated carbon using an HCL activator with a concentration of 0.3 M, is the best-activated carbon from 2 types of activators with independent variable concentrations.
- 2) The characteristics of activated carbon produced from solid waste for the assay results of water content and iodine number have met the standards of SNI 06-3730-1995. However, the ash content assay results still do not meet the existing standards because the resulting value is high, which is above 10%, precisely the value range of 17-20% for HCL activators and 21-22% for NaOH.
- 3) Comparison of the characteristics of activated carbon from solid waste with zeolite and EDTA as adsorbents for gondorukem color quality results, it is still good to use adsorbent zeolite and EDTA produced color assay 8. Meanwhile, those who use activated carbon adsorbent produce a 10.6 color assay which is physically brownish red.
- 4) The amount of charcoal yield from the solid waste carbonization process of 650 grams produces 123.9 grams of charcoal, so the value yield of charcoal is 19.06%. While the yield of activated charcoal based on the concentration of HCL activator 0.3 M, 0.6 M, 0.9 M, 1.2 M and 1.5 M respectively 95,3%, 93,3%, 90,7%, 89,3% and 86.7%. Meanwhile, for the concentration of NaOH activator 0.3 M, 0.6 M, 0.9 M, 1.2 M and 1.5 M respectively 94,7%, 94%, 92,67%, 90,67%, and 88%.

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