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The Optimization of Sodium Chloride (NaCl) Concentration in the Activated Carbon Activation Process for Environmental Remediation

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ABSTRACT

Activated carbon from coconut shells is an effective adsorbent material for water treatment, textile waste purification, and environmental quality improvement. This study aims to determine the optimal concentration of sodium chloride (NaCl) as an activating agent in the production of activated carbon. The process used involves heating the coconut shells at 500°C, soaking them in NaCl solutions (1 M, 3 M, and 5 M) for 24 hours, drying at 105°C, and then performing a final activation at 800°C. Characterization was conducted by measuring the moisture content, ash content, fixed carbon, and the adsorption capacity for methyl orange dye according to the SNI 06-3730-1995 standard. The results showed that the activated carbon treated with 5 M NaCl exhibited the highest adsorption capacity (19.233 mg/g) and met the SNI standard. These findings confirm that activated carbon from coconut shells can be a cost-effective and efficient adsorbent material for various industrial applications.

INTRODUCTION

Coconut shell, an abundant agricultural waste in Indonesia, has significant potential as an environmentally friendly and high-value raw material for activated carbon production. Data from Agustina and Suryanto (2020) indicate that the annual production of coconut shell charcoal reaches 0.75 million tons. With its high surface area and microporous structure, activated carbon is capable of removing pollutants such as methyl orange from textile industrial wastewater.

Chemical activation methods using agents such as NaOH, KOH, and H3PO4 have been proven to improve the quality of activated carbon (Fitria, 2022). However, research on the use of NaCl as an activation agent is still limited, despite NaCl being safer, more affordable, and more environmentally friendly compared to other commonly used chemicals. Some studies have explored the activation of activated carbon with this salt, but no research has comprehensively optimized NaCl concentration and evaluated its impact on the physicochemical properties of activated carbon derived from coconut shells.

Therefore, this study fills this gap by systematically examining the effect of various NaCl concentrations on the characteristics of the resulting activated carbon. The findings of this study are expected to provide new insights into the use of NaCl as an alternative activation agent and support more sustainable and economical waste management practices.

RESEARCH METHODS

Materials and Equipment

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- **Materials**: Coconut shell, sodium chloride (NaCl), distilled water, methyl orange.
- **Equipment**: Furnace, analytical balance, UV-Vis spectrophotometer, desiccator, 60 mesh sieve.

Research Procedure

1. **Preparation of Activated Carbon**:
   - The coconut shell is carbonized at 500°C to remove volatile compounds and increase the carbon content. The resulting charcoal is then crushed and sieved through a 60 mesh sieve to obtain uniform particle size.
   - NaCl concentrations of 1 M, 3 M, and 5 M are selected based on preliminary studies indicating that higher salt solution concentrations enhance the activation of activated carbon by creating more active sites and microscopic pores.
   - The charcoal is soaked in NaCl solution for 24 hours to ensure optimal penetration of Na^+ and Cl^- ions into the carbon structure before being dried at 105°C to remove any residual moisture.
   - Activation is carried out at 800°C, based on literature suggesting that this temperature is effective in enhancing the surface area and pore structure of activated carbon, thereby improving its adsorption capacity.
2. **Characterization**:
   - The moisture content, ash content, fixed carbon, and adsorption capacity for methyl orange are tested according to the SNI 06-3730-1995 standard.
3. **Adsorption Test**:
   - A methyl orange solution (250 ppm) is treated with 0.5 g of activated carbon, and the adsorption efficiency is evaluated using a UV-Vis spectrophotometer.

RESULTS AND DISCUSSION

Characterization of Activated Carbon
The results of the activated carbon characterization tests are shown in Table 1.

Concentration NaCl (M)	Missing Section (%)	Moisture Content (%)	Ash Content (%)	Pure Activated Carbon (%)	Absorption Capacity (mg/g)
1	9,15	7,63	4,76	86,09	12,23
3	9,12	6,54	4,79	86,09	16,07
5	9,79	6,26	4,80	85,41	19,23
SNI	≤25	≤15	≤10	≥65	-

Data Analysis

1. **Loss on Heating at 950°C**: The loss on heating of the activated carbon ranged from 9.12% to 9.79%, meeting the SNI standard. The loss is correlated with the opening of the carbon's pores, which enhances its adsorption capacity.
2. **Moisture and Ash Content**: The moisture content (≤7.63%) and ash content (≤4.80%) meet the SNI standard. The low moisture and ash content indicate that the activated carbon has high quality with an optimal surface area.
3. **Adsorption Capacity for Methyl Orange**: The adsorption capacity increased with higher NaCl concentrations, with the highest adsorption capacity at 5 M NaCl (19.23 mg/g). NaCl activation expands the pore structure of the activated carbon, enhancing its adsorption efficiency.

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Industrial Implications and Environmental Applications

These results demonstrate that activation using NaCl not only produces activated carbon with high adsorption capacity but also offers an environmentally friendlier alternative compared to activation methods using chemicals like NaOH or KOH, which are corrosive and may pollute the environment.

On an industrial scale, this method is more economical as NaCl is readily available and cheaper than other activating agents. This makes the activated carbon production process more sustainable and suitable for adoption by waste management industries, especially in developing countries.

The produced activated carbon can be widely applied in the textile industry for wastewater treatment containing dyes, as well as in drinking water treatment and other industrial wastewater processing.

Comparison with Other Activation Methods

Activation methods using NaOH and KOH have been widely used in activated carbon production but tend to generate alkaline waste that is hazardous to the environment and requires additional neutralization processes.

Activation using H_3PO_4 is also frequently employed, but this material is a strong acid that can cause pollution if not properly managed.

In contrast, NaCl as an activation agent offers sustainability advantages because it does not produce toxic waste and can easily be washed off from the activated carbon after the activation process.

With an adsorption capacity of 19.23 mg/g, the activated carbon produced from NaCl activation demonstrates competitive effectiveness compared to other methods that often require more complex conditions and higher production costs.

CONCLUSION

The activation method using NaCl has been proven to produce activated carbon with high adsorption capacity, meeting industry standards, and is more economical and environmentally friendly compared to other activation methods. The results of this study provide a foundation for the application of the NaCl activation method on an industrial scale, particularly in the production of activated carbon for textile waste treatment and clean water processing.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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