REMOVAL OF HEAVY METALS FROM DUMPSITE LEACHATE USING CASSAVA PEEL-DERIVED ADSORBENT

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ABSTRACT

Dumpsite leachate contains harmful pollutants including heavy metals which are detrimental to humans and the environment. Conventional metal removal methods are expensive and may result in the production of large volumes of sludge, hence the focus on natural low-cost adsorbents. In this study, the use of an adsorbent derived from cassava peels for the removal of nickel (Ni), lead (Pb), chromium (Cr) and zinc (Zn) from dumpsite leachate was investigated. Leachate samples were obtained from a dumpsite and characterized to determine the concentration of heavy metals. Batch experiments were conducted to assess the effect of adsorbent dose, pH, temperature and agitation speed on the removal of heavy metals from the leachate. The leachate samples analyzed had 8.43mg/l and 1.09 mg/l of zinc and lead respectively, which exceeded the relevant surface water discharge limits. The optimum operational parameters were determined as follows: adsorbent dose (0.3g), pH (4), temperature (35˚C) and agitation speed (150rpm). Overall, the highest removal efficiencies achieved were 66, 83, 63 and 77% for Ni, Pb, Cr and Zn respectively. The results indicate that cassava peel-derived adsorbent can potentially be utilized in the removal of heavy metal pollutants from dumpsite leachate before disposal.

Keywords: *Dumpsite, Leachate, Cassava peel, Heavy Metals, Adsorption*

INTRODUCTION

Dumpsites are often used for waste disposal in lieu of engineered landfills in many developing countries, resulting in the discharge of untreated leachate into the environment. Leachate contains inorganic and organic pollutants which are detrimental to human health and aquatic systems (Ayotamuno and Akuro, 2004; Aiyesanmi and Imoisi, 2011; Asibor et al., 2016).The composition of leachate varies from site to site, depending on the characteristics of waste disposed, age of the landfill, operational practices and climatic conditions (Park et al. 2001). Previous studies on the characterization of leachate from municipal landfills/dumpsites in Nigeria have reported the presence of toxic heavy metals at concentrations above those stipulated in environmental discharge standards. These metals are persistent, non-biodegradable, potentially carconogenic and harmful to human health (Agbozu and Nwosisi, 2015).

Conventional metal removal methods such as precipitation and coagulation are commonly used, however their major drawback is the production of sludge requiring further treatment and disposal (Barakat, 2011). Other treatment methods include flotation, membrane filtration, ion exchange, electrodialysis and photocatalysis. Some of these methods are expensive due to their high energy requirements and overhead cost (Fu and Wang, 2011). Several researchers have explored the use of natural materials, including agricultural wastes as low cost adsorbents for metal removal, with promising findings (Fu and Wang, 2011; Mathew et al., 2016). Cellulosic non-reducing carbohydrate polysaccharides found in plant fibres such as cassava peel have also been tested (Abia et al., 2002; Abia et al., 2003; Horsfall and Abia, 2003; Okoro and Abii, 2011; Ndlovu et al.,2013). The uptake of metal ions by adsorbents is influenced by several factors including the characteristics of the adsorbent, adsorbent dose, metal concentration, ph, contact time, temperature, competing ions and agitation speed(Malamis and Katsou, 2013).

Aim of this study is to investigate the removal of heavy metals (Pb, Cr, Zn and Ni) from landfill leachate in batch systems using cassava peel-derived adsorbent. The effects of adsorbent dose, pH, temperature and agitation speed on the perfomance of the adsorbent will be examined.

Methods and Materials

Cassava peel-derived adsorbent (CPDA)

Cassava peels obtained from local factories in Auchi, Edo state were washed, dried at 65°C and ground to powdered form. The powder was carbonized at 350°C, cooled and stored in a dessicator (Gin et al., 2014). The carbonized powder was activated using Phosphoric acid (H_3PO_4) and Hydrochloric acid (HCL) (Yalc and Sevinc, 2000; Kobya et al.,2005). The fixed carbon, pore volume, porosity and bulk density of the cassava peel-derived adsorbent were determined and are shown in Table 1.

Table 1: Physical parameters of cassava peel-derived adsorbent (CPDA)

Parameter	Cassava Peel-Derived Adsorbent
Fixed carbon (%)	79.8
Pore volume (cm^3)	1.11
Porosity (ml/g)	0.161
Bulk density (g/cm^3)	0.36

Dumpsite leachate collection and sampling

Leachate samples were obtained from a dumpsite located in Eneka, Obioakpor Local Government Area, Rivers State. Samples were collected from surface run-off drains at the dumpsite in pre-rinsed plastic bottles with airtight corks. They were filterered and heavy metals (zinc, nickel, lead and chromium) were analyzed using a Flame Atomic Absorption Spectrophoto-meter (FAAS).

Batch adsorption experiments

All adsorption experiments were performed in 250-mL Pyrex conical flasks, with the effect of each parameter studied by keeping the other variables constant. Known weights of CPDA were suspended in 50 ml of dumpsite leachate. The suspensions were agitated for a specified time period, filtered using Whatman No. 40 paper, centrifuged and subsquently analyzed using FAAS to determine the concentration of metals. The effects of pH (2-7), temperature (20-50˚C), adsorbent dose (0.05-0.30g), agitation speed (50-200 rpm) were studied. pH adjustments were carried out by using 0.1 M H_2SO_4 and 0.1 M NaOH.

The percentage removal of metals by CPDA was determined using the equation:

$$\%\,Removal = [(C_o - C_e)/C_o] \times 100 \quad (1)$$

Where C_o and C_e are the initial and equilibrium concentrations of metals in solution respectively (mg/L).

Results and Discussion

Heavy metals in dumpsite leachate

The leachate samples were analyzed to determine the concentration of some heavy metals. The average concentrations of Pband Ni were above the effluent limitation guidelines for discharge into surface water (FEPA, 1992) as presented in Table 2. The Ni and Cr concentrations are similar to those reported in Aiyesanmi and Imoisi (2011) and Eni et al. (2014) for landfills in Benin and Calabar respectively. These values further highlight the need for adequate leachate collection, treatment and disposal.

Table 2: Comparison of heavy metal concentrations in dumpsite leachate with FEPA effluent limitation guidelines

Metals	Dumpsite Leachate (mg/l)	Surface Water Discharge Limits (mg/l) (FEPA, 1992)
Zn	8.43	<1
Cr	0.77	<1
Pb	1.09	<1
Ni	0.31	<1

Effect of adsorbent dose

The effect of adsorbent dose (0.05-0.30g) on the adsorption process was investigated as shown in Figure 1.The results indicate that the percentage uptake of Ni, Pb, Cr and Zn increased with increase in the mass of CPDA used. This occurred due to an apparent increased availability of sorption sites on the larger surface area provided, which also reduced the effect of competing ions (Kocaoba et al, 2007). The metal removal percentages at 0.30g CPDA/50ml of leachatewere 50.26, 62, 44.64 and 60.33 % for Ni, Pb, Cr and Zn respectively.

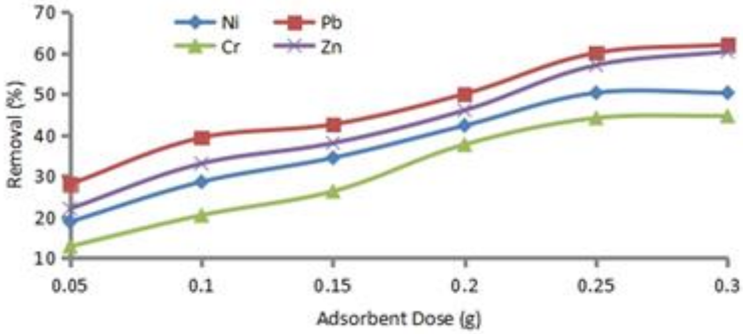

Figure 1: *Effect of adsorbent dose on the removal of Ni, Pb, Cr and Zn from leachateby CPDA.*

Effect of pH

The effect of pH (2-7) on metal uptake is illustrated in Figure 2. Maximum metal removal was observed at pH 4. The maximum percentage uptake of metal ions were 58.19, 64.67, 54.75 and 60.33 % for Ni, Pb, Cr and Zn respectively.

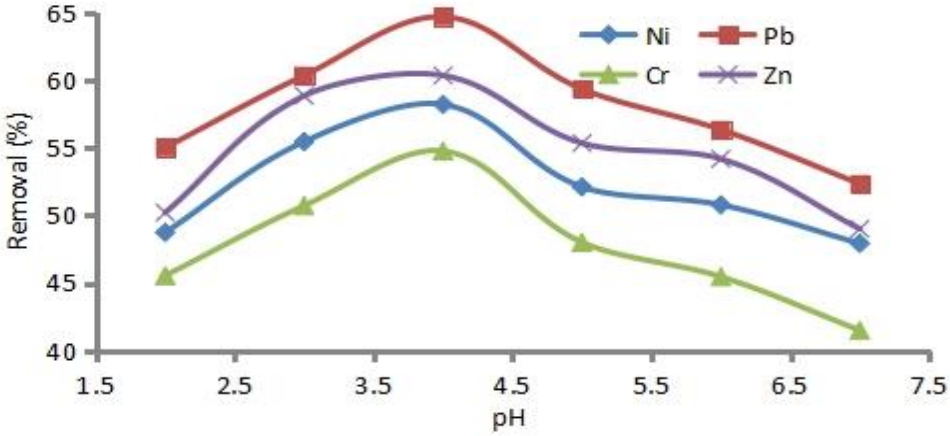

Figure 2: *Effect of pH on the removal of Ni, Pb, Cr and Zn from leachate by CPDA*

Metal removal is heavily influenced by pH, as it influences metal speciation and the surface properties of the adsorbent. The decrease in percentage uptake at lower pH values indicates that there was more competition for available sorption sites due to the presence of H^+ ions in the leachate, in addition to the multisolute nature of the leachate samples. However at higher pH, precipitation due to metal complexation with OH^- ions resulted in decreased metal uptake (Akgul et al., 2006; Malamis and Katsou, 2013).

Effect of temperature

The effect of temperature (20, 30, 35, 40, 45 and 50˚C) on metal uptake is shown in Figure 3. The results show maximum percentage uptake of 60.44, 70, 56.07 and 65 for Ni, Pb, Cr and Zn respectively at 35˚C. At higher temperatures, water molecules may be removed from hydrated ions, thus reducing their size and increasing their accessibility to active sorption sites (Malamis and Katsou, 2013). However at temperatures 40-50˚C, there was a gradual decrease in metal uptake.This can be attributed to the exothermic nature of the adsorption process (Benguella and Benaissa, 2002), which results in decreased uptake at temperatures above optimum levels.

Effect of agitation speed

The removal of Ni, Pb, Cr and Zn by CPDA was studied at agitation speeds ranging from 50 to 200 rpm. Figure 4 shows that maximum metal removal was observed at 150rpm, with 66.40, 82.67, 62.68 and 76.67% removal of Ni, Pb, Cr and Zn respectively. At lower agitation speeds, film diffusion was the rate-limiting step due to the thickness of the film boundary layer surrounding the adsorbent particles.

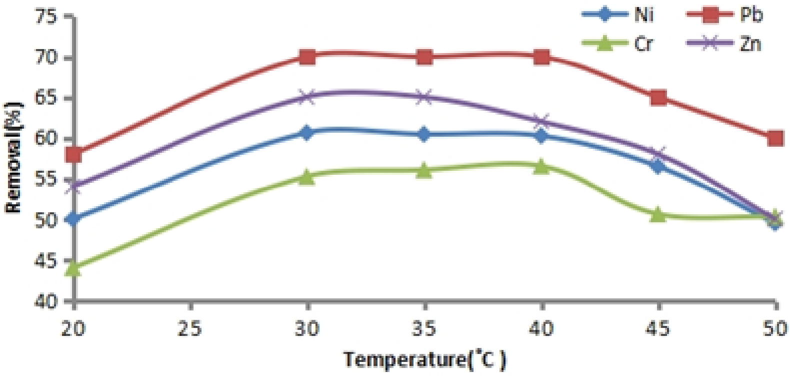

Figure 3: *Effect of temperature on the removal of Ni, Pb, Cr and Zn from leachate by CPDA.*

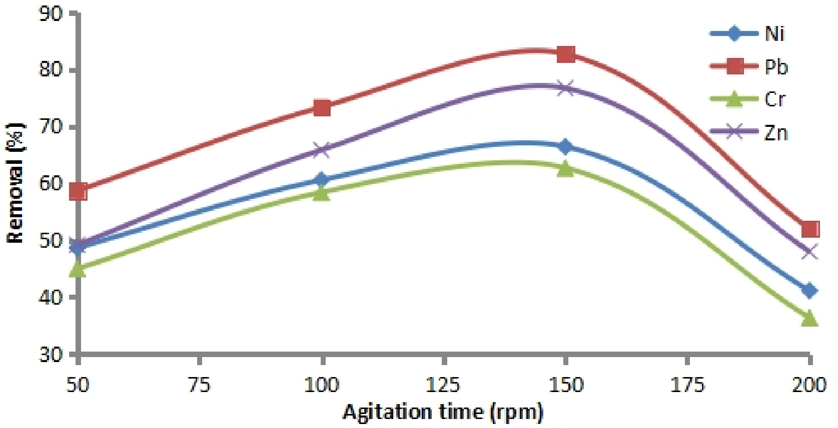

Figure 4: *Effect of agitation speed on the removal of Ni, Pb, Cr and Znfrom leachate by CPDA.*

However, as the agitation speed increased to the optimum level (150rpm) for the system under study, the rate of metal uptake increased. This was due to a reduction in the film boundary layer and the resultant decrease in resistance to bulk diffusion. The lower removal percentage observed at 200rpm indicates that at higher speeds, pore diffusion became the rate limiting step because metal ions did not have enough time to attach to the surface of the CPDA particles, thus decreasing the rate of metal uptake (Benguella and Benaissa, 2002) . Similar observations have been reported in metal removal studies using other adsorbents (Kocaoba et al., 2007).

Conclusion

The removal of heavy metals (Ni, Pb, Cr and Zn) from dumpsite leachate by cassava peel-derived adsorbent (CPDA)has been investigated in this study. Heavy metal analysis of leachate samples obtained from Eneka dumpsite revealed that the samples contained 0.31, 1.09, 0.77 and 8.43 mg/l of Ni, Pb, Cr and Zn respectively. The process parameters (pH, agitation speed, adsorbent dose and temperature) were found to affect the adsorption performance. The optimum conditions were pH 4, agitation speed 150rpm, temperature 35˚C and adsorbent dose 0.3g for all metals in the system.Overall, the highest removal efficiencies achieved were 66, 83, 63 and 77%

for Ni, Pb, Cr and Zn respectively.These results demonstrate that cassava peel-derived adsorbent can potentially be utilized as a low cost material for the removal of metals from dumpsite leachate.

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