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Aged Refuse Characterization as Resource for Wastewater Treatment and Landfill Remediation

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Abstract

Landfilling has become the most effective solid waste disposal option in developing countries. Aged Refuse (AR) in this context is solid wastes from landfill which has become stabilized after several years of placement. The aged refuse sampled from Air Hitam landfill site in Malaysia is characterized as follows: moisture content 29.5%, Loss on Ignition (LOI) 9.90%, porosity 51%, ash content 95.99%, bulk density 1.23 g/cm^3, hydraulic conductivity 0.31 cm/min, electrical conductivity 143.10 ms/cm and Carbon-Nitrogen-Sulphur (CNS) of 0.64%, 0.04% and 0.009%, respectively. Cation Exchange Capacity (CEC) is 2.69 meq/100 gm, with exchangeable cations of Calcuim, Magnesium, Potassium and Sodium. The SEM/EDX showed available specific surface area of 3.376 m^2/g and negligible heavy metals presence with abundance of Silicon and Oxygen as compounds. The AR texture is similar to loamy clay, with the abundance of microbes at 7.1 × 10^6 CFU/100 ml, which removed up to 92.1. 88.6, 68.0, 84.7 and 95.1% of COD, turbidity, chromium, NH_3-N and colour, respectively from fishpond wastewater.

Keywords: Aged refuse; Adsorptive properties; Landfill resource; Landfill remediation; Cation exchange capacity; SEM/EDX

Introduction

One of the challenges of urbanization is the containment and management of municipal solid waste [1-3]. Effective management of urban solid wastes will reduce some of the environmental effects associated with solid waste generation such as pollution and environmental health hazards [4,5]. Several authors including [6-9] and many others identified landfilling as one of the major solid waste disposal system in developing countries. However, due to the increasing rate of solid waste generation, most landfill sites are exhausted and the large area required for selecting landfill site has necessitated the need to recycle landfilled refuse [10].

In recent times, several authors have investigated the properties of aged refuse in order to provide the necessary parameter for reusing the material [11,12]. As a result, landfill mining which is a process of excavating materials from landfill for recycling purposes and landfill reclamation, has become a research interest [13-16]. In addition Nelson [17], Reinhart and Townsend [18] and other pioneers highlighted a lot of factors to have encouraged landfill reclamation in different perspectives which include; recovering stabilized solid waste in a bioreactor landfill operation to be used for treatment of wastewaters.

Furthermore, researchers have focused on exploiting the characteristics of available surface area and abundance of microbes in aged refuse to design bio-filters for treating landfill leachate and various wastewaters [10,19-22] and the results obtained were satisfactory as well as cost reduction when compared with traditional methods. Also, the excavated aged refuse could be used as regular cover material, nutrient for soil, and processed constructing material.

Lou et al. [23] compared the properties of aged refuse and soil, and results showed that for soil fraction with a particle size of 0.2-1 mm, the organic content was 1.40%, and that in aged refuse was 4.53%, while for soil fraction below 0.2 mm, the organic was 0.77%, and that in aged refuse was 5.69%. According to Zeng et al. [24], the properties of aged refuse from Jinkou Landfill in China are 6.31-13.76% organic content, moisture content 22.19 - 55.67%, saturated conductivity 2.91 × 10^6 -1.12 ×10^5 cm s^{-1} with a compacted density of 800 kg m^{-3} and 1200 kg m$^{-3.}$ These results differ according to region and the composition.

This paper however is aimed at investigating the material composition of aged refuse obtained from Air Hitam landfill site in Malaysia as an adsorbent material for wastewater treatment. Also, the percentage removal efficiency for pollutants from fishpond wastewater using the AR as the adsorbent will be investigated.

Methodology

The aged refuse used for this analysis was obtained from the Air Hitam Sanitary Landfill (AHSL) site located in Puchong, Selangor, Malaysia. There are six phases in the landfill site and each phase contains different volumes of solid waste placed for over 8 years. Studies have shown that aged refuse of 8 years and above provide better pollutant removal efficiency [20] (Figures 1a and 1b).

A pre-investigation was carried out using fishpond wastewater sampled from UPM fish pond located at Ladang 10, Universiti Putra Malaysia and the aged refuse sampled from AHSL as the adsorbent. The experiment was carried out at room temperature (25°C) in batch mode and in 250 ml flasks using an electric shaker. 2 g/100 ml of sample was agitated at 250 rpm, pH 6, adsorbent size of ≤ 0.600 mm and contact time of 70 minutes. After the set time, the sample was removed from the shaker, separated using a centrifuge at 3000 rpm for 8 minutes and then filtered using Whatmann filter paper 140 mm diameter. Turbidity was determined by the nephelometric method (NTU), COD was determined by Closed Reflux Titrimetric Method, colour was determined by spectrophotometric method using colorimeter in

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Figure 1: a) Map of air hitam sanitary landfill (AHSL), Selangor, Malaysia and **b)** sampling method by using excavator.

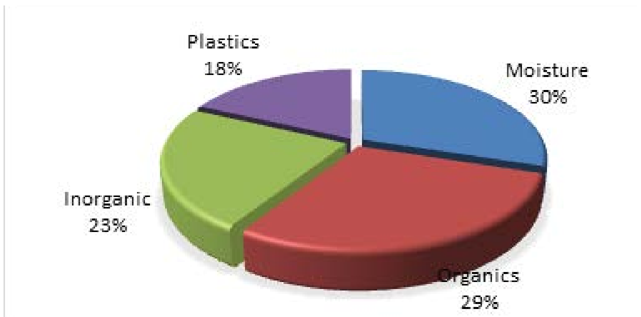


Figure 2: Composition of AR by weight of materials.

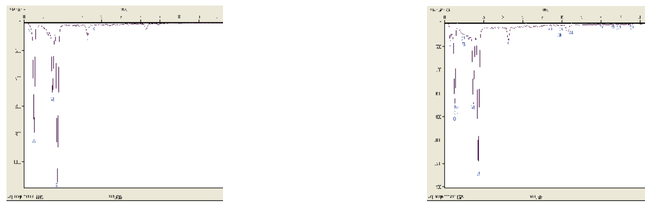
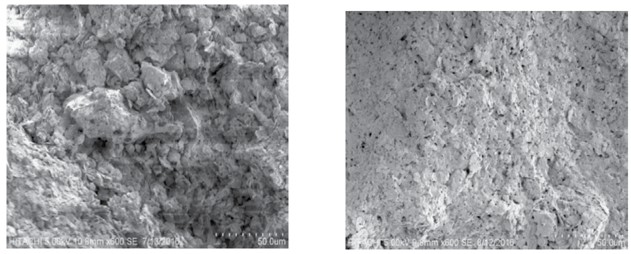


Figure 3: Image EDX spectrum of the AR taken at accurate voltage of 20.0 kV and take off angle of 35.0 degree before and after adsorption process. **a)** Sample before adsorption treatment. **b)** Sample after adsorption treatment.



a b

Figure 4: SEM image of the AR before and after adsorption process. **a)** Sample before adsorption treatment. **b)** Sample after adsorption treatment.

Pt-Co (Platinum-Cobalt) and Chromium (Cr6+) was determined by 1,5-Diphenylcarbohydrazide Method. All analysis was carried out according to American public health association [25] and the samples were investigated before and after adsorption process.

Results and Discussion

The results of all analysis on the aged refuse are characterized below. The composition of the AR is shown in (Figure 2).

The sampled aged refuse comprises 30% moisture, 29% organic matter, 18% plastics and polystyrene and 23% inorganic wastes. The image EDX spectrum of the material was carried out by using a scanning Electron Microscope (SEM) and Energy Dispersive X-ray spectroscopy (EDX) carried out at high-resolution is shown in (Figures 3 and 4). The EDX spectrum before adsorption in (Figure 3a) shows negligible proportion of' metals in the sample which favors the adsorption process because presence of heavy metals can hinder some process reactions and also lead to the formation of oxides in the presence of oxygen. Figure 3b presents the spectrum of the material after the adsorption process which highlights some metals and other trace elements that have been adsorbed on the surface of the aged refuse.

Oxygen plays a major role in the aerobic bio-degradation of pollutants which is an integral part of most biological wastewater treatment systems. It promotes microbial growth in the wastewater that feed on the organic matter to break down the organic matter to form stable compounds. Biodegradation of organic matter in the absence of oxygen is very slow, odorous and yields incomplete conversion to stable compounds which create low pH conditions in the reactors and make the wastewater difficult to treat. Similarly, the presence of silicon compounds present a high adsorptive property which has ability to remove some heavy metals present in wastewaters such as Cadmium, Aluminum, Lead and Zinc as reported by numerous authors including Liang et al. [26], Zeng et al. [27], Kaya et al. [28] and Bharwana et al. [29]. Silicate clay minerals adsorb cations (positively charge ions), such as ammonium (NH_4^+) onto negatively charged surfaces and are effective in adsorbing bacteria, viruses, and many organic compounds.

Figure 4a presents the image of the AR before adsorption process which shows large number of pores and uneven surfaces available for adsorption of pollutants while (Figure 4b) shows image of the AR after the adsorption process. Some pollutants are adsorbed on the surface of the aged refuse a process which allows time for die-off, predation, and inactivation processes to occur. All other results obtained from the material characterization of the aged refuse are presented in (Table 1).

Table 1 shows perfect exchangeable adsorptive properties for the AR with available specific surface area of 3.376 m^{2}g-1. The texture grading of the screened AR shows that the AR media is similar to loamy clay with an average moisture content of 29.5% which is close to values obtained from similar studies [20,30]. This percentage of moisture will also provide the required oxygen for aerobic microorganisms to grow and when there is lack of oxygen the anaerobic microorganisms take place. The material also presents a very porous surface with a porosity level of up to 51% which would prevent clogging and fouling during the treatment process. The high percentage of microorganisms in the aged refuse helps in the decomposition of the organic matter present in the wastewaters. According to Elmholt et al. [31] some active and resistant organic constituents, together with available microorganisms in the AR aid in the binding of small soil particles into larger aggregates and this process is important for aeration and water infiltration of the material.

The Carbon-Nitrogen-Sulphur content which was analyzed using the TRUMAC CNS macro analyzer at a temperature of 1350°C presented low levels for the trace elements which is very favorable because high levels of suphur will further lower the pH of the material which will affect the biological treatment process since pH is a major operating factor to consider during adsorption. The results also showed negligible amounts of some elements with capacity for cation exchange and exchangeable cations of calcium, magnesium, potassium and sodium at l.31, 0.15, 0.59 and 0.52, respectively, which will influence nutrient supply thereby increasing microbial degradation of organic substances. Although microbes take away only a small amount of nitrogen as biomass, they however play a major role in biological nitrification, where NH_3-N is readily oxidized to NO_3- N and de-nitrification; the reduction of nitrates to nitrogen gases which is the most significant nitrogen removal mechanism in wastewater treatment.

Treatment efficiency

The results on the adsorption of some pollutants from the fishpond wastewater shows that the aged refuse was very effective in the removal of COD, Colour, Chromium, NH_3-N and turbidity from the wastewater with initial concentrations of 640, 3200, 25, 54 and 138 mg/l respectively. The percentage removal efficiency of pollutants from fishpond wastewater is illustrated in (Figure 5).

The results shows that aged refuse can effectively remove up to 92.1. 88.6, 68.0, 84.7 and 95.1% of COD, Turbidity, Chromium, NH_3-N and Colour, respectively from fishpond wastewater after a maximum treatment time of 70 mins. Other treatment conditions are; adsorbent dosage of 2 g/100 ml, pH of 6 and room temperature. Most of the parameters reached equilibrium after 30 minutes of treatment.

Conclusion

This study presents the use of aged refuse as a cheap, available and

Parameter	Unit	Result	Parameter	Unit	Result
Texture		Loamy clay	Cation Exchange Capacity	meg/100 gm	2.69
pH		7.14	Carbon	%	0.64
Moisture content	%	29.5	Nitrogen	%	0.04
Loss on ignition	%	9.90	Sulphur	%	0.009
Ash content	%	95.99	Electrical Conductivity	µS/cm	143.10
Bulk Density	g/cm³	1.23	Hydraulic conductivity	cm/min	0.31
Porosity	%	51	Microbes	CFU/100 ml	7.1 × 10^6
Specific Surface Area	m²/g	3.376			

Table 1: Characterization of aged refuse.

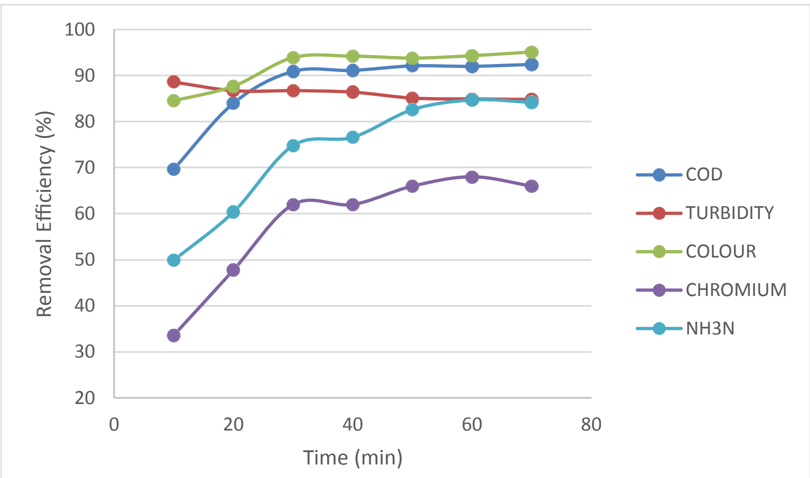


Figure 5: Removal efficiency of' pollutants from fish pond wastewater using aged refuse as adsorbents.

efficient adsorbent capable of removing more than 60% of pollutants from fishpond wastewater after just 30 minutes of contact time. The characterization of the aged refuse revealed that the aged refuse has high porosity and abundance of microbes which enhances biodegradation process. The available specific surface area and exchangeable cations are some of the numerous adsorptive properties of the material as a resource for wastewater treatment. Furthermore, the reuse of this material is useful in landfill reclamation to create more space in the landfill and also to control environmental issues resulting from solid waste disposal which has become the main focus of various studies in recent times.

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