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The potential of Jamblang Bark Actived Carbon (*Syzygium cumini*) in Reducing Lead Heavy Metal (Pb) Levels

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A B S T R A C T

Jamblang wood, also known as jambolin or jambolan, is a plant that is widespread in various tropical regions, including Indonesia. Jamblang bark has great potential as a source of raw material for making active carbon because it is rich in organic compounds, cellulose, and lignin, which can provide an ideal pore structure to capture and bind heavy metals. The literature search process was carried out on various databases (PubMed, Web of Sciences, EMBASE, Cochrane Libraries, and Google Scholar) regarding the potential of jamblang bark (*Syzygium cumini*) activated carbon in reducing lead heavy metal (Pb) levels. This study follows the preferred reporting items for systematic reviews and meta-analysis (PRISMA) recommendations. Activated carbon produced from jamblang bark (*Syzygium cumini*) has significant potential in reducing levels of heavy metal lead (Pb) in various wastewater treatment settings, drinking water treatment, and recovery of heavy metals from industrial waste.

1. Introduction

Activated carbon is a material that has an important role in controlling environmental pollution, especially in reducing levels of heavy metals such as lead (Pb) in various water sources and the environment. Heavy metals such as lead are dangerous contaminants that can poison aquatic ecosystems and have a negative impact on human health if they accumulate in excessive amounts. Therefore, efforts to identify, develop, and utilize natural ingredients that are effective in reducing heavy metal levels are very important in the context of sustainability and environmental protection.[1-3]

One natural material that is interesting to research is activated carbon obtained from jamblang bark (*Syzygium cumini*). Jamblang wood, also known as jambolin or jambolan, is a plant that is widespread in various tropical regions, including Indonesia. Jamblang bark has great potential as a source of raw material for making active carbon because it is rich in organic compounds, cellulose, and lignin, which can provide an ideal pore structure to capture and bind heavy metals. Previous research has revealed that activated carbon obtained from various natural raw materials can be effective in reducing heavy metal levels in various water environments.[4-6] However, further research is still needed to explore the potential of activated carbon from jamblang bark in this context. This study aims to investigate the ability of jamblang bark-activated carbon to reduce levels of the heavy metal lead (Pb) in various solutions, as well as to understand the interaction mechanism between this active carbon and heavy metals. It is hoped that the results of this study will provide a valuable contribution to the development of more effective waste processing and environmental protection methods, as well as explore the potential of Indonesia's natural raw materials, such as jamblang bark, in these efforts.

2. Methods

The literature search process was carried out on various databases (PubMed, Web of Sciences, EMBASE, Cochrane Libraries, and Google Scholar) regarding the potential of jamblang bark (*Syzygium cumini)* activated carbon in reducing levels of the heavy metal lead (Pb). The search was performed using the terms: (1) "jamblang" OR "java plum" OR "*Syzygium cumini*" OR" *Syzygium cumini* active carbon" AND (2) "*Syzygium cumini*" OR "Pb level." The literature is limited to preclinical studies and published in English. The literature selection criteria are articles published in the form of original articles, an experimental study about the potential of jamblang bark (*Syzygium cumini)* activated carbon in reducing levels of the heavy metal lead (Pb), studies were conducted in a timeframe from 2013-2023, and the main outcome was the potential of jamblang bark (*Syzygium cumini*) activated carbon in reducing levels of the heavy metal lead (Pb). Meanwhile, the exclusion criteria were studies that were not related to the potential of jamblang bark (*Syzygium cumini*) activated carbon in reducing levels of the heavy metal lead (Pb), the absence of a control group, and duplication of publications. This study follows the preferred reporting items for systematic reviews and meta-analysis (PRISMA) recommendations.

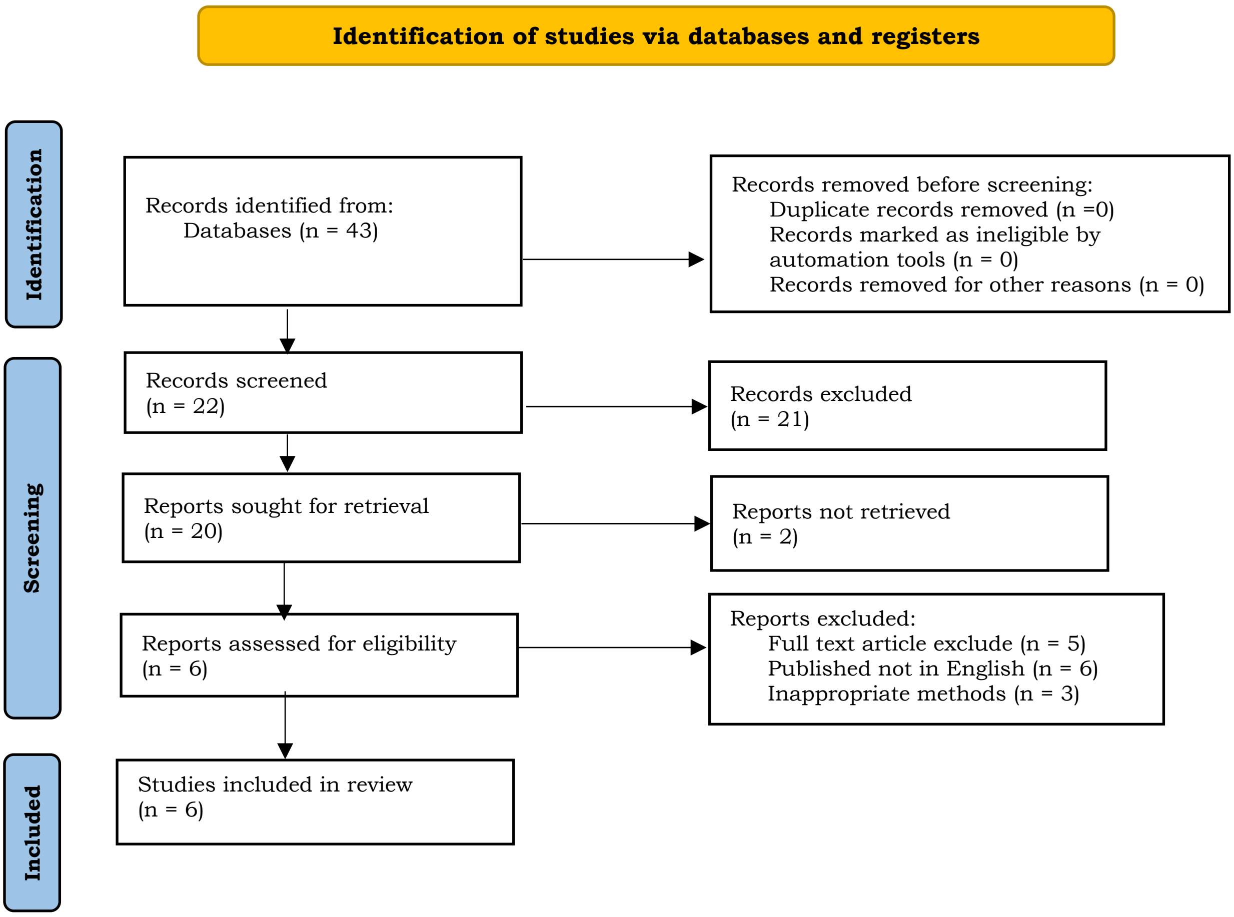

Figure 1. PRISMA flowchart.

3. Results and Discussion

The potential of jamblang bark

Jamblang bark (*Syzygium cumini*) is a part of the plant that is often ignored and considered waste or agricultural residue. However, in fact, jamblang bark has enormous potential to develop active carbon, which can be used to absorb heavy metals and other dangerous compounds from the environment. Jamblang bark contains a variety of natural compounds, including cellulose, lignin, and other organic compounds. These compounds have the ability to be converted into active carbon through carbonization and activation processes. The process of making activated carbon from jamblang bark produces a very effective pore structure. These pores have various sizes, including micro, meso, and macro pores, which provide a large surface area for interaction with heavy metals. Activated carbon produced from jamblang bark has strong adsorption capabilities, meaning it is able to attract and retain heavy metals such as lead (Pb) on its surface. This makes it effective in cleaning water and the environment from heavy metal pollution. Activated carbon from jamblang bark can be used in various applications for wastewater treatment, drinking water treatment, and recovery of heavy metals from industrial waste. This contributes to reducing environmental pollution and protecting freshwater resources. By utilizing the often overlooked jamblang bark as a raw material, we can reduce agricultural waste and promote a more sustainable approach to natural resource use.[7-10]

Activated carbon manufacturing process

Carbonization is the critical initial stage in the manufacture of activated carbon and follows certain procedures to produce a material with the desired carbon properties. The carbonization process is carried out at very high temperatures, usually above 500°C. This high temperature is needed to convert organic raw materials, such as jamblang bark, into carbon. This process involves breaking chemical bonds in organic materials, removing non-carbon elements (such as hydrogen and oxygen), and leaving behind the desired basic carbon structure. Anaerobic conditions, namely conditions without oxygen or with a very limited amount of oxygen, are very important in carbonization. This is because carbonization in an oxygenated atmosphere can result in the complete combustion of organic raw materials to ash. In this process, we want to maintain the high properties of carbon, such as adsorption ability and pore structure, so it is important to avoid complete combustion. The result of the carbonization stage is a material that contains quite high carbon but may still contain impurities or non-carbon substances. This material can then be treated further, such as through chemical or physical activation, to produce purer activated carbon with an optimal pore structure. The carbonization process is a key step in converting organic raw materials into active carbon, which is effective in absorbing heavy metals and other pollutants. By maintaining proper temperature and anaerobic conditions during carbonization, we can create a final product that has a high adsorption capacity and a pore structure that is ideal for environmental treatment purposes.[11-13]

After the carbonization stage, the resulting carbon material may still have a less than ideal pore structure. The activation stage is the next key step in optimizing the pore structure of activated carbon to increase adsorption capacity and effectiveness in capturing contaminants, including heavy metals. The activation process can be carried out through two main methods, namely physical activation and chemical activation. Physical activation involves mechanical treatment or the use of certain gases at high temperatures to open and expand existing pores. Chemical activation involves the use of chemicals such as phosphoric acid or potassium hydroxide, which can help in changing the structure of carbon materials. The goal of the activation process is to increase the number, size, and diversity of pores in activated carbon. These pores will be effective sites for capturing pollutant molecules such as heavy metals. The more and more varied pores formed, the more effective activated carbon is in absorbing pollutants. During the physical activation process, the use of certain gases such as CO_2 or water vapor at high temperatures is common. These gases can carve out and form larger pores. The temperature and type of gas used can be adjusted according to the desired activated carbon production goals. The result of activation is activated carbon with enhanced adsorption capacity. This allows activated carbon to be more effective in absorbing heavy metals, organic compounds, and other pollutants from the water or air environment. Activated carbon that has gone through the activation stage is more suitable for wastewater treatment applications, drinking water treatment, and reducing heavy metal levels in various environmental settings. The optimal pore structure makes it more efficient in purifying the environment from pollutants.[14-16]

Activated carbon shaft structure

Activated carbon produced from jamblang bark has a pore structure, which is very important in reducing heavy metal levels. The structure of the pores in activated carbon is a very important factor in determining its ability to reduce levels of heavy metals and other dangerous compounds from the environment. Micropores have a diameter of less than 2 nanometers. These pores are very small and have a high surface area. They are effective in absorbing small molecules and heavy metals that may be present in the form of small ions. Micropores act as very effective traps for heavy metals dissolved in solution. Mesopores have a diameter of between 2 and 50 nanometers. They are larger than micropores but still small enough to capture larger compounds and particles. Mesopores are important in absorbing heavy metals, which may be in the form of colloids or small particles in solution. Macropores have a diameter of more than 50 nanometers. They are larger pores and can capture much larger particles and compounds, such as solid particles or sediment. Macropores provide physical stability to activated carbon and enable the capture of larger heavy metals. The diverse pore structures in activated carbon, ranging from micropores to macropores, provide a large surface area for interaction with heavy metals. The more pores available and the more diverse their sizes, the greater the active carbon's absorption capacity for heavy metals. Heavy metals can be absorbed into these pores, where they are surrounded by activated carbon and trapped within the structure of the pores. Therefore, a good pore structure is key to making activated carbon effective in reducing levels of heavy metals and harmful compounds in a variety of environmental treatment settings. The wide and varied pores allow activated carbon to be a very efficient adsorbent agent in cleaning water and the environment from heavy metal pollution.[17,18]

Heavy metal absorption ability

Activated carbon produced from jamblang bark has a significant ability to absorb heavy metals such as lead (Pb) from water solutions. The process of absorbing heavy metals by activated carbon involves various mechanisms, including adsorption, ion exchange, and complexation. Adsorption is the main mechanism in the absorption of heavy metals by activated carbon. In the adsorption process, heavy metals dissolved in solution interact with the surface of the activated carbon. Because activated carbon has a large surface area with micro and meso pores, heavy metal ions can be trapped and attached to the surface of activated carbon through physical interaction forces, such as van der Waals forces. Ion exchange occurs when heavy metal ions in solution replace other ions on the surface of activated carbon. Activated carbon has a number of ions bound to its surface, such as hydrogen ions (H^+) or sodium ions (Na^+). Heavy metal ions can compete with these ions for attachment to the activated carbon surface, resulting in effective ion exchange. Complexation occurs when heavy metals form complexes with compounds on the surface of activated carbon. This often happens with heavy metals, which can form complex bonds with functional groups present in active carbon, such as carboxylic acid groups or hydroxyl groups. The complexation process can help in the capture and containment of heavy metals in insoluble forms. The combination of these mechanisms makes activated carbon a very effective agent in reducing heavy metal levels in water and the environment. Activated carbon's ability to adsorb heavy metals is one of the main reasons why it is used in wastewater treatment, drinking water purification, and heavy metal pollution control in a variety of industrial and environmental settings.[15-17]

The ability of activated carbon to reduce heavy metal levels is very important in various applications related to wastewater treatment, drinking water treatment, and recovery of heavy metals from industrial waste. Activated carbon is used in wastewater treatment to remove heavy metals dissolved in water. This involves an adsorption process, where activated carbon absorbs heavy metals from wastewater solutions, reducing environmental pollution and ensuring that water discharged into the environment meets established standards. For safe drinking water, it needs to undergo a treatment process that involves the removal of various contaminants, including heavy metals. Activated carbon is used in drinking water treatment to remove heavy metals that may be present in raw water. This helps protect human health from the potential toxic effects of heavy metals and ensures drinking water is safe for consumption. In several industries, heavy metals such as lead, cadmium, and mercury are used in various production processes. Activated carbon is also used in the process of recovering heavy metals from industrial waste. Once heavy metals are adsorbed on activated carbon, they can be elucidated and recovered, thereby minimizing waste and creating a more sustainable approach to the use of natural resources. The use of activated carbon in wastewater treatment applications and drinking water treatment helps protect aquatic ecosystems and the general environment from the negative impacts of heavy metal pollution. This supports the goals of environmental protection and healthy ecosystem balance. Activated carbon is also a relatively environmentally friendly alternative because it can be made from natural raw materials such as jamblang bark, which is often overlooked. Thus, the use of activated carbon in this context is not only effective in reducing heavy metal levels but also supports the principles of sustainability and wiser management of natural resources.[19,20]

4. Conclusion

Activated carbon produced from jamblang bark (*Syzygium cumini*) has significant potential in reducing levels of heavy metal lead (Pb) in various wastewater treatment settings, drinking water treatment, and recovery of heavy metals from industrial waste.

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