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# Analysis of the Effect of Soaking Time and HCl Concentration on the Synthesis of Water Hyacinth Adsorbent

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**Abstract.** This study aims to evaluate the effect of variations in soaking time and HCl concentration on the characteristics and effectiveness of water hyacinth (Eichhornia crassipes)-based activated carbon as an adsorbent. Water hyacinth was chosen because it is an invasive plant with high cellulose and lignin content that has the potential to be processed into activated carbon through pyrolysis and chemical activation. The research was conducted by soaking the carbon in 5%, 10%, and 15% HCl solution for 1, 2, and 3 days, then characterized through water content, ash content, iodine absorption. The results showed that all samples met the SNI standards for moisture content (<15%) and ash content (<10%), but did not meet the iodine absorption standard (≥750 mg/g), with the highest value of 566.5 mg/g. ANOVA analysis showed that both soaking time, HCl concentration, and their interaction had a significant effect on the characteristics of activated carbon. The optimum condition was obtained at 3 days soaking with 15% HCl concentration. This study shows the potential of water hyacinth as an economical and environmentally friendly alternative adsorbent, but further optimization is needed to increase the adsorption capacity to standard.

## INTRODUCTION

The rapid escalation of industrial, domestic, and agricultural activities over recent decades has significantly contributed to the increase in liquid waste discharged into aquatic systems. These effluents commonly contain a variety of pollutants, including heavy metals, organic compounds, and inorganic substances, which if left untreated can deteriorate environmental quality, pose serious risks to human health, and disrupt ecological balance. Among various wastewater treatment techniques, adsorption is widely recognized as a cost-effective and efficient method, involving the transfer of contaminants from the liquid phase onto the surface of a solid adsorbent.

Activated carbon is one of the most extensively utilized adsorbents in water treatment due to its large specific surface area, intricate pore structure, and high affinity for a broad spectrum of pollutants. It serves not only as a medium for removing organic compounds but also as an agent to eliminate odors and unpleasant tastes from water. Its efficacy in reducing the concentrations of heavy metals, organic, and inorganic contaminants is largely attributed to its tunable surface chemistry, nanoscale structure, and recyclability (Fatmawati et al., 2021). However, the limited availability and high production cost of commercial activated carbon have driven the exploration of alternative, low-cost, and environmentally sustainable raw materials.

Water hyacinth (Eichhornia crassipes), a fast-growing aquatic plant, is often regarded as an invasive weed due to its aggressive proliferation, which can disrupt aquatic ecosystems. In regions such as Banjarnegara, the uncontrolled spread of water hyacinth has led to the obstruction of major waterways like the Bengawan Solo River (Kompas.com), adversely affecting aquatic biodiversity by reducing dissolved oxygen levels and hindering the mobility of aquatic organisms. This ecological challenge simultaneously presents an opportunity; given its high lignocellulosic content, water hyacinth holds significant promise as a biosorbent for the removal of heavy metals, organic, and inorganic pollutants (Andarista et al., 2023).

Previous studies have confirmed the sorptive capabilities of water hyacinth toward a wide range of contaminants, positioning it as a strong candidate for the development of natural adsorbents. When subjected to appropriate physical or chemical activation processes, the biomass can be transformed into activated carbon with enhanced adsorption

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performance, thereby increasing its functional value while mitigating its ecological footprint, particularly its contribution to eutrophication.

Activated carbon, commonly derived from various biomass sources, remains a key material in adsorption-based treatment systems. Its effectiveness stems from its large surface area, presence of functional groups, and its capacity for chemical modification and regeneration (Fatmawati et al., 2021)

In this context, the present study aims to investigate the potential of water hyacinth-derived activated carbon as a viable adsorbent for water purification. This is achieved through comprehensive characterization and application testing under varying process parameters. The utilization of water hyacinth as a raw material for activated carbon production aligns with sustainable technological practices that emphasize environmental conservation and resource circularity.

## METHODS

The research design employed in this study is an experimental laboratory method. The independent variables are the concentration of hydrochloric acid (HCl) and the immersion time of the water hyacinth-based activated carbon. The dependent variable is the adsorption effectiveness of the resulting activated carbon. The relationship among these variables will be statistically analyzed using a two-factor analysis of variance (ANOVA) with replication. This design was selected to ensure that the research objectives and problem statements are addressed in a scientifically rigorous manner.

The primary equipment to be used in this study includes beakers, a grinder, filters, a 60-mesh sieve, a drying oven, a furnace for carbonization, filter paper, and a titration apparatus for the iodine adsorption test. The materials required for the experiments include dried water hyacinth (Eichhornia crassipes) (in the form of simplicia), hydrochloric acid (HCl) at concentrations of 5%, 10%, and 15%, sodium thiosulfate ($Na_2S_2O_3$), iodine ($I_2$), potassium iodide ($KI^-$), and starch as an indicator.

### Research Step

The procedural steps of the research are presented schematically in the Figure 1 below.

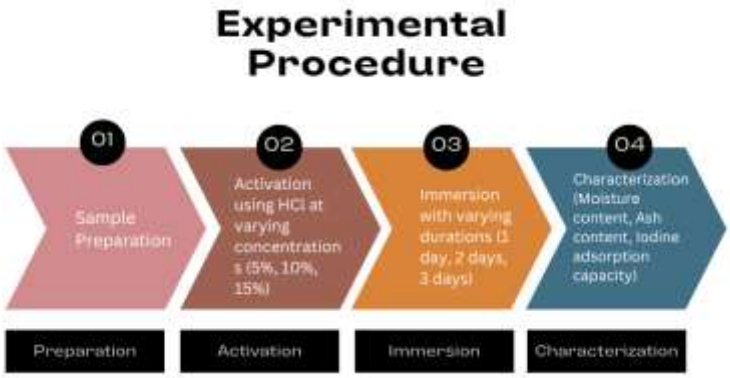


**FIGURE 1.** Experimental Procedure

### Sample Collection And Preparation

Samples were collected from the Cengklik Reservoir, Karanganyar Regency. The water hyacinth plants were first washed thoroughly to remove dirt and impurities. Subsequently, the plants were chopped into small pieces and dried in an oven to reduce moisture content prior to carbonization.

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## Activated Carbon Production and Characterization

The dried water hyacinth was placed in an oven at 150°C for 1 hour. The dried simplicia were then carbonized in a furnace at 320°C for 1 hour. The resulting char was ground using a blender or mortar and sieved through a 60-mesh screen. The sieved carbon was then chemically activated using hydrochloric acid (HCl) at concentrations of 5%, 10%, and 15%. The activation involved soaking the carbon in HCl for varying durations of 1, 2, and 3 days. After immersion, the samples were rinsed with distilled water and dried again in an oven at 120°C for 1 hour.

The produced activated carbon was characterized through moisture content analysis, ash content determination, iodine adsorption capacity analysis.

*Moisture Content Test*

One gram of activated carbon was placed in an oven at 150°C for 30 minutes, then cooled in a desiccator for 5 minutes. The moisture content was calculated with formula [1] below.

$$\text{Moisture Content Test (\%)} = \frac{\text{w1} - \text{w2}}{w1} \times 100\% \quad (1)$$

Where
W1 = Weight before heating (g)
W2 = Weight after heating (g)

*Ash Content Test*

One gram of activated carbon was placed in a furnace at 500°C for 1 hour, then cooled in a desiccator for 30 minutes. Ash content was calculated using the following formula [2] below.

$$\text{Ash Content Test (\%)} = \frac{\text{w1}}{w2} \times 100\% \quad (2)$$

Where
W1 = Weight of total ash (g)
W2 = Weight of the sample (g)

*Iodine Adsorption Capacity Test*

A 0.5 g sample of activated carbon was treated with 100 mL of 0.1 N iodine solution and $KI^-$, stirred using a magnetic stirrer for 15 minutes. Then, 25 mL of the filtrate was titrated with 0.1 N sodium thiosulfate ($Na_2S_2O_3$) solution until a yellow color appeared. When the yellow color began to fade, 1 mL of 1% starch solution was added as an indicator. Titration continued until the solution turned from dark brown to colorless. Iodine adsorption capacity was calculated using the following formula [3] below.

$$\text{Iodine Absorbed } \left(\frac{mg}{g}\right) = \frac{6 - \left(\frac{V \; x \; N}{0,1}\right) x \; 12,69 \; x \; 10}{w} \quad (3)$$

Where
V = Volume of $Na_2S_2O_3$ used (mL)
N = Normality of $Na_2S_2O_3$
W = Mass of the sample (g)

## RESULTS AND DISCUSSION

The activated carbon obtained in this study was evaluated in accordance with the quality requirements specified in the Indonesian National Standard (SNI) No. 06-3730-1995 for technical-grade activated carbon. The parameters examined include moisture content, ash content, and iodine adsorption capacity. The experimental work was conducted at the Chemical Engineering Laboratory, Universitas Muhammadiyah Surakarta.

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## Moisture Content Analysis

Moisture content analysis was performed on activated carbon samples subjected to different HCl concentrations and immersion durations. As depicted in Table 1 and Figure 2, all samples exhibited moisture content levels below the SNI maximum threshold of 15%. The lowest moisture content was recorded at 0.0050% for the 1 day immersion in 10% HCl. For the 2 days immersion, the lowest value was 0.0037% at 5% HCl, and for the 3 days immersion, it was 0.0060% at 15% HCl. A general trend of decreasing moisture content with increasing HCl concentration was observed for 2 and 3 days immersions, whereas the 1 day immersion results were more fluctuating across concentrations.

**TABLE 1.** Moisture content results (in percentage)

| Soaking Time | HCL Concentration | | |
|---|---|---|---|
| | 5% | 10% | 15% |
| | % | % | % |
| 1 | 0,0067 | 0,0050 | 0,0055 |
| 2 | 0,0037 | 0,0048 | 0,0063 |
| 3 | 0,0153 | 0,0072 | 0,0060 |

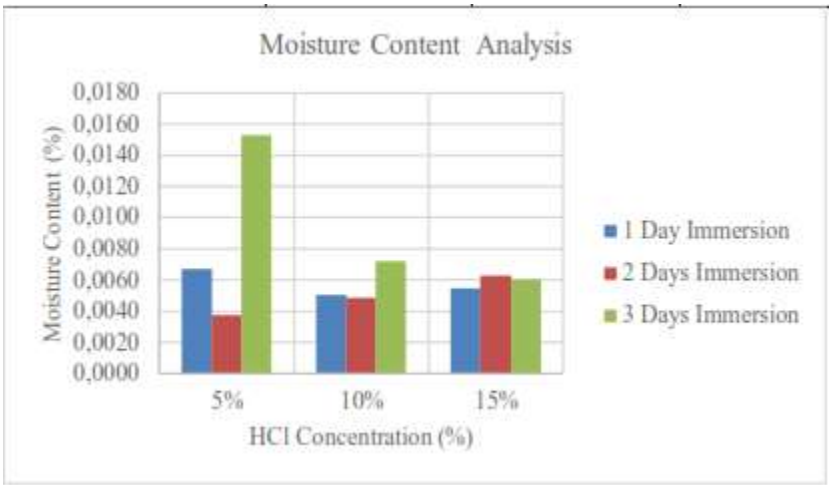


**FIGURE 2.** Graph of Moisture Content Results

These low moisture values indicate that the activated carbon samples successfully met the SNI standard, which is critical as excessive moisture can reduce adsorption efficiency and accelerate material degradation. Furthermore, low moisture levels imply that the available active sites on the adsorbent surface are not significantly blocked by water (Naftaly & Takwanto, 2024) The data suggest that varying HCl concentrations during activation did not lead to significant increases in moisture content, demonstrating that HCl activation at 5–15% remains a safe and effective treatment.

ANOVA two-factor with replication analysis confirmed that both immersion time and HCl concentration had statistically significant effects on moisture content. The F values for immersion time and HCl concentration were 746.2114 and 357.7915, respectively, both substantially exceeding the critical F value, with p-values of 1E-10 and 2.65E-09 ($\alpha = 0.05$). Additionally, their interaction effect was also significant, with an F value of 411.1159 and a p-value of 3.55E-10. These results emphasize the importance of optimizing the combination of immersion time and HCl concentration to achieve ideal moisture content in activated carbon.

## Ash Content Analysis

The presence of metal oxides in activated charcoal is indicated by its ash content, which consists of residual minerals. During the carbonization process, these minerals cannot be volatilized (Maylani et al., 2023). According to

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**Table 2** and **Figure 3**, the ash content test results for the activated carbon show that all samples exhibited very low ash levels, ranging from 1.0040% to 1.0170%, which is significantly below the maximum ash content allowed by the Indonesian National Standard (SNI), set at 10%. This demonstrates that activation using HCl solution was effective in removing most of the unwanted inorganic compounds. The lowest ash content, 1.0040%, was recorded in the sample treated with 15% HCl for 3 days, indicating the effectiveness of this treatment in reducing ash content.

**TABLE 2.** Ash content results (in percentage)

| Soaking Time | HCL Concentration | | |
|---|---|---|---|
| | 5% | 10% | 15% |
| | % | % | % |
| 1 | 1,0116 | 1,0116 | 1,0116 |
| 2 | 1,0114 | 1,0114 | 1,0114 |
| 3 | 1,0107 | 1,0107 | 1,0107 |

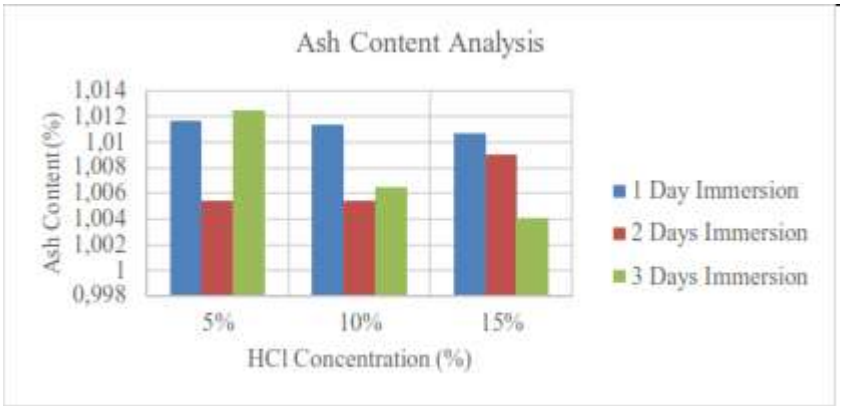


**FIGURE 3.** Graph of Ash Content Results

The data show that higher HCl concentrations and longer immersion durations tend to reduce ash content, although slight fluctuations are still observed. This can be explained by the fact that chemical activation with HCl helps dissolve inorganic compounds from the carbon material, and longer immersion time allows the chemical reactions to proceed more optimally. Higher HCl concentrations also contribute to accelerating the dissolution of ash- forming components. Therefore, a combination of 15% HCl concentration and 3-day immersion can be considered the most effective and optimal condition for producing activated carbon with the lowest ash content.

Based on the results of the two-factor ANOVA with replication for the ash content data, both immersion time and HCl concentration were found to have a statistically significant effect on the ash content of the activated carbon. This is indicated by the F-values for immersion time (437.5213) and HCl concentration (113.8471), both of which are far above the critical F-value of 4.256495. Moreover, the extremely low p-values (1.08E-09 for immersion time and 4.08E-07 for HCl concentration) compared to the alpha level of 0.05 confirm the statistical significance of these effects. This means that both variables exert a real influence on ash content outcomes.

The interaction between immersion time and HCl concentration also showed a significant effect, with an F-value of 257.2563, exceeding the critical value of 3.633089, and a p-value of 2.87E-09, which is well below the significance threshold. This indicates that the two factors interactively influence the final ash content. Therefore, to obtain activated carbon with low ash content that meets quality standards, an appropriate combination of immersion duration and HCl concentration must be applied during the activation process.

## Iodine Adsorption Capacity

The iodine adsorption capacity is a key indicator of the microporous structure of activated carbon and its ability to adsorb small molecules. As illustrated in **Table 3** and **Figure 4,** none of the tested samples met the minimum SNI requirement of 750 mg/g. The highest adsorption capacity recorded was 566.4816 mg/g in the sample treated with15% HCl for 3 days, while the lowest was 8.6292 mg/g in the 1-day immersion with 15% HCl.

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**TABLE 3.** Ash content results (in percentage)

| Soaking Time | HCL Concentration | | |
|---|---|---|---|
| | 5% | 10% | 15% |
| | % | % | % |
| 1 | 128,1690 | 128,1690 | 128,1690 |
| 2 | 48,4758 | 48,4758 | 48,4758 |
| 3 | 8,6292 | 8,6292 | 8,6292 |

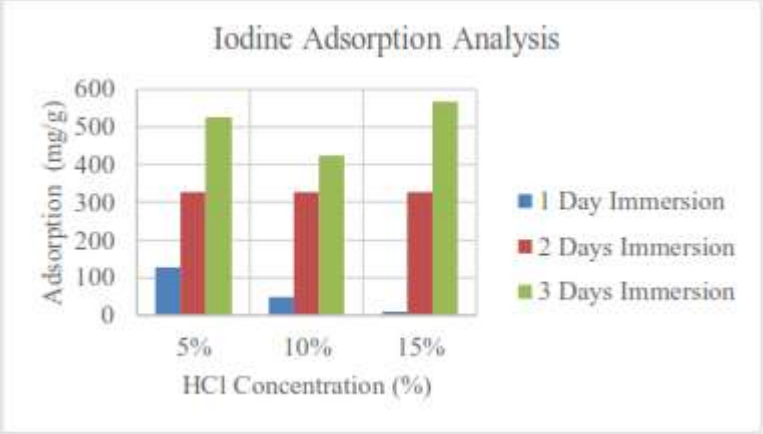


**FIGURE 4.** Graph of Ash Content Results

The adsorbent's capacity to uptake small molecules was evaluated using an iodine solution. This approach also indicates the presence of a microporous structure within the adsorbent, as a higher iodine uptake generally corresponds to a more optimal adsorbent performance (Manurung et al., 2022). Based on the graph in Figure 4, all tested activated carbon samples exhibited iodine adsorption capacities significantly below the minimum standard set by the Indonesian National Standard (SNI), which is 750 mg/g. The highest observed value was 566.4816 mg/g, obtained under treatment with 15% HCl for an immersion period of three days. Conversely, the lowest value was recorded at 8.6292 mg/g under a one-day immersion using the same HCl concentration. These findings suggest that the activation conditions employed in this study were insufficient to produce activated carbon with iodine adsorption performance that meets SNI quality standards.

In terms of trends, a general increase in iodine uptake was observed with prolonged immersion time, particularly at HCl concentrations of 5% and 15%. At 5% HCl, iodine adsorption increased significantly from 128.1690 mg/g (1-day immersion) to 526.6350 mg/g (3-day immersion). Similarly, at 15% HCl, the adsorption capacity improved markedly from 8.6292 mg/g to 566.4816 mg/g after three days of immersion. These results indicate that both higher HCl concentration and longer immersion time play crucial roles in enhancing the porosity of activated carbon. Nevertheless, the resulting iodine values remain suboptimal, warranting a reevaluation of the activation parameters, such as the type of activating agent, carbon washing procedures, or stirring duration. Optimization is therefore essential to achieve iodine adsorption levels compliant with the SNI standard.

According to the results of a two-factor ANOVA with replication, both immersion time and HCl concentration exerted statistically significant effects on iodine adsorption. This is evidenced by the F-values: F(immersion time) = 555.6512 and F(HCl concentration) = 10.76744, both of which exceed the critical F-value of 4.256495. Additionally, the p-values of $3.73 \times 10^{-10}$ and 0.004097, respectively, are well below the alpha level of 0.05, confirming the significance of both factors. These findings suggest that variations in immersion duration and acid concentration significantly influence the adsorption capacity of the resulting activated carbon.

Moreover, the interaction between immersion time and HCl concentration also showed a significant effect on iodine uptake, with an F-value of 12.74419 exceeding the critical F-value of 3.633089 and a p-value of 0.000948. This result highlights that the combination of these two variables has a synergistic effect on the adsorption performance. Therefore, to achieve iodine numbers that meet or exceed the minimum standard of 750 mg/g, it is necessary to simultaneously optimize both immersion conditions and acid concentration rather than evaluating them in isolation.

## CONCLUSION

Based on the research findings, all activated carbon samples exhibited moisture content below the maximum limit set by the Indonesian National Standard (SNI), which is 15%, with the lowest recorded value being 0.0037%. Furthermore, the ash content across all treatments remained well below the SNI threshold of 10%, with the lowest ash content observed at 1.0040% in the treatment involving 3 days of soaking with 15% HCl concentration.

However, the iodine adsorption capacity of all samples did not meet the SNI minimum standard of 750 mg/g, with the highest value recorded at only 566.4816 mg/g. Despite this, the variation in HCl concentration and soaking duration significantly influenced the moisture content, ash content, and iodine adsorption. This was supported by statistical analysis, where the F-values exceeded Fcrit and the p-values were less than the alpha level of 0.05, leading to the acceptance of the alternative hypothesis.

Overall, the optimal condition for water hyacinth-based activated carbon was achieved with 15% HCl concentration and a soaking time of 3 days, resulting in a moisture content of 0.0060%, ash content of 1.004%, and an iodine adsorption capacity of 566.5 mg/g.

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