ZIBELINE INTERNATIONAL™
PUBLISHING

Engineering Heritage Journal (GWK)

DOI: http://doi.org/10.26480/gwk.02.2022.45.50

ISSN: 2521-0904 (Print)
ISSN: 2521-0440 (Online)
CODEN: EHJNA9

RESEARCH ARTICLE

ADSORPTION OF CD II AND CR VI IONS ON UNRIPE BANANA (musa sapientum) PEEL BIOMASS, A SUSTAINABLE ENVIRONMENTALLY BENIGN MATERIAL

Kaywood Elijah Leizou[a*], Muhammad Aqeel Ashraf[b]

[a]Sciences, Niger Delta University, Wilberforce Island, P.M.B 071, Yenagoa, Nigeria
[b]International Water, Air & Soil Conservation Society INWASCON 59200 Kuala Lumpur, Malaysia
[*]Corresponding Author E-mail: pastorkayeleizou@yahoo.com

ARTICLE DETAILS

Article History:

Received 24 May 2022
Accepted 28 June 2022
Available online 07 July 2022

ABSTRACT

Under batch equilibrium approach, the removal of cadmium and chromium from aqueous solution with a sustainable eco-friendly material, unripe banana (musa sapientum) peel biomass was investigated. Cd (II) and Cr (VI) ions were discovered to be removed from aqueous solutions by unripe banana peel. From pH > 6, the removal rate of Cd (II) increases, whereas the removal rate of Cr (VI) declines. The best fit between the Langmuir and Freundlich models was found using adsorption equilibrium data. The best fit for Cr (VI) adsorption data was the Langmuir model type 1I, with $R^2 = 0.988$. The optimum pH for cadmium and chromium was 4.00 and 10.00, respectively, with qm of 1.38 mg/g and 48.47 mg/g and percentage removal of 96.6 and 46.6 for cadmium and chromium respectively. The Langmuir adsorption isotherm correlated well with adsorption for cadmium and chromium, indicating that chemisorption is the dominant mechanism in the sorption process. As a result of the findings, it was discovered that unripe banana peel biomass may be used to effectively and efficiently remove Cd (II) and Cr (VI) ions or other pollutants from wastewater and the environment.

KEYWORDS

Musa sapientum, biomass, adsorption isotherms, chemisorption pseudo-second order

1. INTRODUCTION

Sustainable eco-friendly, green plant biomass has received unprecedented interest and utilization in batch equilibrium investigations in recent years due to its low cost, availability, low application cost, distinctive structure, phytochemicals, and great physicochemical features.

There are numerous well-documented conventional processes for removing metals from industrial effluent, including precipitation, ion exchange, electrolytic techniques, and so on (Blanco et al., 1999). The use of non-living biomaterials as metal-binding compounds has lately gained popularity. Because large levels of pollution have no effect on them, they require no care and maintenance, and they are inexpensive to obtain (Horsfall et al., 2003).

Rapid industrialization brings with it the difficulty of rising industrial waste-water discharges including heavy metals. High quantities of these metals are indeed poisonous to aquatic ecosystems, causing harm to living animals, plants, and humans. Thus, extreme caution is required (Ahluwalia and Goyal 2007).

The direct or indirect release of heavy metals into aquatic systems has become a global problem in recent decades. Because of their potential to accumulate, harmful effect, and toxicity to human life and environmental health, they have been highlighted as important inorganic contaminants in the environment (Nguyen et al.,2013; Ali et al., 2020).

Cadmium is a highly hazardous metal that has a variety of side effects. Cadmium II sorbs weakly to organic materials, clays, and oxides at pH less than 6 and may be released into the environment as the ionic composition of the pore fluids changes. It is often found in batteries, paints, and plastics, and the majority of biological exposure occurs through food. Cadmium is particularly important due to its severe toxicity in little amounts (Zimmerman, 2010). Chromium exists in four valency states: Cr (II), Cr (III), Cr (IV), and (VI). The metal enters the ecosystem mostly through industrial waste discharges . Cr(VI) is recognized to be very hazardous and carcinogenic, causing cancers of the lung, nasal cavity, and paranasal sinus, as well as being suspected of causing cancers of the stomach and larynx (Akan et al.,2010; ATSDR., 2000).

Musa sapientum, also known as banana, is a herbaceous plant in the Musaceae family. It is thought to have originated in Southern Asia's tropical region. It is currently grown across the tropics, according to (Leslie, 1976). According to the plant is principally farmed for its fruit and, to a lesser extent, for the manufacture of fiber (Abasi and Abia, 2011). It's also thought to be an ornamental plant.

The musa sapientum can reach a height of 2-8m and has leaves that can reach a length of 3-5m. The stem, also known as the pseudo stem, produces a single bunch of bananas before withering and being replaced by a new pseudo stem. The fruit grows in a hanging cluster of 20 fruits per tier and 3-20 tiers per bunch. The fruit is protected by its skin, which is discarded after the interior fleshy portion has been consumed. Minerals, nutritional and anti-nutritional contents such as potassium, calcium, sodium, iron, manganese, bromine, rubidium, strontium, zirconium, niobium, moisture, ash, organic matter, protein, crude lipid, carbohydrate, crude fibre, hydrogen cyanide, oxalate, phytate, and saponins are commonly found in plants (Anhwange, 2008).

The origin of the banana plant, which has been cultivated for approximately 10,000 years, has been identified as South-East Asia. One hundred thirty countries in tropical/subtropical regions of the world, small and large-scale farmers alike, produce more than 100 tons each year. In terms of quantity, the banana plant is the most traded fruit, followed by apples and citrus fruits/group. The local population consumes the most, accounting for 85 percent of the world's desert and cooking banana

Quick Response Code	Access this article online	
	Website: www.enggheritage.com	**DOI:** 10.26480/gwk.02.2022.45.50

Cite The Article: Kaywood Elijah Leizou , Muhammad Aqeel Ashraf (2022). Adsorption of Cd Ii and Cr Vi Ions on Unripe Banana (Musa Sapientum) Peel Biomass, A Sustainable Environmentally Benign Material. *Engineering Heritage Journal, 6(2): 45-50.*

quantities (Unctad, 2012). According to the peel biomass of bananas accounts for around 40% of the total weight of the fruit and is often regarded as waste material, (Anhwange, 2008). According to the above-mentioned production data, more than 40 million tons of banana peel (waste) are generated annually. As a result, there is a need to investigate other uses for banana peel. Against this backdrop, banana peel is recognized as an economically effective and environmentally sound adsorbent for the removal of heavy metals from contaminated streams (Kkiu et al., 2013).

Adsorption is a separation process used to remove dilute contaminants and recover valuable products from aqueous solutions based on the ability of the adsorbate to adhere or attach to the adsorbent (Chia-Chan and Hwai-shen, 2000; Igwe and Abia, 2006).

The current study aims to assess: (1) the potential use of unripe banana (Musa sapientum) peel biomass as an adsorbent for the sorption of Cd (II) and Cr(VI) ions from aqueous solutions; and (2) the interactive effect of contact time, metal ion concentration, pH, adsorbent mass dose, and the efficiency of unripe banana (Musa sapientum) peel biomass in removing Cd(II) and Cr(VI).

2. Materials and Methods

2.1 Adsorbent: Collection and Preparation

Banana (musa sapientum) peel biomass was collected from a local market in Elebele, Ogbia Local Government Area, Bayelsa State, Nigeria. Then it was rinsed and dried for fifteen days before being mashed with a blender. To obtain a fine biomass, the powdered material was sieved through a 106m mesh Tyler sieve. 500 g of sieved adsorbent was soaked in 250 mL of 0.3 M HNO_3 solution for 24 hours before being thoroughly rinsed with distilled water to achieve a pH of 7.0. After air drying for 12 hours, the washed adsorbent was crushed and sieved for usage (Horsfall et al., 2003; Horsfall Jnr and Spiff 2005; Ekpete et al., 2010; Leizou et al., 2019).

2.2 Reagents and Chemicals

All of the chemicals employed were of analytical quality, and the sample was prepared with distilled water. A stock solution of 1000 mg/L cadmium chloride CdCl2 and 5.65 g potassium dichromate, K_2Cr2O_7 was created, and the working solution was made by diluting the stock solution with double distilled water. The concentration range of cadmium II and chromium VI ions obtained from stock solution was 100 to 350 mg/L. Using concentrated 1M NaOH and 1M HCl, the desired pH was adjusted and maintained (Leizou et al., 2019).

2.3 Determination of Operational Parameters

For adsorbent dosage analysis, each conical flask received 100 mg/L of metal ion solutions of Cd II and Cr VI at pH 7. Each flask was filled with a known amount of absorbent (2.0 g, 2.5 g, 3.0 g, and 4.0 g) and agitated intermittently. The influence of pH on the number of Cd II and Cr VI metal ions was studied at four different pH levels: 4, 6, 8, and 10. The pH of the flask solutions was changed with 1 M HCl and 1 M NaOH solutions.

For cadmium and chromium, batch adsorption tests were carried out by contacting 2.0g of the adsorbent with 100 mL of aqueous solutions of various starting concentrations (100 mg/L, 150 mg/L, 250 mg/L, and 350 mg/L) at pH 7. A total of 2.0 g of the adsorbent was weighed and placed in four 250mL conical flasks. The biomass was treated with 50mL of 100mg/L concentration Cd II and Cr VI solutions produced in distilled water from the stock solution. These suspensions' pH was adjusted to 7.0. Time intervals of 30, 60, 90, and 120 minutes were labeled on the flasks. The flasks were carefully wrapped in cellophane and shaken on an electric shaker at 250 rpm for the necessary time intervals.

The samples were filtered using Whatman No. 1 filter paper, centrifuged for 5 minutes, and the initial and final cadmium and chromium ion concentrations were determined. The procedures employed are identical to those previously published (Horsfall Jnr and Spiff, 2005; Ekpete et al., 2010; Leizou et al., 2019). AAS was used to determine the initial and final concentrations of cadmium and chromium ions, as well as the amount adsorbed. The following formulae were used to calculate the percentage and capacity adsorption of adsorbent:

$$\% \text{ R} = \frac{Co-Ce}{Co} \; X\ 100 \qquad (1)$$

$$\text{Qe} = \frac{V(Co-Ce)}{m} \qquad (2)$$

Where,

V = Volume of solution (L)

M = mass of adsorbent (mg)

Co = Initial Concentration

Ce = Final Concentration at equilibrium (mg/L)

Qe = Adsorption capacity at equilibrium (mg/g)

3. Results and Discussion

When the contact duration was increased from 30 to 120 minutes, the adsorptive capacity of Cd (II) and Cr (VI) metal ions rose from 68.9 percent to 71.34 percent and 5.5 percent to 11.9 percent, respectively. The sorption rate is affected by particle size and temperature (Abasi and Abia, 2011). [19] The amount of Cd (II) and Cr(VI) ions removed by the biomass increased until a contact time of 60 minutes at a time interval of 30 minutes and an initial metal ion concentration of 50mg/L.

The pH investigation found that the highest adsorption occurred at pH 10 for Cd(II) and pH 4 for Cr (VI). 96.6 percent of Cd (II) and 46.6 percent of Cr (VI) were eliminated for each pH range. The percentage of Cd (II) adsorbed was higher than the percentage of Cr (VI), indicating that banana (musa sapientum) peel biomass is more effective at removing Cd (II) from solution than Cr (VI).

The pH of the adsorbent influences its surface charge, degree of ionization, and adsorbate specification (Rawajfih and Nsour, 2008; Imamoglu and Tekir, 2008; Tiwari et al ., 2017).

Four different adsorbent dosages were investigated in this study by altering the amount of adsorbent from 2.0g to 4.0g. The amount of Cd II and Cr VI adsorption rose steadily as the initial metal ion concentrations climbed from 1000mg/L to 350 mg/L. Cd (II) removal percentage is 96.8 percent, while Cr (VI) removal rate is 88.7 percent. With increasing initial adsorbate concentrations, the equilibrium adsorption capacity (Qe) rose. The equilibrium adsorption capacity of musa sapientium rose as the initial concentration of adsorbate increased from 100 mg/L to 350 mg/L. (Table 1). This suggests that the starting concentration has a significant impact on adsorption capacity. This conclusion is consistent with the findings of (Vijayakumar et al ., 2012).

3.1 Adsorption Isotherm

The following isotherms were used in this study: Langmuir, Freundlich, Temkin, and Redlich-Peterson, among others. However, for the purposes of this work, the attention is limited to the employment of the Langmuir and Freundlich models to expose the adsorption process of Cd II and Cr VI ions by unripe banana peel biomass (musa sapientum).

The main characteristics of a Langmuir isotherm can be defined in terms of a dimensionless constant, the separation factor "R_L," which is used to predict the adsorption system, whether favorable or unfavorable (Ho et al., 2002).

It can be stated numerically as:

$$RL = \frac{1}{1 + Kl * Co} \qquad (3)$$

Where:

C_0 is the initial metal ion concentration in (mg/L,),

K_L is the Langmuir equilibrium constant.

The value of R_L indicates the type of Langmuir isotherm,

(R_L =0), favourable (0<R_L<1),

Cite The Article: Kaywood Elijah Leizou , Muhammad Aqeel Ashraf (2022). Adsorption of Cd Ii and Cr Vi Ions on Unripe Banana (Musa Sapientum) Peel Biomass, A Sustainable Environmentally Benign Material. *Engineering Heritage Journal, 6(2): 45-50.*

linear (R_L =1)

unfavourable (R_L>1).

In all of the Cr VI (Table 1) situations, the value of RL was less than one.

This demonstrates that the Langmuir isotherm model is favorable for Cr VI adsorption by banana peel biomass (musa sapientum).

This concept, based on the Freundlich Isotherm, suggests a heterogeneous distribution of active sites, accompanied by interactions between adsorbed molecules (Tiwari et al 2017, Freundlich, 1906).

The Freundlich isotherm's linear form is written as:

$$logQe = logKf + \frac{1}{n}\, x\, logCe \qquad (4)$$

Where:

K_F is a constant that is related to adsorption capacity.

n is proportional to the adsorbent's adsorption intensity.

The linear plot of log Qe versus log Ce can be used to calculate KF and 1/n.

The findings of this investigation (chromium and cadmium) demonstrated that the removal of Cr (VI) best fit the Langmuir model (Fig. 2-3) with a higher coefficient of determination, i.e., R^2 =0.988. All four Langmuir types were plotted, although Langmuir type II, a plot of 1/qe vs 1/Ce, appears to have a superior regression coefficient than the others. While for Cd II, the plot best fit with the Freundlich model, which is a plot of log Qe versus log Ce (Fig.4-5), having a higher coefficient of determination, i.e., R2 =0.974 with a (n) value which is the sorption affinity, n =1.1, thus n>1 and this indicates favorable physical process, which is attributed to the active sites present. Table 1 shows the evaluated constants.

Table 1: Adsorption isotherm constants for Cd (II) and Cr (VI)

Metal	**Cd**	**Cr**
Langmuir Parameters		
Qmax (mg/g)	1.38	48.47
KL (L/mg	67.19	1.74
R^2	0.954	0.988
Freundlich Parameters		
K_f	1.24	1.78
$^1/_n$	0.937	4.361
n	1.10	0.2
R^2	0.974	0.944
Pseud-Second Order Parameters		
K_2	4.925	0.577
Qe	1.176	0.0885
H	8.094	0.00293
R^2	0.989	0.796

Table 2 shows the maximum adsorption capacity of several of the adsorbents utilized in this work for the adsorption of Cd and Cr ions as well as musa sapientium. As can be shown, musa sapientium peel biomass has a high level of qm, making it an effective adsorbent.

Table 2: *qm* of various adsorbents for the removal of Cd (II) and Cr (VI) ions .

Adsorbent Used for the Removal of Metal Ions from Solution	Type of Metal Ion Adsorbed	Maximum Monolayer Adsorption Capacity (*qm*, mg/g)
Activated Coal	Cr III	13.552
Oxidized MW Carbon Nanotubes	Cr VI	4.262
Rhizopus Arrhizus for Removal	Cr VI	23.92
Dried Activated Sludge	Cd II	84.30
Tamarindus Indica Seeds	Cr VI	0.098
Coconut Copra Meal	Cd II	4.92
Crude Tamarind Fruit Shells (CTFS)	Cr VI	74.62
HCl-Treated Shells (H-TS)	Cr VI	140.84
Oxalic Acid-Treated Shells (O-TS)	Cr VI	151.51
Orange Peels	Cd II	123.65
Pinus Bark	Cd II	10.384
Pinus Bark	Cr VI	–10.661
ATK Cola Nut Leaves	Cr VI	178.57
UTK Cola Nut Leaves	Cr VI	555.56
ATK Cola Nut Leaves	Cr VI	200
UTK Cola Nut Leaves	Cd II	185.19
This Study	Cd II	1.44
This Study	Cr VI	47.67

Source: (Ibrahim and Faruruwa , 2020)

The kinetic investigation was carried out using pseudo-first and pseudo-second order. According to the findings, the adsorption kinetics were pseudo-second order, Figures 6 and 7 show the plots of the kinetics models. Adsorption data fit almost all models well, with correlation values all larger than 0.70. The pseudo-second order was the best correlated in the kinetics plots, with 0.978 for Cd (II) and 0.796 for Cr (VI). The pseudo-second order was the primary rate limiting mechanism for sorption. The optimal pH for cadmium and chromium was 4.0 and 10.0, respectively, while the qm for cadmium and chromium was 1.38 mg/g and 48.48.47 mg/g. Cadmium and chromium adsorption isotherms corresponded well with both the Langmuir type and the Freundlich adsorption isotherm, indicating that chemisorption is the dominant mechanism in the sorption process. Furthermore, the adsorption process for the two metals was discovered to follow pseudo second - order adsorption kinetics, indicating that chemisorption could be the rate–limiting factor (Ali et al., 2020).

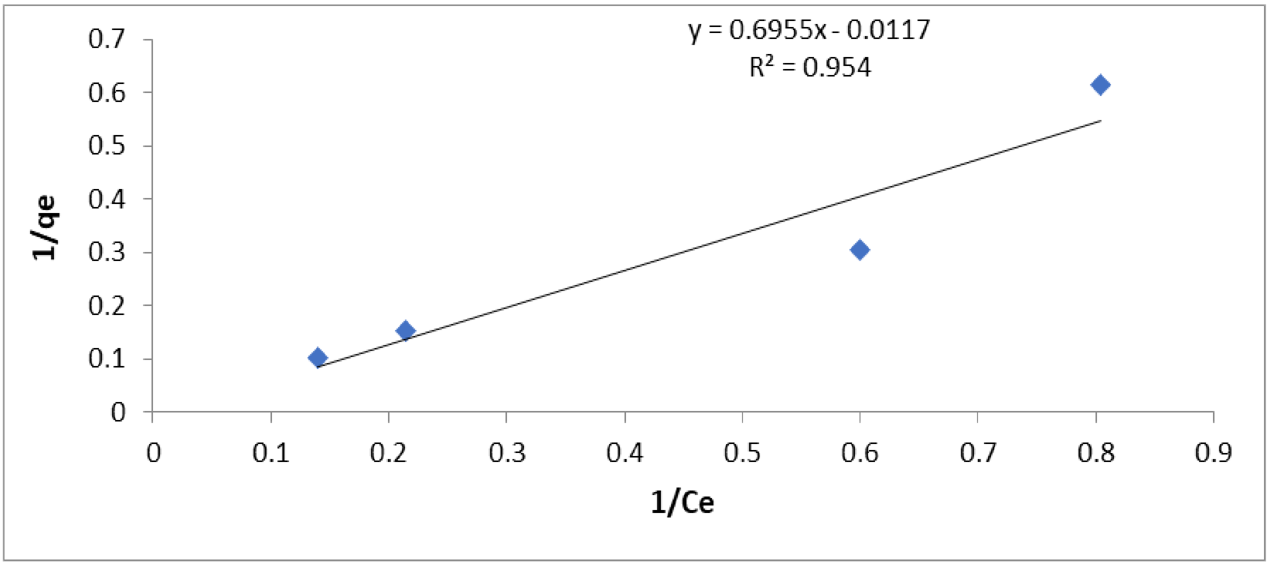

Figure 1: Langmuir isotherm for cadmium removal

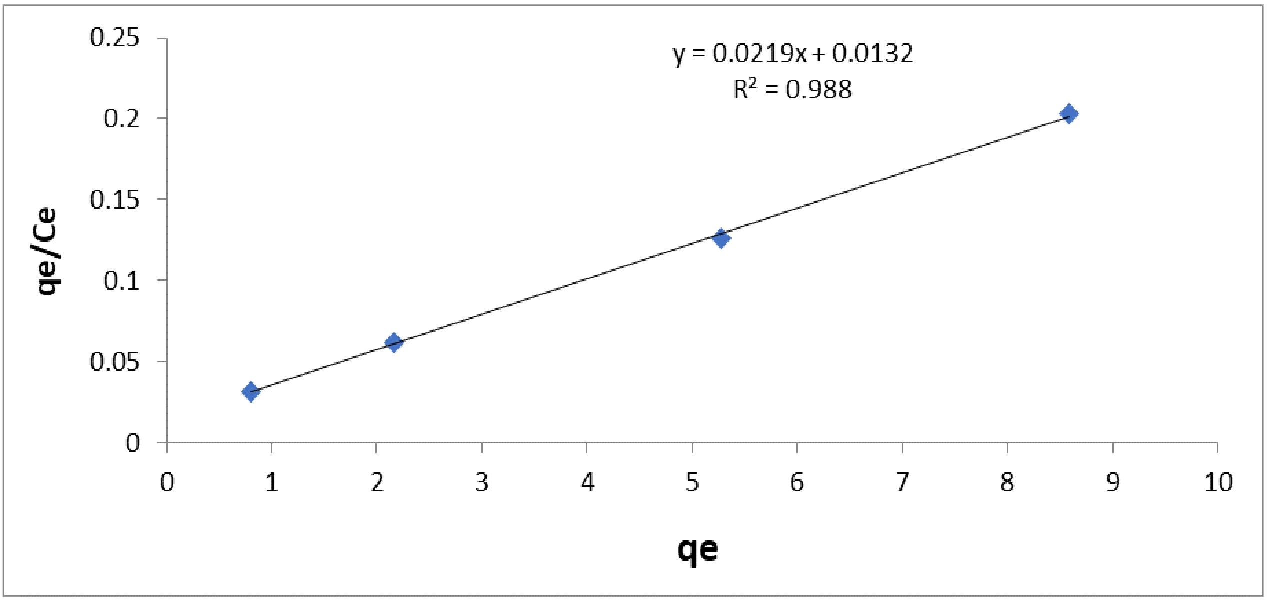

Figure 2: Langmuir isotherm for Chromium removal

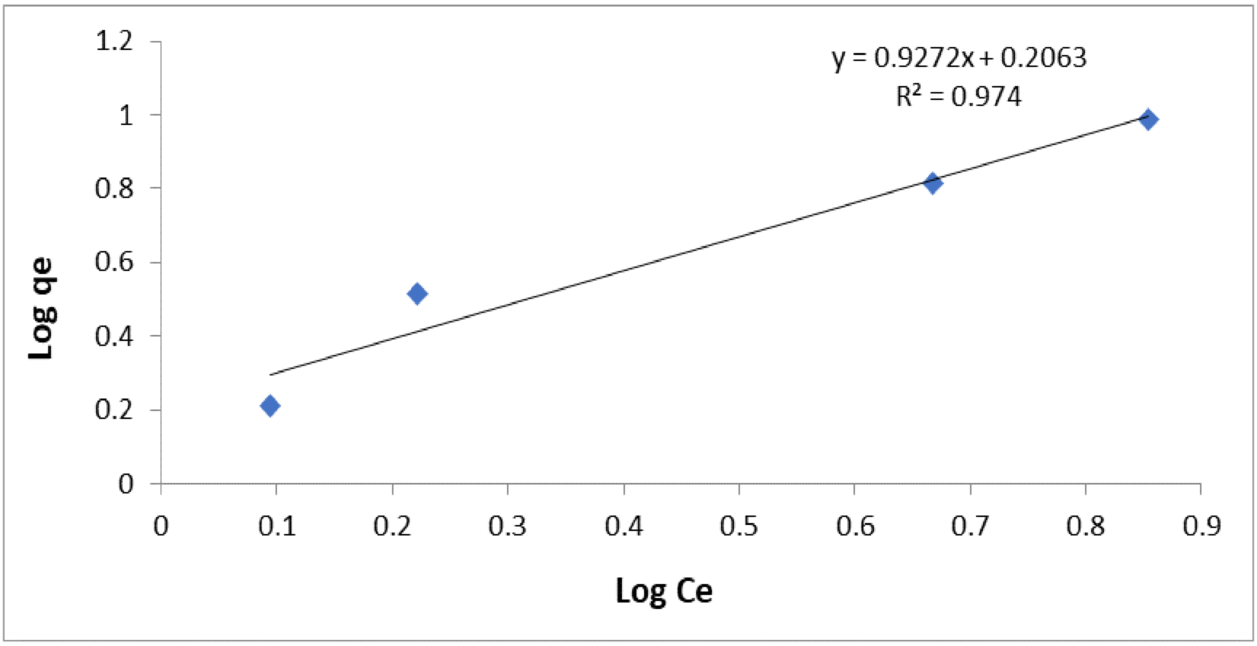

Figure 3: Freundlich isotherm for Cadmium removal

Cite The Article: Kaywood Elijah Leizou , Muhammad Aqeel Ashraf (2022). Adsorption of Cd Ii and Cr Vi Ions on Unripe Banana (Musa Sapientum) Peel Biomass, A Sustainable Environmentally Benign Material. *Engineering Heritage Journal, 6(2): 45-50.*

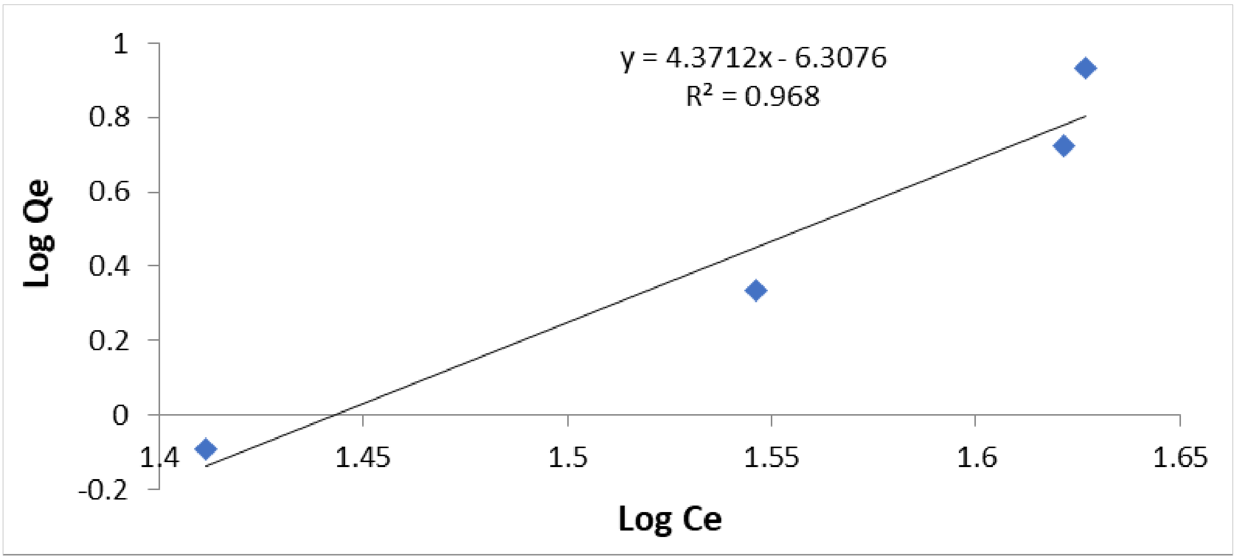

Figure 4: Freundlich isotherm for Chromium removal

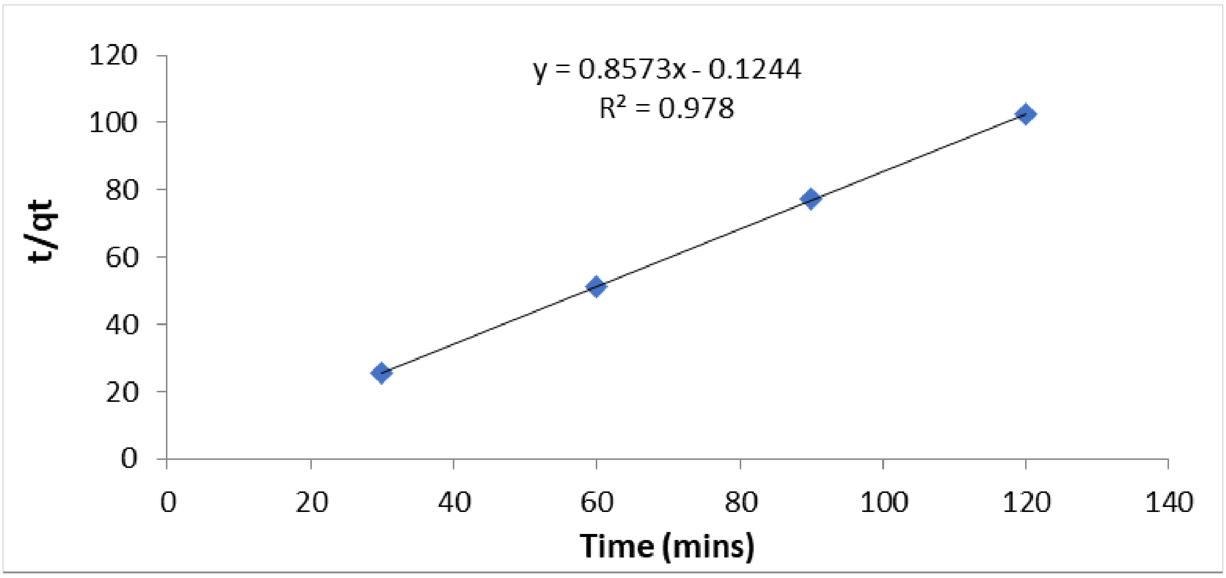

Figure 5: Pseudo second order for cadmium removal

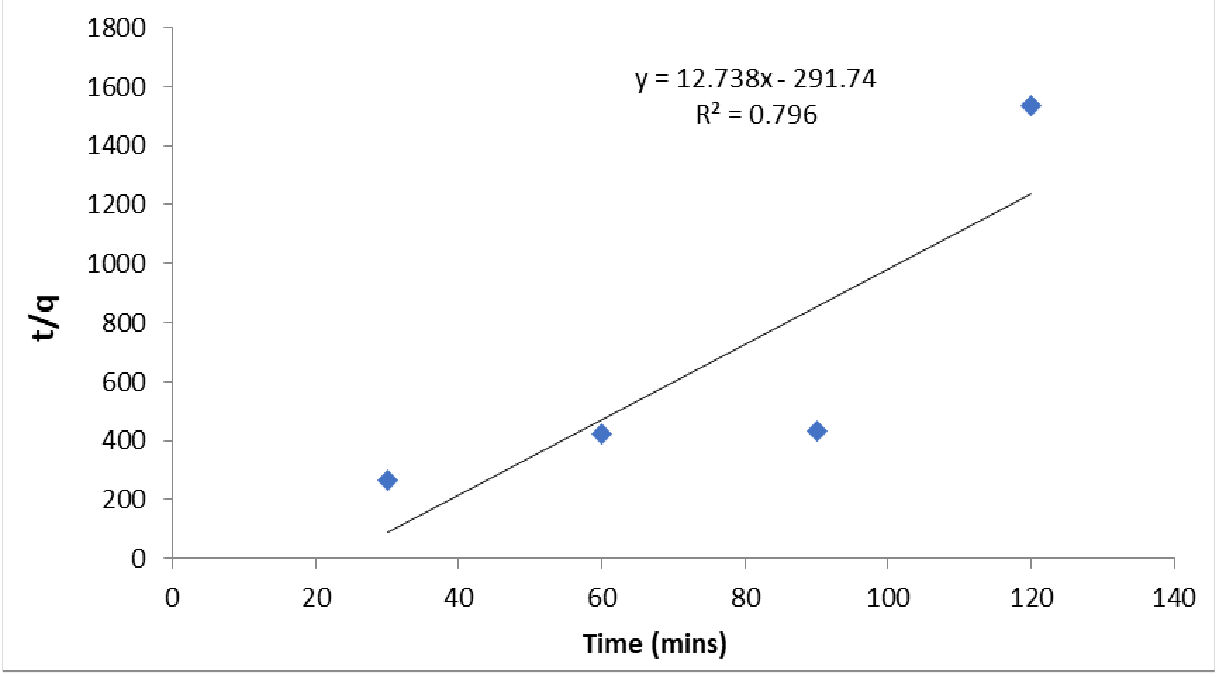

Figure 6: Pseudo second order for chromium removal

4. CONCLUSION

The metals adsorption isotherms are strongly associated with the Langmuir type of adsorption isotherm, indicating that chemisorption is the dominant mechanism in the sorption process. Furthermore, the adsorption process for the metals was discovered to follow pseudo second - order adsorption kinetics, indicating that chemisorption could be the rate–limiting factor. This study found that, rather than purchasing more expensive materials, unripe banana peel biomass can be successfully employed as an effective and promising low-cost adsorbent material and as an alternative to more expensive adsorbent.

REFERENCES

Abasi CY, Abia. AA., 2011. Adsorption of iron (III), lead (II) and cadmium (II) ions by unmodified Rapha palm. (Raphia hookeri) fruit endocarp". Environmental. Research Journal, 5 (3), Pp. 104-103.

Ahluwalia SS, Goyal D., 2007. Microbial and plant derived biomass for removal of heavy metals from wastewater". Biores. Technol; 98, Pp. 2243–57.

Akan JC, Abdulrahman FI, Sodipo OA, Ochanya AE, Askira YK., 2010. Heavy metals in sediments from River Ngada, Maiduguri Metropolis, Borno State, Nigeria. J. Environ. Chem. Ecotoxicol, 2 (9), Pp. 131-140.

Akinyosoye VO., 1991. Tropical agricultural, Manmillan publishers limited, Ibadan, Pp. 65-68

Ali AS, Hassan AMA, Nour MH., 2020. Equilibrium and Kinetics studies for Removal of Heavy Metals from simulated Wastewater using Chitosan/Activated carbon composite, Inter J Res in Environ Sci, 6,(4), Pp. 12-27. DOI: http://dx.doi.org/ 10.20431 /2454-9444.0604002

Anhwange BA., 2008. Chemical compostion of musa sapientum (banana) peels. J food technology, 6 (6), Pp. 263-266.

ATSDR. 2000. Agency for Toxic Substances and Disease Registry, Toxicological Profile for Chromium. Atlanta, GA: U.S. Department of Health and Human Service, Public Health Service. 1600 Clifton Road N.E, E-29 Atlanta, Georgia, 30333 (6-9), Pp. 95-134.

Blanco AB, Sanz B, Llama MJ, Serra JL., 1999. Biosorption of heavy metals to immobilized Phormidium laminosum biomass. J. Biotechnol, 69, Pp. 227-240.

Chia–Chang L, and Hwai-shen L., 2000. Adsorption in a centrifugal field: Basic dye adsorption by activated carbon. Ind. Eng. Chem. Res; 39, Pp. 161-166.

Ekpete OA, Nugabisor E, Ogiga E, Amadi JN., 2010. Adsorption of Pb2+ and Cu2+ ions from aqueous solutions by mango tree (Mangifera indica) saw dust. Inter J Biol. Chem. Sci, 4 (5), Pp. 1410-1416.

Freundlich HMF., 1906. Over the adsorption in solution. J. Phys. Chem, 57, Pp. 385- 471.

Ho Y. S., Huang, C. T. and Huang, H. W., 2002. Equilibrium sorption isotherm for metal ions on tree fern, Process Biochem., 37, Pp. 1421–1430.

Horsfall Jnr M, Abia AA, Spiff AI., 2003. A removal of Cu2+ and Zn2+ ions from wastewater by cassava Manihol esculentus cranz Waste Biomass. African J. Biotech, 2, Pp. 969-976.

Horsfall Jnr M, Spiff AI., 2005. Equilibrium Sorption Study of Al3+, Co2+ and Ag+ in Aqueous Solutions by Fluted Pumpkin (Telfairia Occidentalis HOOK f) Waste Biomass (Technical Paper). Acta Chim. Slov, 52, Pp. 174–181.

Ibrahim ZH, Faruruwa MD., 2020. Biosorption of Cd2+andCr6+from aqueous solution using cola-nut leaves as low-cost biosorbent. Journal of Chemistry, 1-10.

Igwe JC, Abia AA., 2006. A bio-separation process for removing heavy metals from wastewater using biosorbents. African J Biotechnology, 5 (12), Pp. 1167-1179

Imamoglu M, Tekir O., 2008. Removal of copper (II) and lead (II) ions from aqueous solutions by adsorption on activated carbon from a new precursor hazelnut husks. Desalination, 228, Pp. 108–113.

Kkiu A, Walpola BC, Min-Ho Y., 2013. Banana Peel: A Green Solution for Metal Removal from Contaminated Waters. Korean. J Environ Agric, 32 (2), Pp. 108-116.

Leizou KE, Muhammad AA, Samah MAA, Chowdhury AJK., 2019. Evaluation of green solution potentials of unripe banana (musa sapientum) peel biomass. Acta Scientifica Malaysia (ASM), 3 (1), Pp. 09-16. DOI : https://doi.org/10.26480/asm.01.2019.09.16

Leslie SC., 1976. An introduction to the botany of tropical crops. 2nd edn. Longman group limited, London, Pp. 153-155.

Nguyen TAH, Ngo HH, Guo WS, Zhang J, Liang S, Yue QY, Li Q, Nguyen TV., 2013. Applicability of agricultural waste and by-products for adsorptive removal of heavy metals from wastewater. Bioresource Tech; 148, Pp. 574-585.

Rawajfih Z, Nsour N., 2008. Thermodynamic analysis of sorption isotherms of chromium (VI) anionic species on reedbiomass. J Chem. Thermodyn, 40, Pp. 846–851.

Tiwari P, Vishwakarma MC, Joshi SK., 2017. Sharma H, Bhandari NS. Adsorption of Pb (II), Cu (II), and Zn (II) Ions onto Urtica dioica Leaves (UDL) as a Low-Cost Adsorbent: Equilibrium and Thermodynamic Studies. Modern Chemistry, 5 (1), Pp. 11-18.

UNCTAD. 2012. Infocomm commodity profile banana. http://www.unctad.info/en/ Infocomm/AACP Products/commodity-profile---Banana/.

Vijayakumar G, Tamilarasan R, Dharmendirakumar M., 2012. Adsorption, Kinetic, Equilibrium and Thermodynamic studies on the removal of basic dye Rhodamine-B from aqueous solution by the use of natural adsorbent perlite. J. Mater. Environ. Sci, 3 (1), Pp. 157-170.

Zimmerman AJ. 2010. Speciation of heavy metals in disturbed and undisturbed sediments from Atchafalaya Bay, Houma Navigation Canal, and Southwest Pass; Louisiana, M. Sc. Thesis, Department of Geology and Geophysics, B.S. University of Hawaii Hilo, Pp. 5.

Cite The Article: Kaywood Elijah Leizou , Muhammad Aqeel Ashraf (2022). Adsorption of Cd Ii and Cr Vi Ions on Unripe Banana (Musa Sapientum) Peel Biomass, A Sustainable Environmentally Benign Material. *Engineering Heritage Journal, 6(2): 45-50.*