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UTILIZATION OF BANANA PEELS AS ACTIVE CARBON FOR POLLUTANT REMOVAL IN WASTEWATER (REVIEW ANALYSIS)

Vina Rofikoh[1], Badrus Zaman[2], Budi Prasetyo Samadikun[2]
[1]Environmental Engineering Master's Study Program, Diponegoro University
[2]Department of Environmental Engineering, Diponegoro University
Jl. Prof. Soedharto SH, Tembalang, Semarang
E-mail: rofikohvina16@gmail.com

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ABSTRACT

Utilization of Banana Peels as Active Carbon for Pollutant Removal in Wastewater (Review Analysis). Pollutants from human activities released into the environment, including heavy metals, dyes, and chemicals, can harm the environment and living organisms. One solution offered to treat these pollutants is an adsorption technique using activated carbon from banana peel waste. The research aims to review the potential of banana peel waste as active carbon to remove various contaminants in wastewater and highlight the opportunities and challenges. This research uses a systematic literature review method, or what is usually called a Systematic Literature Review (SLR), to collect data from the Google Scholar online article database and E-Journal at SSO Undip (Single Sign On). The results of the literature review show that active carbon from various types of banana peels, such as Musa Acuminata, Musa sp., Musa paradisiaca L., and Musa Acuminatabalbisiana has been proven to be able to remove organic materials, inorganic anions, heavy metals, dyes, and chemical compounds from wastewater.

INTRODUCTION

Each year, many pollutants from human activities are released into the environment, including heavy metals, chemicals, and other harmful substances that are now present in most ecosystems. [1]. Most toxins are insoluble in water and stay there for years. These toxins not only harm plants, animals, and humans, but also marine life [2]. Several methods have been developed to treat wastewater, which can be divided into three categories: physical, chemical, and biological methods [3]. The simplest and most common methods are physical methods, such as filtration, adsorption, distillation, skimming, and sedimentation. Various organic or inorganic contaminants are removed from wastewater using this technique. The adsorption process is the most effective technique and is often applied to treat wastewater from all physical approaches [4].

Adsorption with activated carbon has been proven as a potential technique for removing pollutants from wastewater due to its flexibility, effectiveness, large surface area, simple and straightforward operation process, and economy. Recently, cheap adsorbents with high pollutant binding capacity have been in great demand [5]. Effective and economical adsorbents can be made from locally available materials, including agricultural waste. Various types of agricultural waste, such as rice straw and husks, coconut husks and shells, stems, fronds, empty fruit bunches, palm fibre and shells, and bamboo stems, have been investigated for pollutant removal from wastewater. [6]. Banana peels are one of the agricultural waste products that are produced in large quantities as a result of fruit consumption. The peel accounts for approximately 40% of a fresh banana's weight. The banana industry produces more than 57.6 million metric tonnes of banana peels per year [7].

Banana peels contain organic molecules rich in carbon, such as cellulose, hemicellulose, pectin, and lignin, which form fibres of fairly good quality. The contents of lignin, cellulose, hemicellulose, fibre, crude protein, and ash in banana peels are 16.45%, 18.06%, 21.40%, 1.4%, 10.56%, and 4.5%, respectively [8]. Cellulose in plant biomass plays a role in processing liquid waste to remove various contaminants, such as toxins, heavy metals, and dyes [9]. Due to their organic molecule content, banana peels have been used to remove various pollutants from wastewater. Mohammed et al. reviewed banana peel as a biosorbent for heavy metal removal [10]. Meanwhile, Farias et al. reviewed banana peel powder as a biosorbent for removing dangerous organic pollutants from wastewater [11]. Banana peels, as active carbon, have a great potential to remove pollutants from wastewater. However, the application of activated carbon from banana peel waste in wastewater treatment still receives less attention. The aim of this research is to review the potential of banana peel waste as active carbon to remove various contaminants from wastewater and highlight the opportunities and challenges faced.

MATERIALS AND RESEARCH METHODS

The method used in this research is a technique known as a systematic literature review, or SLR. A systematic literature review begins with the identification and synthesis of all related publications to evaluate various matters regarding the topic being studied [12]. SLR allows for more thorough and enlightening research critique and summary. In this research, SLR was carried out by accessing scientific articles in an online database called Google Scholar and an e-journal at SSO Undip (Single Sign On). The keywords used in the article search were "activated carbon from banana peel to remove pollutants in wastewater" and "banana peel-based activated carbon to remove pollutants in wastewater."

After screening peer-reviewed articles, a total of 70 articles on this topic were found in the search results. The process of screening articles is a crucial step in conducting a comprehensive and systematic review of the literature, which can enhance the rigor of educational and research planning, particularly when reviewing publications [12]. After reading the abstracts of 70 articles, the number of articles was reduced to 52 by evaluating the relevance of the abstract content and inclusion criteria. After reading all 52 manuscripts, it was found that 18 manuscripts meet all the prerequisites for inclusion in the 29 journals that have been determined.

The inclusion criteria in the article search carried out were: 1) articles related to activated carbon, banana peel waste, and wastewater treatment; 2) publication of works from a maximum of five previous years, namely from 2018 to 2023; 3) accreditation and publication in reputable international journals; and 4) the text of the journal article is complete and accessible. The article screening process is presented in Figure 1.

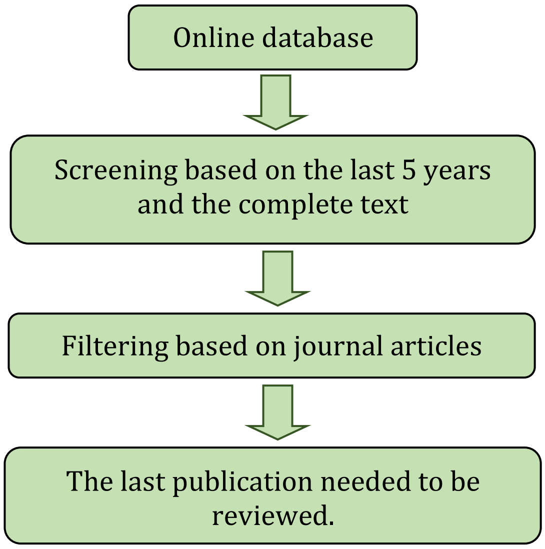

Figure 1. Article screening diagram

RESEARCH RESULTS AND DISCUSSION

Making Activated Carbon

Various precursors, such as banana peel waste, can be used to make activated carbon. These precursors' high carbon content leads to the production of activated carbon with high yields [13]. The activated carbon production process generally includes two methods, namely carbonisation and carbon activation. Before going through the carbonisation process, raw materials usually undergo initial treatment, including chopping, grinding, and filtering, with the aim of ensuring that the particle size is appropriate and making it easier to handle the raw material further. [14]. Figure 2 shows an illustration of the process of making activated carbon from banana peels.

Carbonisation involves the thermal decomposition of the raw material, which removes the non-carbon portion and creates a solid carbon mass with a porous structure. Carbonisation is carried out through pyrolysis or gasification at high temperatures and in the atmosphere [15]. Tools that can be used for carbonisation include tubular furnaces, muffle furnaces, and modified microwaves [16]. The temperature required for carbonisation ranges from 300 to 900 °C.

The activation process can be carried out physically and chemically, which can cause an increase in pore diameter and create new pores [17]. In addition to physical and chemical methods, activation can also be done physico-chemically [18]. Physical activation often uses a two-step procedure that begins with carbonisation of the dry material at 400–700 °C and ends with activation using an oxidising gas in the form of steam, air, CO_2, or a combination thereof. [19]. Chemical activation is used more often than other activations. The chemical compounds used as activators are KOH, $ZnCl_2$, K_2CO_3, and $CaCl_2$. Excessive use of chemicals may contribute to chemical activation, but various studies have shown that adsorbents can remove up to 99% of contaminants from water. [20].

Figure 2. Illustration of making activated carbon from banana peels

The use of activated carbon derived from banana peel

Extensive industrial expansion has accelerated environmental pollution, which eventually enters water bodies. Agricultural waste, such as banana peels, has been thoroughly researched as a starting point for solving water pollution problems. Banana peel is a suitable raw material for the production of activated carbon that can be used for various wastewater treatment applications, including the removal of organic and inorganic materials, heavy metals, chemical compounds, and dyes (Table 1).

Table 1. Pollutant removal in wastewater using activated carbon from banana peels

Types of bananas	Manufacturing method	Wastewater	Pollutant	Efficiency	Reference
Musa Acuminata	Carbonization (400°C), H3PO4 activation 30% + temperature 800°C	Synthetic domestic wastewater	Turbidity	90%	(21)
			BOD	89%	
			COD	84%	
			Cr	68%	
			PB	94%	
Musa sp.	Carbonization (230°C) KOH Activation 50%	Synthetic wastewater	PB	100%	(10)
			Fe	64%	
Musa Acuminata	Carbonization (200°C) 25% HCl Activation	Contaminated water	M N	52%	(22)
			Fe	68%	
			PB	80%	
			Zn	99%	
Musa sp.	Carbonization (600°C) 1 M H2SO4 Activation	Synthetic wastewater	CD	75%	(23)
			PB	30%	
		Real waste water	CD	99%	
			PB	92%	
Musa paradisiaca	Carbonization (400°C) NaOH Activation 45%	Synthetic wastewater	La	40%	(24)
			Ce	35%	
			Nd	22%	
			Sm	8%	
			Y	55%	
*Moses*sp.	Carbonization (50°C)	Brewery wastewater	Cl	3%	(25)
			SO4	2.8%	
			PO4	37%	
			NO3	70.6%	
			N	70.5%	
*Musa Acuminata*balbisiana	Carbonization (400°C) 1.5 M KOH Activation	Wastewater	*Methylene blue*	80%	(26)

Active carbon from banana peels can be used as an adsorbent to remove pollutants from wastewater, according to Table 1. Previous research has reported that biomass from the banana peels of Musa sp., Musa Acuminata, and banana peels can effectively remove pollutants from both synthetic and natural wastewater. *Musa paradisiaca*, and Musa acuminata balbisiana. Activated carbon from banana peels *(Musa acuminata) is able* to remove turbidity, BOD, COD, and heavy metals (Cr, Pb, Mn, Fe, and Zn) with an efficiency of 52–99%. Carbon from Musa sp. banana peels is capable of removing Pb, Fe, and Cd, as well as the inorganic anions Cl, SO4, PO4, NO3, and N by 2.8–100%. Activated carbon from Musa paradisiaca banana peel is able to remove rare metal ions such as La, Ce, Nd, Sm, and Y from synthetic wastewater with an efficiency of 8–55%. Methylene blue dye from wastewater can be removed with activated carbon from Musa acuminata balbisiana banana peels, up to 80%.

Opportunities and Challenges

Various studies have recently been conducted to demonstrate the potential of using sewage as a precursor for the treatment of pollutants in wastewater. Banana peel is an agricultural waste that is easy to obtain, economical, and environmentally friendly, making it an alternative precursor choice. In addition, the waste precursors are comparable to commercial precursors such as coal and lignite. This is because activated carbon from banana peel waste has a large surface area and high porosity, so its contaminant absorption capacity is also high. [(27)]. Various types of pollutants in wastewater can be removed by applying activated carbon from banana peels [(28)].

Activated carbon from banana peel waste has many advantages. However, activated carbon may have varying degrees of effectiveness in removing certain pollutants. Therefore, it is necessary to choose the right type of banana peel that can absorb specific contaminants in wastewater. In addition, banana peels require pre-processing and activation processes to convert them into effective and efficient activated carbon. This process can increase the cost of producing activated carbon [(29)]. Over time, activated carbon reaches the limits of its adsorption capabilities and must be replaced or renewed. To guarantee the useful life and effectiveness of activated carbon, proper regeneration techniques are essential. This is because disposing or handling used activated carbon can cause environmental problems.

CONCLUSIONS AND RECOMMENDATIONS

Banana peel waste has been reported as an alternative precursor for treating pollutants in wastewater. The use of activated carbon from Musa acuminata banana peels is very effective in removing turbidity, organic matter, and heavy metals from wastewater. Carbon from banana peel Musa sp. has proven effective for removing heavy metals and inorganic anions from wastewater. Banana peel Musa paradisiaca is capable of removing up to 55% of rare metal ions from wastewater. Meanwhile, banana peel Musa Acuminatabalbisiana is able to remove up to 80% of methylene blue dye. Activated carbon from banana peels has the advantages of being easy to obtain, economical, and environmentally friendly. However, this carbon has varying effectiveness against certain pollutants, and its manufacture requires pre-treatment. This carbon application has been proven on a laboratory scale. Suggestions for further research include the need to apply activated carbon on a wider scale or in real industry.

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