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The potency of palm kernel shell as an adsorbent

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KEYWORDS

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ABSTRACT

The palm kernel shell (PKS) is the endocarp of the oil palm fruit that protects the kernel of the oil palm crops. PKS is a by-product of separating the kernel of the palm kernel nut This by-product tends to be used as a solid biofuel because of it's high carbon content. Meanwhile, the need for clean water in Indonesia grows year after year. The increased production of clean water is accompanied by the use lot of chemicals as water purification medium. PKS is lignocellulosic biomass with a lot of potential because of its characteristics and contents, including the use of materials as adsorbents. PKS has been evaluated and shown to be useful in dealing with heavy metal pollution. The use of activated carbon-based PKS as an adsorbent has also been intensively investigated such as using various activation techniques including acid activation and steam activation at high temperatures. There will be variances in their adsorption capability and adsorption process due to differences in structural properties and functional groups, as well as originating from different biomass sources with different varieties.

Introduction

Rapid industrial and economic development have an influence on the environment and raise awareness of the importance of water quality, particularly its impact on human health. Some of these pollution issues include an increase in nitrate (NO3-) contamination in the Bandung area of West Java, albeit remaining below the WHO criteria (Taufiq et al., 2019), impact of the high number of industrial activity in the Surabaya and Sidoarjo districts of East Java, the arsenic content in groundwater tests has above the threshold (Rochaddi et al., 2019), and according to study on the potential for hazardous components in well water in the Maros district of South Sulawesi, the lead and chromium content surpassed the WHO and national criteria. Exposure to these metals may raise the community's chance of developing cancer (Astuti et al., 2021). Various kinds of water purification methods have been widely used, one of which is by using the adsorption method. The adsorption method utilizes the ability of a solid to concentrate certain substances in a fluid, either in the gas or liquid phase on the solid surface (Tien, 2019). Environmentally friendly adsorbents are an important innovation in industrial waste treatment, because industrial waste treatment usually uses biological decomposition which is more costly and time consuming (Ezzuldin et al., 2019). Some examples of biosorbents used for water treatment are rice hull treated by NaOH, rice husk coated by cellulose (Basu et al., 2019; Dan et al., 2021), and sugarcane bagasse immobilized by Na-alginate (Ullah et al., 2013). These materials contain complex carbohydrates such as cellulose, hemicellulose and lignin. The three biopolymers (lignocellulose) include several functional groups and can be employed as heavy metal adsorption medium in water (Ullah et al., 2013). Carbohydrate biopolymer has a distinct structure and physicochemical properties, the reactive groups in the polymer chain, such as hydroxyl, acetamide, or amino functional group attract sorbents due to their stability, sensitivity, and high selectivity (Fouda-Mbanga et al., 2021). The oil palm shell (CKS) is the endocarp of the oil palm fruit that protects the

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kernel of the oil palm kernel. CKS is a by-product of separating kernels from oil palm fruit shells. Based on data from the Indonesian Central Statistics Agency in 2020, the volume of palm oil shell production reached 3,168,848 tons, with an export value of 299,007,000 dollars. (Indonesian Central Statistics Agency, 2021). Nearly 90% of the CKS were used as fuels, even though it has the potential as an adsorbent, one of which is for water purification.

Discussion

Lignocellulosic Materials as an Adsorbent

Agricultural waste, algae, bacteria, and industrial waste can all be employed as biosorbents. Furthermore, the use of biosorbent will not contaminate the environment because it will not develop secondary contaminants after being used as an adsorbent. Because it is made from natural substances, this material contains a large number of functional groups that promote hydrophobic interactions during the adsorption process, which usually depends on the pH of the solution. The use of biosorbents is determined not only by their absorption capacity, but also by their reusability; lignocellulosic material is one of the most often utilized biosorbents (Adewuyi, 2020). The most abundant biomass on the planet is lignocellulose. This substance has long been recognized as an alternate source for the production of fuels and chemicals. The major components of biomass are carbohydrate polymers (cellulose and hemicellulose) and non-carbohydrate polymers (lignin). To reinforce and harden plant cell walls, lignin bonds to cellulose and hemicellulose fibers (Abdel-Hamid et al., 2013). Due to their abundance in nature, affordability, capacity for biodegradation, and availability of efficient adsorption sites in their macromolecules, lignocellulosic materials have received considerable interest for their ability to absorb various heavy metal ions from water.

Adsorbents from biomass have been studied for water purification from heavy metals using a variety of material sources with varying treatment, optimization, and lignocellulosic content. Adsorption capacity and mechanism will differ due to variances in structural properties and functional groups, as well as originating from distinct biomass species (Wang et al., 2019). Ion exchange, chelation, and complexation with functional groups on the adsorbent's surface, as well as the release of H_3O^+ into a liquid solution, are the working principles of biosorption on heavy metals using lignocellulosic biomass. The electrostatic interaction between positive cations and negative anions in the biosorbent causes ion exchange. The method of biosorption can vary, but it can be anticipated if the sorbent's surface structure and functional groups are known (Sarker et al., 2017). The functional groups of materials have a significant impact on the adsorption of heavy metal ions because they can develop a relationship with these metal ions through chelation, complexation, chemical sorption, diffusion through pores, and surface adsorption (Baby et al., 2019).

Some lignocellulosic materials used as adsorbents are as follows (Table 1). Rice hull is material based on lingocellulosic component with hemicellulose is 32% in weight total, Cellulose is 21% in weight total, and lignin is 21% in weight total. Based on the research, most heavy metal ions are effectively removed from rice hulls treated with sodium hydroxide. The electrostatic interaction between the negatively charged rice hulls and the positively charged metal ions is thought to be the primary removal mechanism. pH had a significant impact on metal ion removal, with a pH of 5 working best for the majority of the metal ions of interest. Because of the quick removal kinetics, the processed rice husk is a suitable solid phase extraction type material for preconcentrating and recovering metal ions at low concentration levels, allowing for the employment of less expensive analysis methods for further detection. If scaled up to a big scale, this sort of green biosorbent might be used to remove and recover heavy metals from the environment (Dan et al., 2021). In other research, a humic acid-coated cellulose produced from rice husk was created to remove chromium and nickel from potable water while maintaining fundamental water quality criteria. The developed sorbent was described and employed for chromium and nickel uptake from aquatic medium. The humic acid layer over the cellulose was found to dramatically boost Ni and Cr sorption. A batch-method uptake analysis revealed more than 95 percent sorption of both chromium and nickel in the concentration range of 5 to 100 ppm. Several factors, including pH and equilibrium time, were tuned. The Langmuir sorption isotherm was used, and the sorption capacity for Nickel was 12.41 mg/g and 19.39 mg/g for Chromium cSugarcane is made up of an outer rind and an interior pith. The inner pith contains the bulk of the sucrose as well as bundles of tiny fibers. The outer rind has longer and finer fibers that are arranged randomly throughout the stem and are held together by lignin and hemicelluloses. Sugarcane bagasse is a lignocellulosic plant waste that contains roughly 40% cellulose, 24% hemicellulose, and 25% lignin. Immobilized sugarcane bagasse by Na-Alginate (2 percent w/v) provided significant absorption of Cr(VI) and Cr(III) at 80.6% and 41.5%, respectively, while at optimum conditions, up to 73 percent chromium adsorption was reported onto immobilized sugarcane bagasse biomass. Sugarcane bagasse biomass sorption capacity varies substantially depending on beginning pH, biosorbent dosage, initial metal ion concentration, and contact period. The Langmuir model and the pseudo-second order best described the biosorption kinetics (Ullah et al., 2013). Banana peel contains lignin (6-12%), cellulose (7,6-9,6%), and hemicelluloses (6,4-9,4%) (Arunakumara et al., 2013). Activated carbon from this material is utilized as a natural adsorbent to absorb the metal content of Mn, Fe, Pb, and Zn in water. According to the findings of this investigation, maximal absorption (99,27%) occurred at neutral pH with a contact period of 120 minutes and an adsorbent weight of 200 mg (Khairiah et al., 2021). Cellulose fibers from coconut husk were treated with tannin and used as a biosorbent to remove heavy metal ions from wastewater, including Cu(II), Cd(II), and Pb(II). The adsorption capacity of Pb(II), Cd(II), and Cu(II) ions was 38.02 mg/g, 59.52 mg/g, and 72.99 mg/g under optimal conditions of pH 5.0 and 30 min of contact time, respectively (Taksitta et al., 2020). Coconut husk has a high content of hemicelullose up to 17,73% and cellulose up to 26,72% in total weight (Muharja et al., 2020).

Table 1. The Findings of Various Investigations on Lignocellulosic Materials as Adsorbents

Biosorben	Treatment	pH	Contact Time	Temp	Adsorbent concentration	Result	Reference
Sugarcane Bagasse	Immobilized by Na-Alginate	2	24 h	25 °C	100 mg	80,6% for Cr(VI) with maximum capacity of adsorption 41,7 mg/g	(Ullah et al., 2013)
Rice Hull	-	4,9 – 5,0	24 h	Room temp.	100 mg	70 – 80% max. for Pb, Cd, Cu, dan Ag ion	(Dan et al., 2021)
Rice Husk	Coated by Humic Acid	5,0 – 6,0	8 h	3 °C, 25 °C, 60 °C	100 mg	More than 95% uptake, sorption sapacity of Nickel 12,41 mg/g and Chromium 19,39 mg/g	(Basu et al., 2019)
Banana Peel	Activated Carbon	4,0 – 8,0	30 – 150 min	200 °C	50 – 200 mg	99,27% maximum for Mn, Fe, Pb, and Zn adsorption	(Khairiah et al., 2021)
Coconut Husk	Immobilized by Tannin	5,0	30 min	Room temp.	20 mg	8.02 mg/g for Pb(II), 59.52 mg/g for Cd(II), and 72.99 mg/g for Cu(II).	(Taksitta et al., 2020)

Palm Kernel Shell potency as an Adsorbent

Palm oil is involved in a wide variety of consumer items, from meals to cosmetics (Oliphant & Simon, 2022). Over the last 50 years, the output of palm oil has expanded dramatically. The globe produced only 2 million tonnes in 1970. This is now 35 times higher: the world produced 71 million tonnes in 2018. Figure 1 depicts the change in worldwide output (Ritchie & Roser, 2021). Oil palm plantations have grown significantly throughout Southeast Asia over the last decade, thanks to the subtropical Asian monsoon and conditions of high rainfall, high temperature, and high intensity of sunshine, all of which are conducive to the rapid development of tropical plants. A 5-year-old oil palm tree may produce 40-60 kg of fruit 5-6 times each year and can live for 20 years or more. The productivity is 2.8 tons per acre, which is around seven times that of soybean oil production (Sakai et al., 2022). Indonesia is the world's largest producer of palm oil, with an annual output of 48.8 million tons (Indonesian Central Statistics Agency, 2021). The typical oil palm fresh fruit bunch (FFB) comprises 20% to 25% oil, with the majority mainly moisture and biomass including 7% palm kernel shell and 5% of kernels itself. After oil recovery, the main biomass available at mills is mesocarp fiber (MF), palm kernel shell (PKS), and EFB. The majority of the MF and a portion of the PK shell are used as fuel for the boilers, which provide steam and energy for mill operation (Sakai et al., 2022).

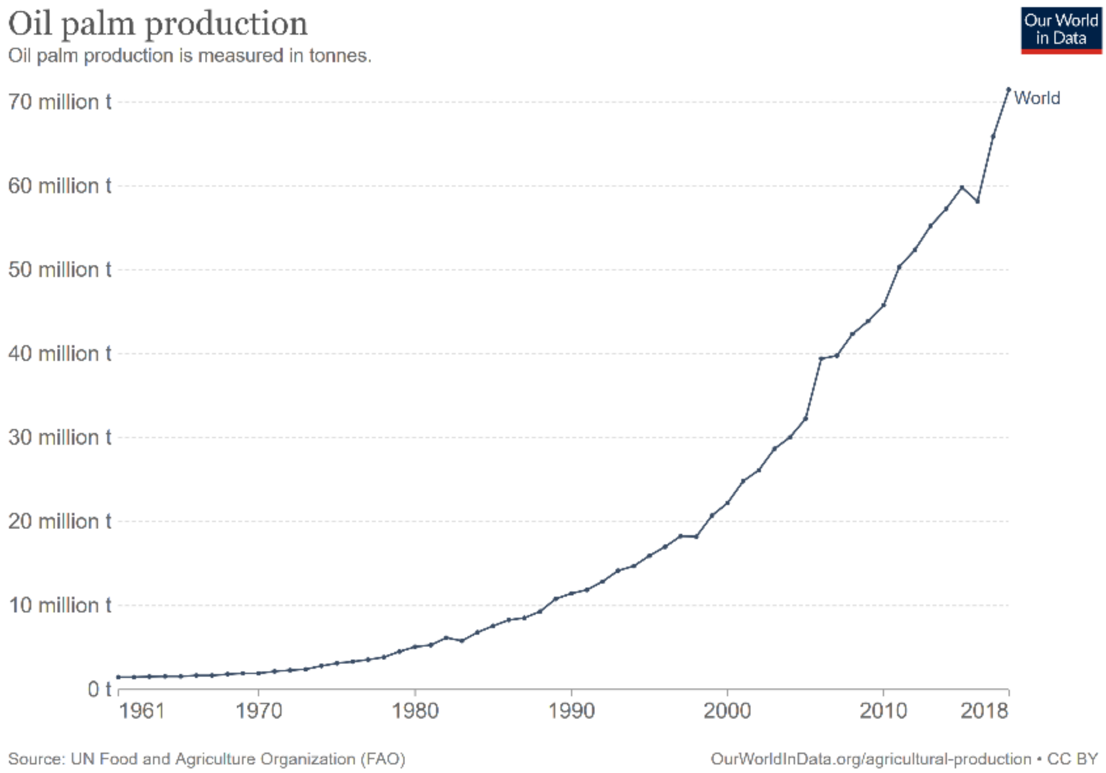

Figure 1. Oil Palm Production (Ritchie and Roser, 2021)

The palm kernel shell (PKS) (Figure 2.) is the parts of the oil palm fruit that protects the kernel, also known as the endocarp. PKS is a rather prevalent by-product of the process of releasing kernels in oil palm seeds. Only the dura and tenera varieties feature an inner shell ranging in thickness from 0.5 to 8 mm. (Goh et al., 2016). PKS is a lignocellulosic biomass composed primarily of cellulose with 21.60 – 22.70% wt, hemicellulose 20.80 – 27.70% wt, and lignin 44.00 – 50.70% wt. These contents demonstrate that several conversion methods can be carried out on PKS, indicating that lignocellulosic materials have a high potential for application as heat generators and biofuel production. PKS's structural strength is sustained by intricate hydrogen bonds formed by the cross-linking of lignin with hemicellulose and cellulose (Nizamuddin et al., 2016). The disposal of significant quantities of PKS has negative environmental consequences since it is disposed of by burning, resulting in a lot of pollution. PKS can be used as an adsorbent for the treatment of heavy metal polluted water according to this evaluation.

Palm kernel shell (PKS) is a valuable material for use as an adsorbent for the removal of heavy metal ions, due to the high quality of organic compounds in it capable of adsorption of metal ions by biosorption processes like other lignocelullose materials. Several researchers have conducted numerous PKS-related biosorbent studies. Activated carbon from PKS impregnated by phosporic acid (Kundu et al., 2015), bioadsorbent from charred PKS used for reduction of palm oil mill effluent final discharge (Zainal et al., 2018); Carbonized PKS for envorimental-friendly adsorben (Ezzuldin et al., 2019) is some of example use of PKS as an bioadsorbent. However, the process to manufacture activated carbon often uses a lot of energy and money (Sulistiyo et al., 2022). According to study by Baby et al., (2019) PKS can be utilized as an adsorbent without first being converted into carbon, and only require minimum treatment and preparation. It shows the capability of creating low cost and more enviromentally friendly biosorbent. Altough in this study has not discussed the varieties of PKS used for creating the biosorbent. The dura variety is more rigid and more dense than tenera variety. Based on that fact, different variety will lead to diversity of lignocellulose composition and will impact to the adsorption capacity and mechanism. Further research need to verify the impact of different varieties on the adsorption process.

Figure 2. Palm Kernel Shell

Conclusion

Palm Kernel Shell is a lignocellulosic material that can be used for adsorption. Principles of biosorption utilizing lignocellulosic biomass varied into ion exchange, chelation, and complexation with functional groups of the adsorbent. However, if the surface structure and functional groups of the sorbent are known, the mechanism of biosorption and Adsorption capacity may be predicted. As a result, understanding of the functional groups and surface structure of PKS dura and tenera variants is required in order to maximize the utilization of adsorbents derived from these materials.

Declarations

Conflict of interests The authors declare no competing interests.

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