International Journal of Human Capital in Urban Management
(IJHCUM)

Homepage: http://www.ijhcum.net/

ORIGINAL RESEARCH PAPER

Adsorption studies of Iodine removal by low-cost Bioinspired Mushuma and Mupane bark derived adsorbents for urban and rural wastewater reuse

O. Gotore [1,2*], V. Mushayi [2], R. Rameshprabu [3], L. Gochayi [4], T. Itayama [1]

[1] *Department of Water and Environmental Engineering, Graduate School of Advanced Engineering, Nagasaki University, Nagasaki, Japan*

[2] *Department of Civil Engineering, Harare Polytechnic College, Harare, Zimbabwe*

[3] *Department of Renewable Energy Engineering, School of Renewable Energy, Maejo University, Chiang Mai, Thailand*

[4] *Department of Water Management and Governance, Institute for Water Education, IHE Delft, Netherlands*

ARTICLE INFO

Article History:
Received 22 February 2022
Revised 19 April 2022
Accepted 18 May 2022

Keywords:
Bayesian analysis
Frequentist analysis
Iodine
Kinetic adsorption
Mupani biochar
Mushuma biochar
Water reuse

DOI: 10.22034/IJHCUM.2022.03.01

ABSTRACT

BACKGROUND AND OBJECTIVES: Water pollution and scarcity are becoming a serious challenge worldwide and methods of treating or recycling the wastewater are becoming expensive, especially in rural areas of least developed countries. An affordable wastewater recycling approach is imminent and should be cost-effective, using local materials to alleviate the water shortage and pollution challenges. The use of adsorbents from different biomass has been on the highway and tree barks are no exception for that matter. This research, therefore, intends to test the use of novel material's capacity to remove Iodine from an aqueous solution under set conditions and use Bayesian statistics to validate the results as compared to the Frequentist approach.

METHODS: This study is qualitative and developmental research where Bayesian and Conventional statistics were applied to complimentarily validate the results. Kinetic models, Field Emission Scanning Electron Microscopy, and Energy Dispersive X-ray Spectroscopy were used to characterize the novel adsorbent to check for its potential and capability in removing Iodine from water. Akaike Information Criterion (AICc) was then used to select the best model.

FINDINGS: The findings demonstrated that the Bayesian approach was simultaneously applied with classical methods to compare their parameter estimation. Mupane biochar performed better than Mushuma, Pseudo-Second-Order model described both materials better with lower AICc values of 37.76 and 38.03 than other kinetic models respectively, indicating a chemisorption mechanism. Bayesian approach remarkably revealed slightly higher qt estimations of 40.712 and 41.639 mmol/g than conventional statistics with 40.01 and 40.29 mmol/g for Mushuma and Mupane biochar. Elovich model subsequently fit the data, henceforth demonstrating a heterogenous surface property with chemisorption phenomena. Field Emission Scanning Electron Microscopy and Energy Dispersive X-ray Spectroscopy exhibited C (81.93 mol% and 86.91 mol %) and O (16.12 mol% and 11.49 mol%) for Mushuma and Mupane respectively.

CONCLUSION: Material performances were insignificant however, Mupane marginally outperformed Mushuma bark. However, further examination is required in determining the surface area, adsorption isotherms, and functional groups available. This African tree-bark biochar promised to be good adsorbents of wastewater contaminants and their kinetic mechanisms can be a benchmark to suggest their applications as potential candidates for environmental-ecosystem-protection and water re-use strategy, especially in rural and urban areas.

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
34	5	3

*Corresponding Author:
Email: *gotoreobey@gmail.com*
Phone: +817044862303
ORCID: 0000-0001-8556-0151

Note: Discussion period for this manuscript open until October 1, 2022 on IJHCUM website at the "Show Article.

INTRODUCTION

In most remote rural areas of developing countries, tree barks are dominant bioresources that become available post forestry commission operations, seasonal shifts, and some industrial activities. Harkin *et al*. (1971) reiterated that tree bark institutes between 9 and 15 % of stem volume. Mushuma tree, an African native species, is dominant in the Midlands province of Zimbabwe. The Shuma fruits (Jackle-berry, *Diospyros mespiliformisare)* (Ajayi and Mafongoya, 2017) are syruplike juice, and smooth with soft-transparent- jelly inside. The tree has a medium to huge tree stem with the outer bark peeling off naturally as the tree grows as well as the season changes. Additionally, the Mupane tree *(Colophospermum mopane)* (Ajayi and Mafongoya, 2017) is a legume family vegetation abundantly found in the Midlands of Zimbabwe under hot, dry low-lying areas between the altitude of 200m and 1150 meters. They are also found in the Northwestern part of South Africa. Tree barks of Mushuma and Mupane are usually used to start fires because of their common availability in the province as well as their affinity to fires. It is very quick to start fires and the tree wood itself takes a long time without extinguishing. Generally, these trees' bark is either left in the forest after the tree ages or the outer barks peeled off or used as fuel by the local communities. However due to high rural to urban movements, the availability of tree barks is increasing, and the rest is getting decomposed in the bush with no value to the community. Moreover, environmental concerns regarding soil quality would be at stake when considering the effect of the natural decomposition of tree bark. Sometimes, they block waterways, and river trash screens, and fill in the shallow water wells which can become a danger to humans at night as well as wild and domestic animals. However, the use of tree barks had been recently researched in looking for better material for use in the adsorption field of study when they can be used as an adsorption substrate for the elimination of water pollutants including dyes (Ajaelu *et al*., 2017; Cong *et al*., 2017; Tan *et al*., 2021) heavy metals (Agarwal *et al*., 2020; Cumberland *et al*., 2018; Afroze *et al*., 2016; Cutillas-Barreiro *et al*., 2014) and pharmaceutical compounds (Afroze *et al*., 2016). Zazycki *et al*., (2018) also added that numerous approaches can be employed to eradicate water toxins but among them, adsorption has been found to account for added advantages owing to its simple production process, renewing capacity, high proficiency, and cost-effective. In the adsorption process, activated carbon is widely used owing to its large specific surface area, developed pore structure, high adsorption efficiency, and good chemical stability (Liu *et al*., 2019). Prajapati and Mondal (2020) restated that adsorption normally takes place within mesopores which are conduits for adsorbate particles, and capillary condensation occurs to adsorb these macromolecules. The adsorption process has been proven one of the best wastewater treatment technologies around the world and activated carbon is undoubtedly considered a universal adsorbent for the removal of diverse types of pollutants from water (Dim 2013). However, given the high cost and associated preparations and chemicals required for activated carbon, there is a constant search for alternate low-cost adsorbents. From that end, Liang *et al*., (2021) elucidated that plant barks that are rich in tannin-rich produce the most effective adsorbent materials as compared to other agro-based biomaterials. Plant barks are among the most widely utilized adsorbents in the study of pollutant removal from aqueous media and numerous studies have been conducted in this regard (Obey *et al*., 2021). Plant species investigated include eucalyptus, (Afroze *et al*., 2016, Cumberland *et al*., 2018). African border (Zazycki *et al*., 2018), flamboyant pods (Aremu *et al*., 2018), sycamore (Cong *et al*., 2017), pine (Cutillas-Barreiro *et al*., 2014), and many others. Besides their comparatively low or no cost, there are several recompenses proliferate in using plant barks as precursors (adsorbents) for water treatment, including being eco-friendly, renewable in nature, and requiring less time to process (Eletta *et al*., 2020; Tan *et al*., 2021). In this research, data analysis was conducted with the help of well-known conventional statistics and the application of Bayesian statistics as an emerging powerful approach. Bayesian statistics has the potential to replace the use of classical statistics, addressing most of the latter's inherent inadequacies, and supporting comprehensive and demanding statistical analysis of extensive diversity of pragmatic data (Furia *et al*., 2019, Gelman *et al*., 2004). Bayesian analyses provide unswerving probabilistic evaluations between groups/treatments and are suited to material science studies as they provide more defense against over-confidence in small sample sizes (Borg *et al*., 2018; Mengersen *et al*.; 2016; Ntzoufras 2011; First *et al*., 2016) as compared to traditional techniques. In this context, The R2JAGS (Just another Gibbs sampler) package provides an interface to the R programming language, which uses the Hamiltonian Markov Chain Monte Carlo (MCMC) method to generate MCMC chains used to characterize the posterior distribution (Ntzoufras 2011; Firat *et al*., 2016). Therefore, Bayesian techniques do not suffer from several restrictions as frequentist statistics do and can sustain rich, vigorous analyses in numerous circumstances (Furia *et al*., 2019; Swinton *et al*., 2018), concomitantly, illustrating how conventional techniques analysis works and the deficiency they hold (Furia *et al*., 2019; Gelman *et al*., 2004). This novel study aims to investigate and understand the physicochemical properties of Mushuma and Mupani barks and their characterization to evaluate the kinetic mechanism of adsorption from different models and statistical methods for the determination of equilibrium analysis. Additionally, the novel study will bring about an investigation of the fundamental use of biochar in rural areas to treat wastewater and remove environmental pollutants. Thus, it is the first research to be conducted on these two materials from literature and the results will be used in further studies. Additionally, the implementation of Bayesian statistics in this study will help validate the data and unlock and authenticate their application in material science studies. A comparison between classical and Bayesian posterior distribution will be made and evaluated for a sound and robust decision. The assessment of model parameter magnitudes will be significant as the equilibrium concentrations will be availed from three models attested in this study. The current study has been carried out in Nagasaki, Japan in 2022.

MATERIALS AND METHODS

Materials and chemicals

The already fallen and dried Mushuma and Mupani barks were obtained in Gokwe, a rural area in the Midlands province of Zimbabwe. After collection from the bush, the materials were transferred to the laboratory, chopped down, washed twice with Ultra-pure water to remove any adsorbed impurities, and allowed to dry in the sun for two weeks. The dried barks were pyrolyzed at 600 °C for 2 hours in a muffle furnace and later cooled down in a desiccator. The produced bark biochar from Mushuma (MSHBC) and Mupani (MPNBC) was then sieved after ground into small particle sizes 0.25-1.0mm. they were then washed with tap water to adjust the pH to 7.0. The temperature was monitored by a thermocouple sensor (K-87 type, HTK0251, HAAKO, Japan) with a digital controller thermometer (E5CB, 88 Omron, Japan). Later vacuumed to eliminate air as much as possible with a stirrer for an overnight period. Only the settled biochar was assumed to be well vacuumed and was preserved in 100 ml with Ultra-pure (from the laboratory) water before being used in the experiment. To conduct the adsorption experiment, Iodine solution and Sodium thiosulphate ($Na_2S_2O_3$) were bought from Nacalai Tesque, INC, Tokyo, Japan, and soluble starch was purchased from Wako pure chemical industries Ltd, Osaka, Japan. All chemicals used in this study were analytical grades.

Kinetic adsorption experiment

Iodine solution (0.1 mol/L) was measured for the adsorbate and diluted with Ultra-pure water to get this concentration, 1.02g wt.% of both MSHBC and MPNBC was weighed and then placed in 300 ml conical flasks with 200 ml iodine solution (0.1 mol/L). This mixture was agitated for 48 hours at 20 ±1 °C with sample collection from 1, 2, 4, 6, 8, 10, 12, and 24 hours post vigorous shaking by EYELA multi-shaker at 152 rpm. A sample of 5 ml was collected each time for kinetic measurement, filtered, and titrated with 0.1 mol/L $Na_2S_2O_3$ using starch for ultimate endpoint equivalence. After the experiment, the changes in qt with time were fitted into the pseudo-first (Eq. 1) and pseudo-second (Eq. 2) order kinetic models to investigate the adsorption kinetics of iodine on MSHBC and MPNBC:

$$q_t = q_e\left(1-\exp\left(-k_1 t\right)\right) \tag{1}$$

$$q_t = \frac{q_e^2 k_2 t}{1+q_e k_2 t} \tag{2}$$

In these equations, qt (mmol/g) represents the amount of iodine absorbed by biochar at time *t*. K_1 (1/min) and K_2 (g. mmol/min) represent rate constants of the adsorption. To further investigate the underlying adsorption mechanism of iodine by MSHBC and MPNBC, the Elovich (Eq. 3) and Intra-particle diffusion (Eq. 4) models were used to describe the kinetic data.

$$q_t = \left(\frac{1}{\beta}\right)\ln(\alpha\beta) + \left(\frac{1}{\beta}\right)\ln(t) \quad (3)$$

$$q_t = k_p t^{\frac{1}{2}} + C \quad (4)$$

Where α is the initial adsorption rate (mmol/g. /min); β (g/mmol) is a constant related to surface coverage and activation energy, and t (min) is the contact time; k_p is the Intra-Particle Diffusion (IPD) model rate constant (mmol/g/min), t is time in mins and C is the intercept reflecting the boundary layer thickness.

Statistics and data analysis

The R software version 4.1.3 was used for data analysis and simulations conducted in this study, which is a well-reputed and open-source statistical programming language. The fitting of the nonlinear curves was completed by using the Nonlinear Least Squares (NLS) command and the prediction function from the R package. Additionally, Bayesian statistics were applied to attest to the applicability of such a powerful method in adsorption studies in parameter estimation. Therefore, R2JAGS (ver. 0.7-1) and the Bayes-plot packages were used to establish the kinetic model parameters and graphically represent this information respectively in the R. Bayes-plot package extracts the Markov chain Monte Carlo (MCMC) results of the posterior distribution and analyses the data graphically from the 10 000 iterations, 1000 burning and 3 MCMC chains used. The prior and likelihood distributions were set (gamma distribution) before the simulations were conducted, and the posterior was presented and evaluated against the conventional statistics. Additionally, the Akaike Information Criterion (AICc), a second-order estimator of prediction error and was used to check the relative quality of statistical models for the adsorption kinetics data. Given that three models were tested in this study, AICc estimates the quality of each model, relative to each model, and the best model will be chosen concerning the lowest criterion generated by the AICcmodavg package in R. The model with the lowest value will be the conventionally selected.

RESULTS AND DISCUSSION

Elemental composition

The EDX elemental composition for MSH and MPN biochar were 74.76 % and 80.92 %, 19.6 % and 14.25 % for C and O respectively. Other inorganic elements are shown in Fig. 1 and Table 1 as confirmed by the EDX analysis. This shows that both barks have enough rich C content with MPHBC having a higher content of carbon. The oxygen content is very high for MSHBC bark than MPNBC, however, both compositions are as expected after pyrolysis. After dehydration and decarboxylation reactions, the O/C ratio diminished to 0.263 % and 0.176 % for MSHBC and MPNBC respectively, and this can be anticipated for the H/C ratio as well. Even though diminished, it is high enough to suggest the existence of polar functional groups on the biochar surface which is connected to the carbonization process.

This reduction could reflect the loss of simply degradable compounds of carbon such as the volatile matter hence this H/C molar ratio as well indicated the formation of aromatic compounds in the biochar. In addition to that, Wu *et al*., (2012) and Dong *et al*., (2013) also reiterated that lower ratios might indicate a unique structural arrangement of aromatic rings (Vishnu *et al*., 2021), which forms from stables graphitic like structures. The O/C molar ratio decreased during carbonization, and that could have induced dehydration responses which abridged the hydrophilicity capacity of the biochar surface (Dang *et al*., 2021; Doumer *et al*., 2015; Al-Wabel *et al*., 2013). Higher temperatures of 600 °C as used in this study might lead to an increased amount of volatile matter which in turn enhanced the content of these aromatic structures, especially when the temperature exceeded 400 °C as narrated by Soars *et al*., (2022), Fang *et al*., (2015) and Al-Wabel *et al*., (2013).

Spectrometric surface morphological analysis

From the FESEM images in Fig. 1, morphology analysis of two bark biochar products revealed that surface texture can be influenced by biomass type even under identical pyrolysis conditions. Biochar produced from Mushuma bark has large surface pores (10-15 μm in diameter), uniformly distributed and separated by a thick carbon wall (2-3 μm) than Mupami bark, while the Mupane has smaller and heterogeneously distributed pores (3-5 μm in diameter). This corresponds to the kinetic results from Iodine adsorption where MPNBC seem to have higher qt values than MSHBC. Larger pores tend to correlate to the limited surface area than small pores, so the adsorption will be higher on smaller pores. Additionally, small pores exhibited on the biochar are

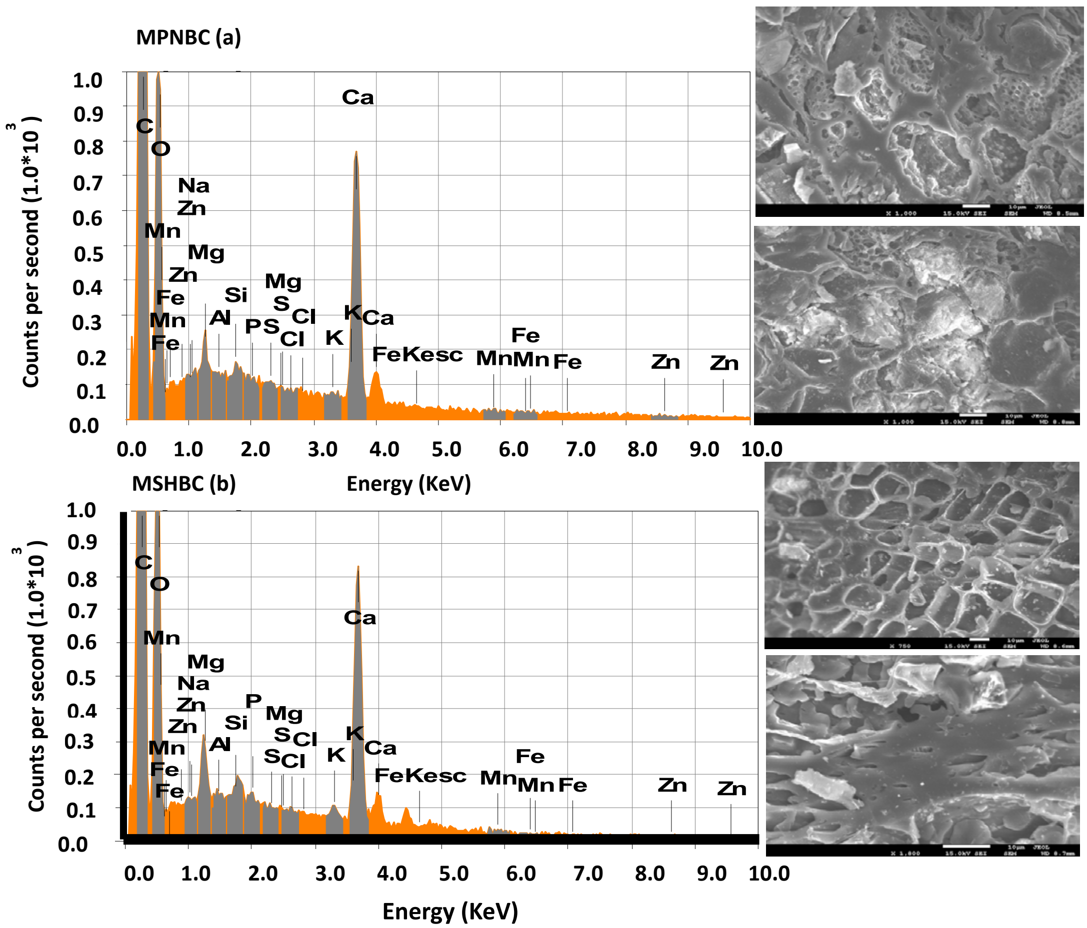

Fig. 1: Presentation of EDX graphical output and FESEM images for elemental composition and surface morphological analysis respectively, of Mupane (a) and Mushuma (b) Tree barks biochar pyrolyzed at 600 ˚C for 2 hr

Table 1: The chemical composition extracted from the EDX analysis for Mupane and Mushuma barks biochar modified at 600 ˚C for 2 hrs. in mass and moles units.

	Mushuma biochar		Mopane biochar	
Chemical formula	ms%	mol%	ms%	mol%
C*	74.76	81.93	80.92	86.91
O*	19.6	16.12	14.25	11.49
Na	nd*	nd*	nd*	nd*
Mg*	0.45	0.24	0.25	0.13
Al*	0.03	0.02	nd*	nd*
Si	nd*	nd*	0.04	0.02
P*	0.11	0.05	0.02	0.01
S*	0.03	0.01	0.07	0.03
Cl*	0.06	0.02	nd	nd
K*	0.23	0.08	0.07	0.02
Ca*	4.51	1.48	4.18	1.34
Mn*	0.07	0.02	0.04	0.01
Zn*	0.15	0.03	0.16	0.03
Total	100	100	100	100

nd*-not detected

clearly associated with high porosity and void volume which corresponds to more capacity for adsorption.

Adsorption kinetics mechanism

MPNBC showed more significant adsorption for Iodine than MSHBC as exhibited in Fig. 2 (a) and (b) correspondingly. Consequently, the Iodine kinetic adsorption process on MPNBC and MSHBC could be divided into three stages: rapid adsorption stage, slow adsorption stage, and adsorption equilibrium stage as elucidated by Zarzycki *et al*., 2018 as well. The first 12 hours were observed to be a rapid Iodine adsorption stage on both biochars. The graph for MPNBC seems to be steeper than MSHBC. The adsorption capacity of the prepared Mupane and Mushuma barks were estimated to be 40.38 and 39.78 mg/g respectively, from the experimental data. From conventional statistical analysis of Pseudo-second order. model, Mushuma and Mupani biochar exhibited adsorption capacity of 40.01 and 40.29 mmol/g (Table 2) which were slightly lower than the Bayesian outcome of 40.712 and 41.639 mmol/g (Table 3) correspondingly. This reveals the strength of Bayesian analysis against classical statistics as different quantile ranges revealed different estimations and the 50% (median) was so close to the actual mean for each parameter. The adsorption rate constants of the two biochar also exhibited the above phenomenon where the conventional method indicated a homogeneous reaction rate (0.014/min) as in Table 2, so as the Bayesian statistics as shown in Table 3. Moreover, the Elovich model revealed that the initial adsorption was 110.701 and 117.88 mmol/g/ min, 112.847 and 120.214 mmol/g/ min for Mupane and Mushuma biochar from Conventional and Bayesian methods respectively. Different adsorption mechanisms could

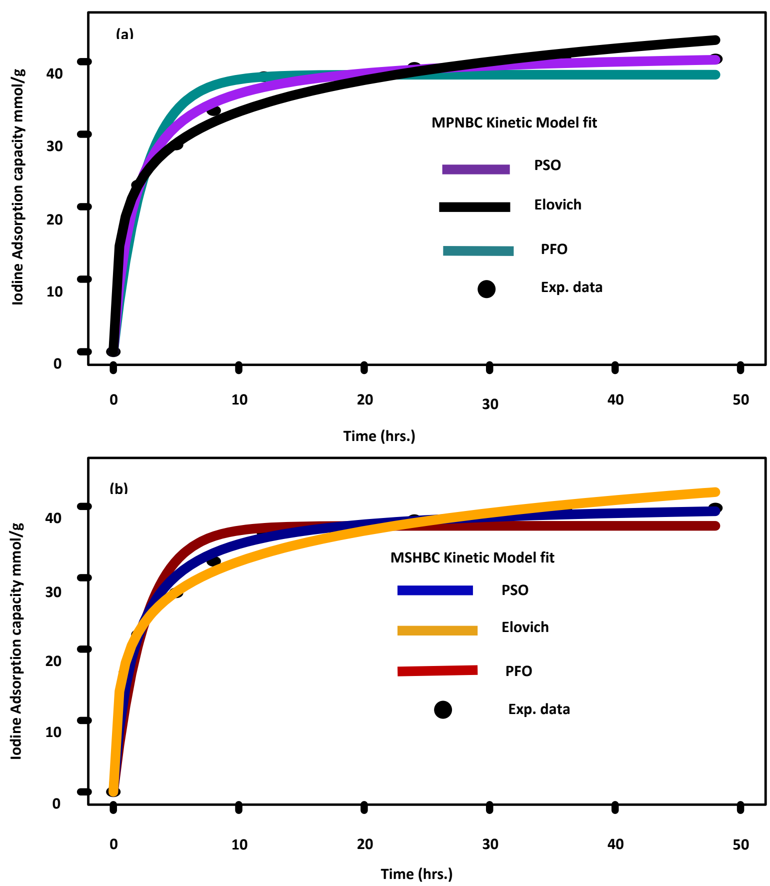

Fig. 2: The effect of contact time on the adsorption of Iodine solution onto the bark biochar, (a) Mushuma, (b) Mupani, fitting three Models (Pseudo first order, second-order, and Elovich) after 48 hr. of agitation

Table 2: The kinetic adsorption model of iodine onto Mushuma and Mupane bark derived Biochar showing the fitting parameters from the conventional statistical analysis of Pseudo first order, second order, and Elovich Models

	Mushuma biochar		Mopane biochar	
Chemical formula	ms%	mol%	ms%	mol%
C*	74.76	81.93	80.92	86.91
O*	19.6	16.12	14.25	11.49
Na	nd*	nd*	nd*	nd*
Mg*	0.45	0.24	0.25	0.13
Al*	0.03	0.02	nd*	nd*
Si	nd*	nd*	0.04	0.02
P*	0.11	0.05	0.02	0.01
S*	0.03	0.01	0.07	0.03
Cl*	0.06	0.02	nd	nd
K*	0.23	0.08	0.07	0.02
Ca*	4.51	1.48	4.18	1.34
Mn*	0.07	0.02	0.04	0.01
Zn*	0.15	0.03	0.16	0.03
Total	100	100	100	100

nd*-not detected

Table 3: Bayesian estimation of posterior distribution parameters (Mean ±SD) from three kinetic adsorption Models generated by the Just another Gibbs sampler (R2JAGS) package from R software

	Mushuma biochar		Mopane biochar	
Chemical formula	ms%	mol%	ms%	mol%
C*	74.76	81.93	80.92	86.91
O*	19.6	16.12	14.25	11.49
Na	nd*	nd*	nd*	nd*
Mg*	0.45	0.24	0.25	0.13
Al*	0.03	0.02	nd*	nd*
Si	nd*	nd*	0.04	0.02
P*	0.11	0.05	0.02	0.01
S*	0.03	0.01	0.07	0.03
Cl*	0.06	0.02	nd	nd
K*	0.23	0.08	0.07	0.02
Ca*	4.51	1.48	4.18	1.34
Mn*	0.07	0.02	0.04	0.01
Zn*	0.15	0.03	0.16	0.03
Total	100	100	100	100

nd*-not detected

have been encountered during the 48-hour contact time, but the adsorption rate gradually decreased until the adsorption reaches the equilibrium state as Ajayi and Mafongoya (2017) elaborated.

Moreover, Table 2 also presents the adsorption kinetic results from conventional statistics which shows that the pseudo-second-order kinetic equation better describes the adsorption behaviors of the tree bark biochar for Iodine adsorption (Dang *et al*., 2021; Doumer *et al*., 2015). The model selection AICc scores for MPNBC and MSHBC were 38.03 and 37.76 respectively, away below other models used. AICc is a strong tool for model selection than using the correlation coefficient on non-linear model functions. This can be theoretically supported by the equilibrium adsorption capacity values from both statistical methods were also close to the experimental equilibrium adsorption capacity, signifying that the pseudo-second-order kinetic model could better describe the Iodine adsorption (Doumer *et al*., 2015; Al-Wabel *et al*., 2013). The estimation from Bayesian simulation is higher than conventional estimations. However, the surface coverage estimations were almost the same from both methods. From this point of view, it can be inferred that both conventional and Bayesian approaches to estimations are well established and seem hard to justify if one of the two is preferred over the other (Furia *et al*., 2019; Gelman *et al*., 2004).

Nevertheless, the Bayesian framework is deemed to be applicable with no restriction to the kinetic adsorption in this study due to a wide and more relevant supporting outcome than the other (Cutillas-Barreiro *et al*., 2014). Most importantly, the use of priors makes the Bayesian method more sensitive to different prior guesstimates which may also lead to different posterior estimations of the parameters. In support of the Bayesian distribution outcome, the posterior distribution of the best two kinetic model parameter estimates was presented by the density and trace plots for the two biochar materials. Figs. 3 and 4 show the density and trace plots for the posterior estimates of Pseudo second order and Elovich model parameters. The trace plot visibly exhibited the convergence of each qt and k_2 for α and β kinetic parameters for Pseudo second order and Elovich models respectively (Dang *et al*., 2021; Doumer *et al*., 2015; Al-Wabel *et al*., 2013).

These kinetic results explain that Iodine adsoption on the two-bark biochar was proximity to chemisorption than physisorption, meaning that new chemicals could have been formed on the biochar surfaces probably during pyrolysis or otherwise during the agitation.

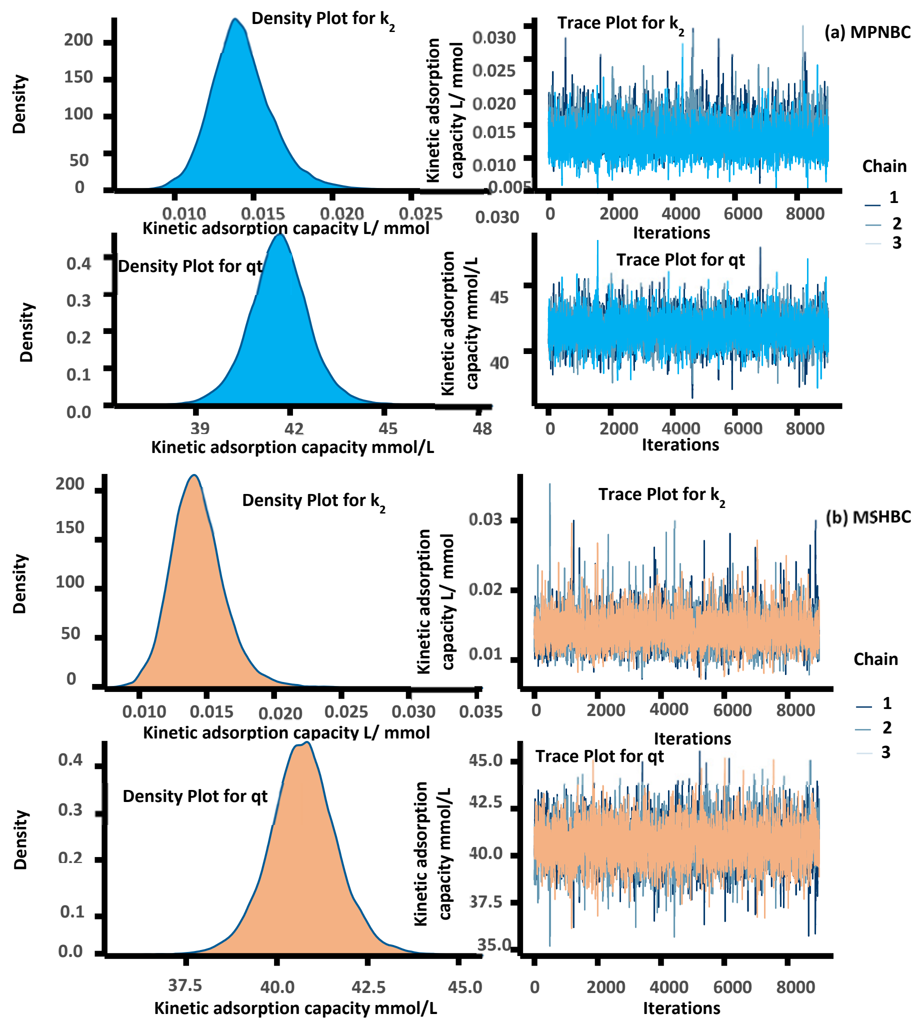

Fig. 3: Density and trace plot parameter presentations of Pseudo second-order model from the Markov chain Monte Carlo chain simulations for the effective use of Bayesian statistics

Fig. 5 shows a fit for the Intra particle diffusion which shows that the linear graph did not pass through the origin and tells us that Intra particle diffusion was not a rate-limiting factor, but other mechanisms are involved (Cutillas-Barreiro *et al*., 2014). The adsorption kinetic results are shown in Fig. 2 and Table 2 revealed that the kinetic model fits follows the order pseudo-second-order> Elovich > pseudo-first-order > Intra particle diffusion.

Besides pseudo-second-order fitting the experiment, the Elovich Model subsequently delineated the data well as a secondary model. The Elovich model assumes that the surface of the biochar adsorbent is heterogeneous, meaning that there are parts of the surface that have more affinity for iodine adsorption than others (Amaku *et al*., 2021). The fit for Iodine adsorption using the Elovich model suggests that it is strongly associated with the biochar, and McMillan (2018) suggested with such scenarios, the adsorbed Iodine could be immobilized. Additionally, the Bayesian statistics should be used to fit adsorption empirical models to validate the estimated parameters through posterior distributions as it offers a powerful simulation and estimations alongside density and trace plots for clear parameter position through convergence. The

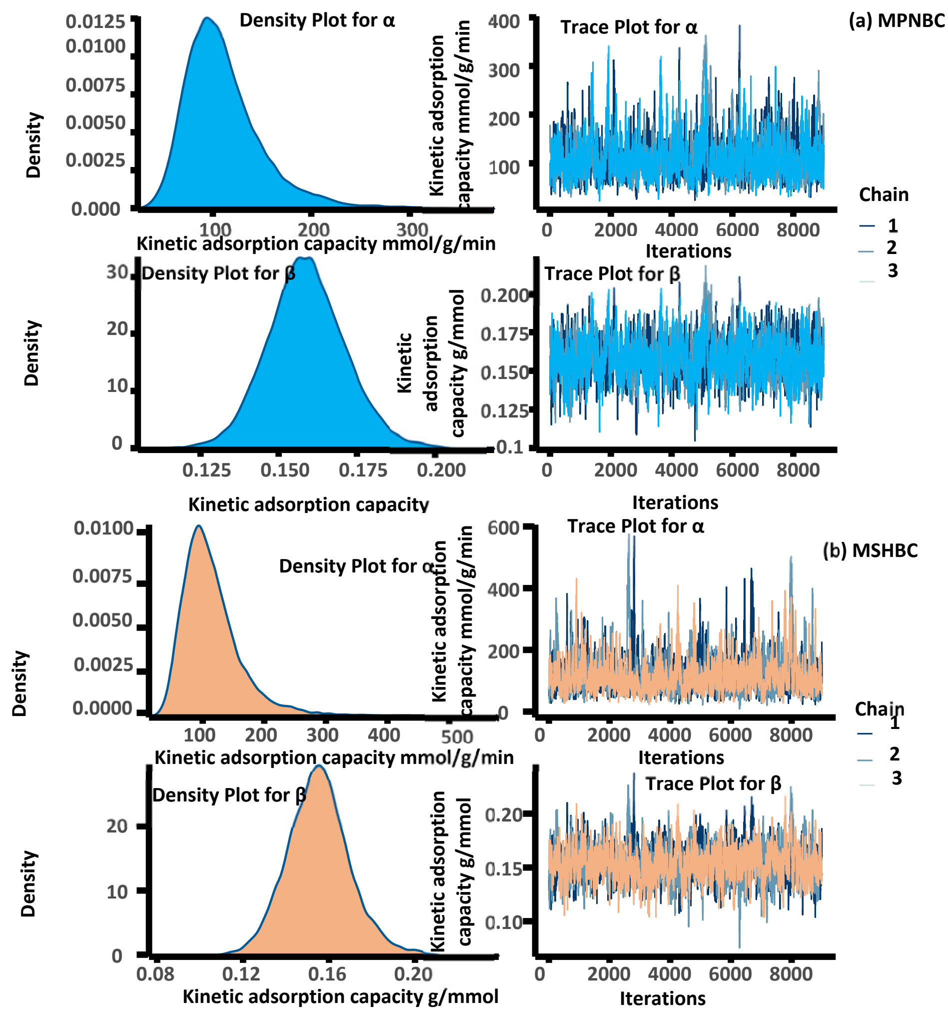

Fig. 4: The density and trace plots of Elovich kinetic model from the Markov chain Monte Carlo chain simulations for adsorption parameters convergence and peaks, demonstrating the application of Bayesian analysis of data

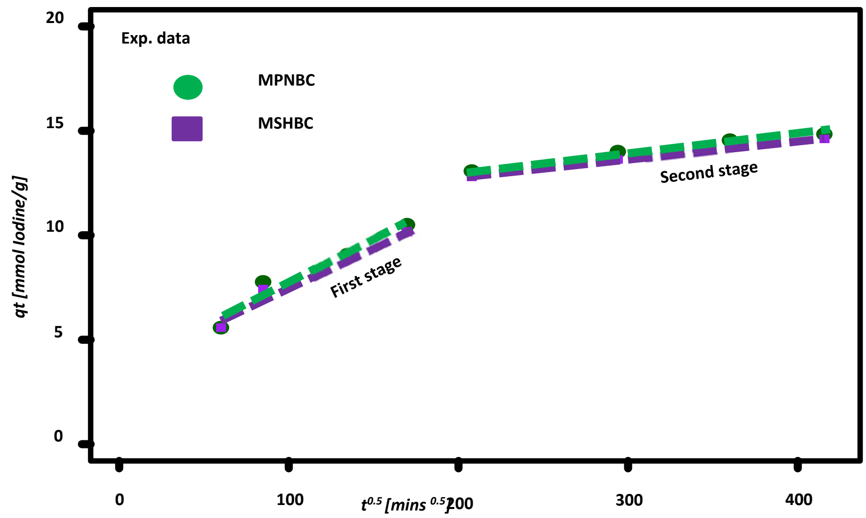

Fig. 5: Illustration of the Intraparticle diffusion model for kinetic adsorption of Iodine onto the Mupane and Mushuma Tree barks biochar measure after 48 hr. of agitation

novel bark biochar investigated in this research for wastewater treatment and reuse carries with it the merits exhibited by the results. It is suggested that the contribution of these two materials from tree bark in combating climate change through carbon sequestration should be investigated concerning the revealed capabilities in contaminant removal.

CONCLUSION

The two tree barks, native to the Southern African region, were successfully converted to a novel non-customized biochar with relevant adsorption kinetic mechanisms examined. These agro-biomass materials used in this study were the first to be investigated for their potential use as water re-use and low-cost adsorbents in rural areas of Zimbabwe. The materials are easy to obtain from the abundant deadwood in the forest and the production can be established easily with locally available and inexpensive materials. The pseudo-second-order model well described the kinetics of Iodine adsorption onto MSHBC and MPNBC, accompanied by the Elovich model. The Intra particle diffusion model did not pass through the origin, so it was clear that other mechanisms could have been contributed to the adsorption of Iodine onto the bark biochar. This confirms a heterogeneous surface characteristic with significant chemisorption mechanisms developed during pyrolysis of the agro-biobased biochar. Bayesian analysis was implemented to provide a correlation and support of these material's data to validate the application and significance of conventional methods. The analysis from Bayesian exhibited more merits than classical methods as the outputs are clear and robusts. It was possible to gain adequate information about the adsorption of iodine over time from a small sample, providing supplementary sustenance for the importance of using alternative statistical approaches in this study. The results from both classical and Bayesian analysis were insignificantly different from each other, but it was the former had its shortcomings including a lack of flexibility hence the latter provides tangible benefits that are simultaneously robust and nuanced. The C and O elements were observed to be the main composition in the two biochar as exhibited by the EDX analysis. However, further examination is required in determining the surface area, adsorption isotherms, and functional groups available. However, Mushuma and Mupani tree barks are promising adsorbents for environmental pollution control and wastewater re-use in urban environments and remote areas of developing countries. The obtained results revealed the capability of the locally available tree bark to be used for water recycling strategy for the local people. These materials are affordable and their production process is easy. This is a first step toward studying these new materials and further study will give proper answers for its applications towards the goal with more information brought out through research.

AUTHOR CONTRIBUTIONS

The authors confirm the study's conception and design: data collection was conducted by V. Mushayi and L. Gochayi: O. Gotore performed the analysis and interpretation of the results. The draft manuscript preparation was finalized by O. Gotore and R. Rameshprabu. The results were evaluated by all authors, and the final version of the manuscript was approved.

ACKNOWLEDGEMENTS

The authors appreciate the referees, editors, and reviewers for their effort in their correction and suggestions to improve the quality and content of this paper. Most acknowledgment is given to the JICA (D-17-04963) and HONJO Foundation (FS20-0801) for the provision of these Scholarships to be in Japan for the study period.

CONFLICTS OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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PUBLISHER'S NOTE

ABBREVIATIONS

AICc	Akaike Information Criterion
EDX	Energy Dispersive X-Ray Analysis
IPD	Intra-Particle Diffusion model
MCMC	Markov chain Monte Carlo
MSHBC	Mushuma Biochar
MPNBC	Mupane Biochar
Eq.	Equation

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HOW TO CITE THIS ARTICLE

Gotore, O.; Mushayi, V.; Rameshprabu, R.; Gochayi, L.; Itayama, T., (2022). Adsorption studies of Iodine removal by low-cost Bioinspired Mushuma and Mupane bark derived adsorbents for urban and rural wastewater reuse. Int. J. Hum. Capital Urban Manage., 7(3): 297-308.

DOI: 10.22034/IJHCUM.2022.03.01

url: http://www.ijhcum.net/article_252222.html