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USAGE OF PALM SHELL ACTIVATED CARBON TO TREAT LANDFILL LEACHATE

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Abstract

Leachate generated from the municipal landfill contains organic and inorganic pollutants, including heavy metals, which makes it unsuitable to be discharged in natural bodies without any prior treatment. The objective of this study is to investigate the capability of palm shell activated carbon activated carbon powder to remove heavy metals from landfill leachate, by using an adsorption process. Batch experiments were carried out to investigate the performance of palm shell activated carbon powder powder with different contact times of 30 minutes, 60 minutes and 90 minutes. The results obtained show that the percentage of Fe and Cr removal increases with contact time. The removal of Fe and Cr was 14% and 18.78% respectively activated carbon powder at 90 minutes of contact time. Our results also demonstrated that palm shell activated carbon powder powder shows a better performance in removing Fe and Cr, compared to common activated carbon powder powder. Therefore, palm shell activated carbon powder powder has a good potential as a low cost alternative adsorbent in removing heavy metals from landfill leachate.

Keywords: *Adsorption; Palm Shell Activated Carbon; Leachate; Heavy Metals*

Introduction

Most of the landfills are open dumping grounds and they pose serious environmental and social threats [1]. Landfills have been accepted as the most economical and environmentally friendly way for the disposal of solid waste, compared to other disposal methods, such as composting, incineration, and gasification. However, a major concern associated with this disposal method is the leachate produced from the landfills [2].

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In the last decade, public awareness and concern over the quality of water has resulted in more and more consumers turning to point-of-use devices for treating water to their own desired level of quality. The risks from waste leachate are due to its high concentration of heavy metals. Some of them are dangerous to health and to the environment, such as mercury (Hg), lead (Pb) and arsenic (As) affecting the central nervous, mercury (Hg), lead (Pb), cadmium (Cd) and copper (Cu), which affect the kidneys or liver, and Nickel (Ni), cadmium (Cd), copper (Cu) and chromium (Cr), which affect the skin, bones, or teeth. Unlike organic pollutants, heavy metals do not decay and thus pose a different kind of challenge for remediation.

The adsorption process is found to be the most suitable technique to remove heavy metals from wastewater, especially from landfill leachate. It is mostly preferred due to its convenience, ease of operation and simplicity of design. Activated carbon (AC) is one of the most important types of industrial carbon, with a very high porosity and surface area. However, conventional AC is expensive due to the depletion of coal based sources and especially those for the production high quality AC [3]. It is prepared by carbonization and activation of a large number of raw materials of biological origin such as wood, coconut shells, peat, coal and fruit stones [4, 5]. In general, the raw materials to make activated carbon must accomplish a set of requirements, like high carbon content, easy activation, low mineral content, low degradation during storage and low cost [5].

Therefore, to counter the high cost of AC, finding a low cost and renewable precursor constituted a strong interest among researchers aiming to replace the conventional AC [6], which was mainly from industrial and agricultural by-products, such as date pits [7], silk cotton hulls and maize [8], jute fiber [9], groundnut shell [10], corn cob [11], bamboo [12], rattan sawdust [13] and oil palm fiber [14]. The new alternative source to produce AC is more cost effective and abundantly available [15-17]. Palm shells from palm oil processing mills are an agricultural solid waste in some tropical countries [15]. Palm shell is a good raw material for the preparation and production of activated carbon [18].

Nowadays, wastewater pollution is a major problem in the global context, especially for landfill leachate. One of the problems with landfills is the heavy metals in landfill leachate. Current leachate treatment options include recycling and re-injection, on-site treatment, biological treatment, chemical oxidation, discharge to a municipal water treatment facility or a combination of the above. One way to reduce wastewater pollution is by using adsorption of Palm Shell Activated carbon powder Powder (PSACPP).

Conventional AC is expensive due to the depletion of coal based source and especially for production high quality AC. Utilizing palm shell for the production of AC could give the same performance and may also be more cost effective, compared to conventional AC.

The objectives of this study are to determine the characteristic of the activated carbon powder (ACP) and palm shell activated carbon powder (PSACPACP) to identify the main characteristic of heavy metals in landfill leachate and to determine the capability of ACPACP and PSACPACP in removing heavy metals in landfill leachate.

Literature review

Landfill

Landfill represents one of the oldest and most common methods of municipal solid waste (MSW) disposal. Over the years, landfills have greatly improved resulting in facilities that are efficient, environmentally compatible, and free from many of the problems that created an image of an inadequate facility through the improvement of science and technology, design, operation, and preservation of landfill.

Landfills have many impacts to the environment. In a landfill, waste is packed tightly into piles, preventing sunlight from reaching lower levels of trash. The main by-products of reactions in landfill are gases and leachate, generated at various stages of waste decomposition. Proper management of landfill gases and leachate is essential to prevent environmental pollution. Leachate is a liquid that has seeped through solid waste in a landfill and has extracted soluble dissolved or suspended materials in the process. It is composed of water, organic and inorganic chemicals from the decomposition of waste. The bacteria will degrade the waste to a state which will be relatively harmless if escape to the environment occurs. However, this can take up to ten or perhaps hundreds of years. Leachates are a potential hazardous waste from landfill sites. If not dealt properly, it can cause pollution to groundwater, health problems and affect the environment. It is important that leachates are treated and contained to prevent these occurrences.

Definition of all the compositions in leachate is difficult, complex and time-consuming [19]. Landfill leachate is composed of the liquid that has entered into the landfill from external sources such as surface drainage, rainfall, and the produced from the decomposition of the waste. The typical data of the composition of leachate from new and mature landfill indicated that the leachate contains pollutant loads larger than many industrial wastes [20]. The characteristics and flow of landfill leachates depend on the composition of solid wastes, precipitation and runoff, age of the landfill and permeability and type of cover. The solid waste composition varies substantially with socioeconomic conditions, location, season, waste collection and disposal methods, sampling and sorting procedures and many other factors.

Heavy metals are commonly found in high concentration in landfill leachate include iron, manganese, zinc, chromium, lead, arsenic, copper, nickel, cadmium, and barium. They are a potential source of pollution of groundwater, surface waters and reservoirs.

Activated Carbon

In landfill leachate treatment, activated carbon (AC) adsorption was investigated as an alternative treatment method to chemical precipitation for raw or biologically pre-treated young landfill leachate, as well as polishing treatment combined with coagulation-flocculation for stabilized leachate [21]. Adsorption process is found to be the most suitable technique to remove heavy metals from wastewater especially landfill leachate. A number of adsorbent materials have been studied for their ability to remove heavy metals and they have been sourced from natural materials and biological wastes of industrial processes [22]. These materials include activated carbon [23-26], chitosan and carrageenan [27], lignite [28], kaolinite and ball clay [29], diatomite [30], coconut fiber [31] and limestone [32]. However, the adsorption by activated carbon had been reported as a technically and economically viable technology for heavy metal removal [27, 33, 34].

The advantages of AC are high efficiency in VOC removal, simple and robust technology, suitable for discontinuous processes, easy to maintain and easy to place while the disadvantages are dust can lead to blockages, component mixes may lead to early malfunction, not suitable for wet flue gases (less critical for impregnated activated carbon), risk of spontaneous combustion in the bed (ketones, turpentine), polymerisation risk for unsaturated hydrocarbons on the activated carbon (exothermal and causes blockages) and expensive due to the depletion of coal-based source and especially for producing high quality AC [35].

As such, low cost adsorbents are becoming the focus of many researchers and could be produced from many raw materials such as palm shell. Palm shells are mainly used as a raw material because it can be sought in the country. PSACPACP is the major adsorbent used in filters because it adsorbs a large variety of organic compounds, it is cheap, and it can be reused if the adsorbed substances are removed. This regeneration is often achieved by heating [36]. A large portion of palm shell is either burned in open air or dumped in the area adjacent to the mill, which creates disposal and environmental problems. Therefore, application of palm shell activated carbon as an adsorbent will reduce the heavy metals in landfill leachate and helps reducing environmental wastage with minimum cost required

Besides that, palm shell is also suitable for adsorption due to its ability to be modified, thus becoming high porosity carbon. From the elemental analysis, weight percentage of the carbon the highest. Other elements can be removed in high temperature, due to the gas composition, therefore increase the carbon content [37]. However, upon carbonization, palm shell undergoes high weight loss which is approximately 75% [6].

In this study, the raw material was obtained from Batu Pahat, Johor. The shell was crushed and sieved into different particle sizes, namely, less than 0.18mm for activated carbon powder. PSACP has the capability to remove heavy metals such as lead, chromium and copper ions from wastewater, due to the presence of some functional group on the PSACP that attracts metal ions such as carboxyl, lactone and the sulphur group. Those groups were reported to enhance metal absorption [38, 39].

In this study, we assessed the adsorption potential of PSACP and ACP in removing iron (Fe) and chromium (Cr) from landfill leachate through batch experiment. The effect of contact time on the adsorption of Fe and Cr was also evaluated.

Methodology

Leachate Sampling

Leachate samples were collected from the Simpang Renggam Landfill. The leachate was stored in a high density polyethylene (HDPE) bottle. The preservation of the sample was done in accordance with the Standard Methods for the Examination of Water and Wastewater (APHA, 2008). The dilution of nitric acid was used to assist the leachate preservation. Before collecting the leachate, the HPDE bottle was rinsed with the dilution water and dried. Other than that, to minimize any further changes that may occur before the experimental work, the sample was stored at 4◦C.

Characterization of Landfill Leachate

The Parameter tested was heavy metals such as iron (Fe) and chromium (Cr), as they are highly critical in the landfill leachate sample. The measurement and the value of the parameter obtained were compared with the Environmental Quality Act of Malaysia, 1974.

Adsorbent

PSACP and ACP were used as an adsorbent for this study. Both adsorbents were sieved by using a 125 μm filter. The X-Ray Fluorescence (XRF) method was used to perform the elemental analysis and chemical analysis of the PSACP and ACP.

Adsorption studies

A batch experiment was carried out to investigate the capability of PSACP and ACP to remove heavy metals from landfill leachate. Three reactors were prepared for our study. Reactor A consisted of leachate with PSACP, Reactor B consisted of leachate with ACP and Reactor C acted as control reactor. The optimum conditions for the adsorption study were adopted from the previous studies found in relevant publications. For each reactor, there are 250 ml of wastewater containing 0.25g of adsorbent. The pH adjustment of wastewater was done by using H_2SO_4. The adsorbent was agitated in a mechanical centrifuge at a speed of 120rpm. The solution was filtered by using 42μm Whatman® filter paper. To evaluate the efficiency of each adsorbent, the concentrations of the Fe and Cr in the landfill leachate were determined before and after the experiment. All the reactors were set up in duplicates and the average values were calculated to obtaine our results. The results were analyzed by using an Atomic Adsorption Spectrophotometer (AAS). The percentage of heavy metals removal was calculated by using the following equation (1).

$$\text{Removal (\%)} = \frac{(C_i - C_f)\times 100}{C_i} \qquad (1)$$

where C_i and C_f are the initial and final concentrations of the parameters.

Results and Discussions

The performance of PSACP was compared to that of ACP in treating landfill leachate, based on our laboratory experimental work. The main parameters involved in the batch reactors were iron (Fe) and chromium (Cr). The variables for the batch reactors, to compare the performance of each adsorbent, where contact time.

Characterization of Landfill Leachate

The leachate characterization was conducted to determine the most significant heavy metals to constitute the parameter of interest. The initial leachate characterization study was conducted by using an Atomic Absorption Spectrometer (AAS). The results of our leachate characterization are illustrated in Table 1. To identify the environmental risk of leachate, the obtained parameter values were compared with the Malaysian Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulation 2009, under the Laws of Malaysia Environmental Quality Act 1975 [40].

Table 1. Result of initial leachate characterization

Parameters	Concentrations (mg/L)	Typical Concentration (mg/L)
Fe	16.10	5.0
Cu	0.065	0.2
Cr	0.623	0.2
Zn	0.380	2.0

Characterization of PSACP and ACP

From our XRF analysis, conducted in the Analytical Environmental Laboratory, we determined the characteristic of the adsorbents used in this study. Table 2 shows the characteristics of PSACP and Table 3 shows the characteristics of ACP.

Table 2. The characteristic of PSACP

Formula	Concentration (%)	Formula	Concentration (%)
Al	0.035	Mg	0.025
Ca	0.095	Mn	0.001
CH_2	98.7	P	0.073
Cl	0.068	Rb	0.002
Cu	0.002	S	0.030
Fe	0.106	Si	0.121
K	0.734	Zn	0.003

Table. 3. The characteristic of ACP

Formula	Concentration (%)	Formula	Concentration (%)
Al	0.01	K	0.403
Ca	0.051	Mg	0.013
CH_2	99.2	P	0.054
Cl	0.063	S	0.066
Cu	0.001	Si	0.102
Fe	0.015	Zn	0.001

The results listed in Table 2 and 3 show that most of the elements in ACP are similar to PSACP. This result indicates that PSACP could be one of the potential alternative adsorbents, with almost the same composition as ACP. A similar result was found by Wan Nik et al., in 2006 who also concluded that PSACP has a very large influence on the characteristics and performance of AC [41].

Iron Removal

The existence of high levels of Fe in landfill leachate over a long period of time is one of the most important problems faced by landfill operators [42]. Figure 1 shows the percentage of Fe removal, in comparison between PSACP (Reactor A) and ACP (Reactor B) for various contact times. Slightly different results were obtained between PSACP and ACP in 30 minutes (5%, 4%) and 60 minutes (8.2%, 5.6%) of contact time. However, a significant percentage or removal was obtained at 90 minutes of contact time with PSACP (14%) and ACP (8.7%) respectively. The increase of contact time caused an increase in the removal percentage for both PSACP and ACP. Nonetheless, PSACP achieved a 37% better performance compared to ACP at 90 minutes of contact time.

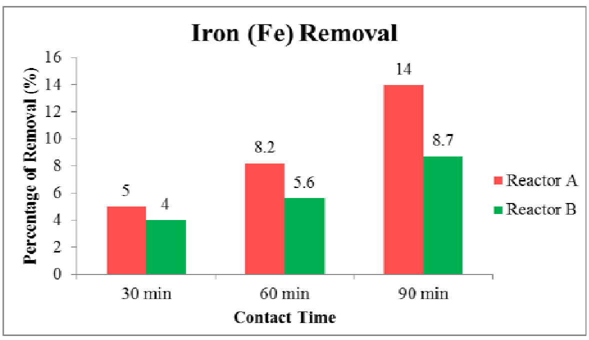

Fig. 1. Percentage removal of Fe using the adsorbent

Chromium removal

As for Cr removal, at 30 minutes of contact time we recorded 7.7% and 3.53% for the PSACP and ACP respectively. The increasing removal in time trend was also demonstrated in Cr removal for both PSACP and ACP. At 90 minutes of contact time, the maximum percentage of removal for PSACP and ACP was 18.78% and 14.13% as shown in Figure 2, which indicated a better performance of PSACP compared to ACP.

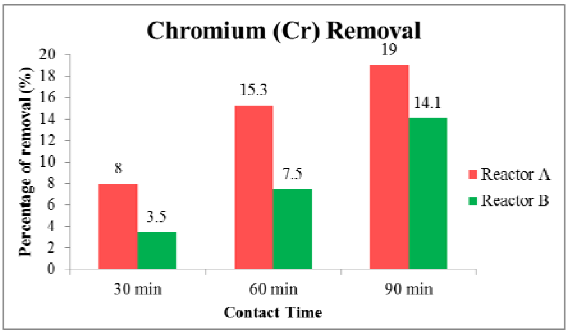

Fig. 2. Percentage of removal of Cr by the adsorbent

The present study demonstrated that the contact time had a considerable influence on the percentage of removal of heavy metals from landfill leachate. Furthermore, we found that calcium (Ca) and magnesium (Mg) are the elements responsible for adsorbing the heavy metals [43]. From our XRF analysis, the concentration of the Ca and Mg was low. Hence the percentage of removal of heavy metals was low. The similar characteristics of PSACP and ACP, with high surface areas and very well developed porosity, ensured a great adsorption capacity. Nevertheless, the concentration of Ca and Mg in PSACP was higher than in ACP. Thus a better performance was recorded for PSACP.

Conclusions

Our results show that the performance of PSACP is better than that of ACP in removing Fe and Cr. The highest removal of Fe and Cr was 14% and 18.78% with PSACP, compared to 8.7% and 14.13% with ACP, at 90 minutes of contact time. As a conclusion, PSACP has a good potential as a low cost alternative adsorbent in removing heavy metals from landfill leachate, as well as in reducing environmental pollution.

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