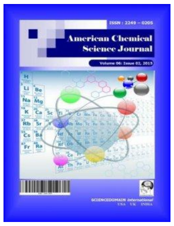

American Chemical Science Journal
8(2): 1-12, 2015, Article no.ACSj.17636
ISSN: 2249-0205

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Kinetic Studies of Bio-sorption of Cyanide Ions from Aqueous Solution Using Carbon Black Developed from Shea Butter Seed Husk as an Adsorbent

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Authors' contributions

This work was carried out in collaboration between all authors. Author DYT designed the study, carried out the preliminary analysis, such as ultimate analysis, equilibrium data analysis and Isotherm analysis and revised the manuscript. Author UHT supervised the analysis of result, worked on the kinetic models and wrote and revised the manuscript. Author EUJ provided valuable suggestions and also assisted in the laboratory work and revised the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ACSj/2015/17636
Editor(s):
(1) T. P. West, Department of Biology and Microbiology, South Dakota State University, USA.
Reviewers:
(1) P. N. Palanisamy, Department of Chemistry, Kongu Engineering College, Perundurai, India.
(2) Anonymous, Jawaharlal Nehru Technological University, Anantapur, India.
(3) Anonymous, Federal University of Santa Maria (UFSM), Brazil.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=1161&id=16&aid=9734

Original Research Article

Received 20th March 2015
Accepted 14th April 2015
Published 12th June 2015

ABSTRACT

This research work was conducted in order to investigate the adsorption of cyanide ions by carbon black developed from Shea Butter Seed Husk (SBSH) an eco-friendly bio-adsorbent. The experiments were carried out in batch reactors with optimum operating parameters at 100 mg/l for the initial cyanide concentration, Temperature 30±2ºC, pH value 10, Adsorbent Dosage (3.0 mg/100 ml) and Contact Time of 120 minutes with maximum percentage cyanide ion removal at 94.56%. The values for the amount of cyanide ions adsorbed at equilibrium (q_e) and amount adsorbed at a given time (q_t) of the experimental results were fitted to the Langmuir, Halsey – Taylor (Freundlich), Henry and Slygin – Frumkin (Temkin) isotherm models with Henry Adsorption Isotherm having R^2=0.966, hence, best described the equilibrium model. Adsorption of cyanide ions by SBSH Carbon Black obeyed the Pseudo-Second Order Model rate equation with the values of

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Coefficient of Determination; R^2=0.999. Q_e=3.257(mg/g) and k_2=0.093(g/mg/min). Therefore, it was observed that Pseudo-Second Order Model was the best applicable model which described the bio-sorption of cyanide ions by SBSH Carbon Black, making Pseudo Second order kinetic reaction the rate limiting step for the batch reaction process.

Keywords: Cyanide ions; kinetics; shea butter seed husk; adsorption; effluent treatment; monolayer.

1. INTRODUCTION

The causes of most environmental challenges take their origins in the developmental process or in its failure and inadequacies [1], this is due to diverse anthropogenic activities such as agriculture, electroplating, metal finishing industries, metallurgical industries, tannery, fertilizer industries, pigments and dyes and manufacturing increases the level of heavy metal and cyanide ions in the environment [2,3]. Basically, waste water discharged by industrial activities is often contaminated by a variety of toxic or otherwise harmful substances which have negative effects on the water environment. For example, metal finishing industry and electroplating unit is one of the major sources of heavy metals and cyanide pollutants which contribute greatly to the pollution load of the receiving water bodies and therefore increase the environmental risk. Cassava is also one of the staple food crops in Nigeria and can be processed in various ways, for instance, fermentation. Sometimes this is carried out in isolated locations such as use of pots or in flowing streams and rivers. This contributes to the cyanide load of the affected water bodies. Also decaying plants can contribute to the cyanide concentrations in natural waters.

Cyanide is a singly-charged anion containing unimolar amounts of carbon and nitrogen atoms triply-bounded together ($C \equiv N$). It is a strong ligand, capable of complexing at low concentrations with virtually any heavy metal. Because the discharge of industrial wastewater is becoming a serious environmental problem in Nigeria, cyanide and heavy metal ions are reported as prior pollutants due to their mobility in natural water ecosystem and their toxicity [4]. Thus cyanide ion goes to the environment and water body as effluents (industrial wastes).

Cyanide is included in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) priority list of hazardous substances [5] and it occupies 28^{th} position in the list of most hazardous chemicals [5]. It is also listed among the 65 toxic pollutants in the Effluent Guideline and Standards given in title 40; section 400-475, of the Code of Federal Regulations [6].

Different forms of cyanide have awful health effects on people as well as other living organisms [7]. Therefore the permissible limit of cyanide in the surface water according to Indian Standard (IS) has set a minimal national standard (MINAS) limit for cyanide ,in effluent as 0.2 mg/L. USEPA (US Environmental Protection Agency) standard for drinking and aquatic-biota waters regarding total cyanide are 200 and 50 ppb respectively, [8]. Therefore, environmental regulations require reducing the cyanide concentration in wastewater to below 0.2 mg/L prior to discharge into the environment. All forms of cyanide can be toxic at high levels, but the more toxic form of cyanide is hydrogen cyanide. Therefore, cyanide and metal cyanide complexes in industrial waste water must be treated or reduced to lowest levels before being discharged. Several treatment processes such as physical, chemical and biological oxidation have been exploited for the reduction of cyanide levels in waste solutions/ slurries in compliance with environmental regulations [8].

Both governmental and private sectors have now recognized the potential dangers that cyanide ion, heavy metal ions and other hydrocarbons (organic wastes) poses to human health and the environment at large. On response to address such environmental menace and outspread of diseases, many technological processes has been developed. Processes such as physical, chemical and biological oxidation methods have been exploited for the reduction of toxic ions and other contaminants during effluents and waste water treatment; in compliance with the environmental regulations such as the US Environmental Protection Agency (USEPA), Federal Environmental Protection Agency (FEPA), and Indian Minimal National Standard (IMINAS). Despite the availability of such skills to the treatment of contaminated sites, yet, the selection depends on the pollutants/contaminants and site characteristics, regulation requirements, costs and time constraints [9,10].

Water pollution is the introduction of chemical, biological and physical matter into large bodies of water that degrade the quality of life that lives in it and consumes it. Water is polluted in many ways like effluent of leather and chemical industries, electroplating industries and dye industries [11]. Several industrial and agricultural processes and mining activities have increased the concentration of toxic contamination in water and waste water around the world.

Water is considered polluted if some substances or condition is present to such a degree that the water cannot be used for a specific purpose. Olaniran [12] defined water pollution to be the presence of excessive amounts of a hazard (pollutants) in water in such a way that it is no longer suitable for drinking, bathing, cooking or other uses. Pollution is the introduction of a contamination into the environment [13]. It is created by industrial and commercial waster, agricultural practices, everyday human activities and most notably, models of transportation. No matter where you go and what you do, there are remnants earths environmental and its inhabitants in many ways.

Water pollution in Nigeria according to Gbamanja [14] arises from various activities, among which are: Sewage leakages, High population density, oil spillage, Building lavatories and visionaries over running water or even the sea as it is the practice in some reverine areas, Radioisotopes, heavy metal, cyanide discharge, combustion, toxic waste disposal at sea, mineral Processing Plant (e.g. coal reduction), Eroded sediments, mining, Pesticides to pollution. The growth of human population, industrial and agricultural practices is the major causes of pollution [15]. Water pollution becomes worse as a result of overcrowding in urban areas. Agricultural, domestic and industrial wastes are the major source of cyanide pollution. Sewage is the biggest pollutant of fresh water when discharged into them. Sewage is the waterborne waster of society and the discharge of untreated sewage into a river is very enormous and unhealthy. The flora and fauna of the rivers experience change and reduction in number due to death by suffocation [16].

Pollution poses a serious risk to life especially when the water is a source of drinking and for domestic purposes for humans. Polluted waters are potent agents of diseases such as cholera, typhoid and tuberculosis. This is why the guided discovery approach is a teaching strategy which when adequately utilized and combined with other methods of science teaching will leave lasting impression on the learner as well as help him solve the problems of his immediate environment [17].

Water polluted by cyanide lead to damage on human health. Drinking water is affected and health hazards result. Acid rain which lowers the pH value of soil and emission of carbon dioxide cause ocean acidification, the ongoing decrease in the pH of the Earth's Oceans as CO_2 becomes dissolved.

The occurrence of cyanide contamination in water body and the environment at large has called for great concern in many countries across the globe including Nigeria as a nation. This toxic ionic compound does not only affect the water bodies like seas, lakes, reservoirs and ponds but enter the underground water in traceable amounts, and thereafter end up in plants and animals creating adverse effects on their systems.

In this research, a low cost agricultural waste, Shea Butter Seed Husk which was converted to modified carbon black (MCB) has been considered in the kinetic study for batch adsorption of cyanide ion from aqueous solution, hence creating a feasible and low cost remediation process.

2. METHODOLOGY

2.1 Materials

The raw material used for this research work shea butter (*Vitellaria paradoxa*) seed were collected free of cost from farmlands in Sabon Gida Tukura, Kurmi Local Government Area and Gidan Idi, Wukari Local Government, Taraba State, Nigeria. The shea butter seed were washed severally with surface water to remove attached films such as the fleshy layers, soil and dusts to expose the indehiscent seed cuticle (husk). The seed husks were removed by breaking/dehusking using mortar and pestle and washed with double distilled water and dried. For the preparation of the adsorbent, the dried and grinded sample was calcined at 500ºC for physical preparation. Chemical activation of the prepared carbon black sample was done by mixing/treating it with dilute hydrochloric acid until paste was formed which was then carbonized again at a temperature of 650-700ºC in the furnace for 2 hours. The black product obtained was dried in an oven for 12 hours at 100ºC and passed through 750 µm sieve size for regulating the uniform particles, hence, the carbonized sample was washed severally with de-ionized water until an approximate pH of 7 was attained, it was filtered with whatman №1 filter paper and again dried for 8 hours at 110ºC in the oven and stored as adopted by [4].

About 100 mg of KCN in 1000 ml was prepared from the stock solution of 6.56 g KCN in 1000 ml solution with KOH pellet. Other concentrations were prepared by serial dilution of the Cyanide (stock). All other chemicals used for the preparation of adsorbent and for adsorption tests were of analytical grade and were used without further purification.

2.1.1 Characterization of the adsorbent

The physical properties and Ultimate analysis of the prepared activated carbon black from *V. paradoxa* seed husk were studied and calculations presented in Table 1.

2.1.2 Adsorption model

The adsorption models employed in this research work are basically categorized into two types: Based on Initial Concentration of the ions present termed the Equilibrium Model (EM) and based on Contact Time for the adsorption to reach equilibrium termed Kinetics Model (KM). These models are presented in Table 2.

2.2 Methods

Three sets of batch mode operation were conducted on prepared adsorbent in order to measure the adsorption behaviour of cyanide contained before and after adsorption. Thus, in a representative experiment, 0.5-4.0 g of dried adsorbent was shaken with 100 ml of the stock solution at varying concentration at 30ºC for 90 minutes. After equilibrium, the mixture was filtered using Whatman filter paper (110 cm) and the filtrate was treated with prepared picric acid solution for colorimetric analysis for the remaining cyanide ions concentration. Ranges of operating parameters for the various batch operations are shown in Table 3.

Adsorption isotherms of cyanide were measured by shaking (using mechanical shaker) 0.5-4.0 g of the adsorbent in 100 ml solution of 100 mg/L concentration of cyanide for 90 minutes. The Initial Cyanide Concentration (ICC) was also varied in the range between 100-600 mg/L for the same time (90 mins) at an adsorbent dose of 3.0 g. Percentage adsorption for each sample was calculated according to Eq. (1), where C_i and C_e (mg/L) represents the initial and equilibrium concentration, respectively. The amount of adsorbed cyanides (q_e, mg/g) were calculated by the mass balance calculation of cyanide ion before and after the adsorption as expressed by Eq. (2). Where, *V* (*L*) is the volume of the test solution used and *W* (g) is the dry weight of the adsorbent.

$$\%A = \frac{C_i - C_e}{C_i} \times 100\% \quad (1)$$

$$Q = \frac{C_i - C_e}{W} \times V \quad (2)$$

$$R_L = \frac{1}{1 + bC_0} \quad (3)$$

Adsorption isotherms of cyanide were measured by shaking (using mechanical shaker) 0.5-4.0 g of the adsorbent in 100 ml solution of 100 mg/L concentration of cyanide for 90 minutes.

Table 1. Ultimate analysis and physical properties of shea butter seed husk carbon black

Physical properties						Elemental analysis			
Ash (%)	**V_M (%)**	**FC (%)**	**M (%)**	**BD (g/cm^3)**	**SG (g/cm^3)**	**H**	**C**	**N**	**S**
1.37	69.3	0.69	4.0	0.95	1.86	5.2	61.3	0.56	0.009

V_M = Volatile Matter; M = Moisture Content; FC= Fixed Carbon; BD = Bulk Density; SG = Specific Gravity

Table 2. Equilibrium and Kinetic models for adsorption processes

Model	Mathematical expression	Parameters involved
Equilibrium models (EM)		
Langmuir model	$C_e/q_e = 1/Q^0 b + C_e/Q^0$	Q^0 is q_{max} (mg/g), and b (L/mg) is the Langmuir constants related to the capacity and energy of adsorption.
Halsey-Taylor (Freundlich) Model [18]	$\log q_e = \log K_f + 1/n \log C_e$	K_f $(mg.g^{-1}(mg.L^{-1})^{1/n})$ and n is the constant, 1/n is the heterogeneity factor
Henry Model	$q_e = K'C_e$	K' is a constant
Slygin-Frumkin (Temkin) Model [19]	$q_e = B \ln A + B \ln C_e$	A = Temkin Isotherm constant (L/g) and B = heat of sorption (Jol/mol)
Kinetic models (KM)		
Pseudo first order model	$\log(q_e - q_t) = \log(q_e) - k_1 t/2.303$	q_e and q_t are sorption capacities (mg/g) of adsorbent at equilibrium and at a given time "t,". k_1 is the pseudo-first order adsorption rate constant (s^{-1})
Pseudo second order model	$t/q_t = 1/K_2 q_e^2 + t/q_e$	k_2 is the pseudo-second-order adsorption rate constant (g/mg s)
Intra particle diffusion model	$q_t = K_i t^{1/2} + C$	q_t is sorption concentration at time t; K_i is the rate constant of intra particle transport (mg/g/time $^{1/2}$); C (mg/g) is the intercept that gives an idea about the thickness of the boundary layer.

Table 3. Time and initial cyanide concentration operating parameters

Batch operation objective	Operating parameters
To study the effect of Initial Cyanide Concentration on Cyanide ion Removal	Adsorbent Dosage: 3.0 g/100 ml; Temp 30ºC; Time 120 min; pH 10; ICC: 100-600 mg/L
To study the effect of Contact Time on Cyanide ion Removal	Adsorbent Dosage: 3.0g/100mg; Temp 30ºC; ICC: 100 mg/L; pH 10; Time: 15, 30, 45, 60, 75, 90, 105, 120 minutes.

Where ICC: Initial Cyanide Concentration

The Initial Cyanide Concentration (ICC) was also varied in the range between 100-600 mg/L for the same time (90 mins) at an adsorbent dose of 3.0 g. Percentage adsorption for each sample was calculated according to Eq. (1), where C_i and C_e (mg/L) represents the initial and equilibrium concentration, respectively. The amount of adsorbed cyanides (q_e, mg/g) were calculated by the mass balance calculation of cyanide ion before and after the adsorption as expressed by Eq. (2). Where, V (L) is the volume of the test solution used and W (g) is the dry weight of the adsorbent.

$$\%A = \frac{C_i - C_e}{C_i} \times 100\% \quad (1)$$

$$Q = \frac{C_i - C_e}{W} \times V \quad (2)$$

$$R_L = \frac{1}{1 + bC_0} \quad (3)$$

2.3 Instrumental Analysis

Replicate samples were prepared in triplicates by transferring known amount of adsorbent into the solution in 250 ml Erlenmeyer flask for statistical treatment, in which certain simple percentage was used to determine the amount of cyanide removal. While determinate errors were minimized by running blank. Free cyanide and weak acid cyanide reacts with picric acid reagent to produce an orange colour that can be measured colorimetrically at the wavelength of 520 nm (Microprocessor UV/VIS Single Beam Spectrophotometer; model T60).

The dissolved base/alkali metal picrate was converted by the cyanide to the coloured salt of iso-purpuric acid.

3. RESULTS AND DISCUSSION

3.1 Equilibrium Models for Cyanide ions Adsorption onto SBSH Carbon Black

An adsorption isotherm represents the equilibrium relationship between the adsorbate concentration in the liquid phase and that on the adsorbents surface at a given concentration and operating conditions. To predict these equilibrium relations during the adsorption of cyanide from aqueous solutions, Langmuir, Halsey-Taylor, Henry and Slygin-Frumkin Adsorption Isotherms were tested. The various values for the parameters present in the isotherms used such as R^2 and others are presented in Table 4.

The Langmuir adsorption isotherm for the adsorption of cyanide ions on Shea butter seed husk activated carbon is presented in Fig. 1. The ratio of the equilibrium concentration to the ratio of the amount of iron adsorbed (C_e/Q_e) was plotted against the equilibrium concentration of cyanide (C_e). The linearity of the plot shows that Langmuir isotherm model can be used to predict the sorption of cyanide ions on Shea butter seed husk activated carbon. The Langmuir plots shows that there is increase in the rate of adsorption at different concentrations. This means that the lesser the concentration of the cyanide ions, the higher the adsorption of ions by the activated carbon. The Langmuir model assumes that the uptake of cyanide ions occurs on a homogeneous surface by monolayer adsorption without any interactions between adsorbed ions [20]. The Langmuir model parameters and the statistical fits of the adsorption data is presented in Table 4 and the correlation coefficient R^2 is less than 0.89 which reveals' that the isotherm is not consistent with Langmuir model.

Table 4. Equilibrium model parameters and their values for the various adsorption isotherms

Isotherms	Parameters	Values
Langmuir	R^2	0.624
	Q^o (mg/g)	41.667
	b (L/mg)	0.017
	R_L	0.367
Slygin-Frumkin (Temkin)	R^2	0.909
	A (L/g)	0.300
	B (J/mol)	6.486
Halsey-Taylor (Freundlich)	R^2	0.933
	n	1.340
	1/n	0.746
	K_f (mg.g^{-1} (mg.L^{-1})$^{1/n}$)	1.086
Henry	R^2	0.966
	K' (L/g)	0.388

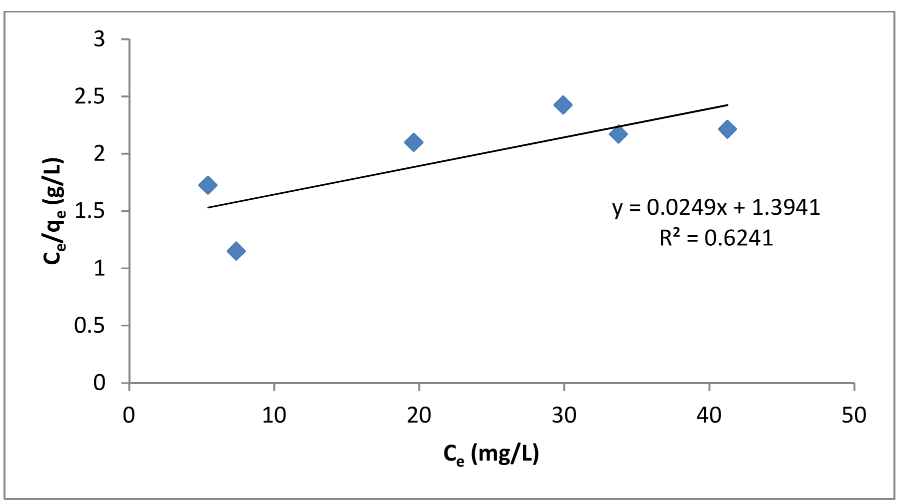

Fig. 1. Langmuir adsorption isotherm for the removal of cyanide ions
(Process Conditions: pH: 10; Temp. 30ºC; Adsorbent Dosage: 3.0 g/100 ml; Contact Time: 120 mins; rpm: 120)

The theoretical monolayer saturation capacity Q° for cyanide adsorption on activated carbon from Shea butter seed husk obtained from the slope was 41.667 mg/g of carbon. The separation factor (R_L) was determined from equation 3, the value was 0.370. Since R_L is less than 1 for all the concentrations it means that adsorption process is favourable [21].

Fig. 2 and Table 4 shows the batch adsorption isotherm of cyanide ion on Shea butter seed husk activated carbon at 30ºC. The log of Q_e amount of cyanide ions adsorbed at equilibrium was plotted against the log of the equilibrium concentration C_e of the cyanide ions adsorbed. The adsorption capacity K_f and the adsorption intensity 1/n are obtained directly from the slopes and intercepts of the linear plot. The linearity of the plot and high correlation coefficient R^2 obtained (0.933) which is also greater than 0.89 reveals that the isotherm is consistent with *Freundlich* model. Atef [22] reported that R^2 greater than 0.89 shows that the adsorption data conforms to the model. The value of adsorption intensity (n=1.34) is more than one for bamboo activated carbon.

Fig. 3 and Table 4 shows the batch adsorption isotherm of cyanide ion on Shea butter seed husk activated carbon at 30ºC. Q_e amount of cyanide ions adsorbed at equilibrium was plotted against the equilibrium concentration C_e of the cyanide ions adsorbed. The linearity of the plot and high correlation coefficient R^2 obtained (0.966) which is also greater than 0.89 reveals that the isotherm is consistent with *Henry Adsorption* Model. Atef [22] reported that R^2 greater than 0.89 shows that the adsorption data conforms to the model.

A linear relationship was also exhibited from the plot of amount of cyanide adsorbed (Q_e) at equilibrium against the natural logarithm of equilibrium concentration of cyanide ions ($\ln C_e$). Similarly the correlation coefficient R^2 (0.906) obtained for Temkin adsorption isotherm model for cyanide ions in Fig. 4 and Table 4 shows that the Temkin model can also be used to predict the sorption of cyanide ions using Shea butter seed husk activated carbon.

In this research work, the R_L value calculated from the formula for the range of cyanide concentration is found to be 0.367 which falls in the range of 0–1, which suggests the favourable sorption of cyanide ions onto the studied Shea Butter Seed Husk Carbon Black, under the conditions used for the operation. For the Shea Butter Seed Husk (SBSH) carbon black, the 1/n value is approximately 0.746 (<1), which indicates a favourable sorption. The present data fit the Henry, Freundlich, and Temkin isotherm models for Shea Butter Seed Husk carbon black, in the following order Henry (0.966) > Freundlich (0.933) > Temkin (0.909).

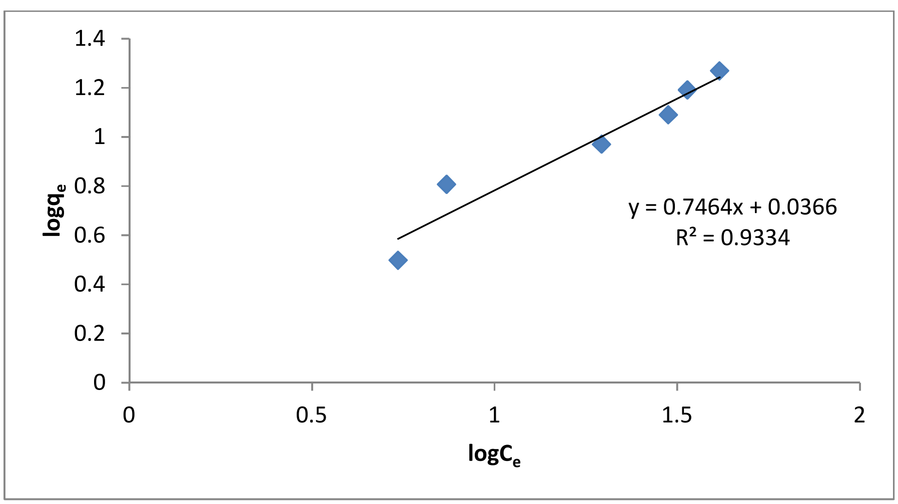

Fig. 2. Halsey – Taylor (Freundlich) adsorption isotherm for the removal of cyanide ions
(Process Conditions: pH: 10; Temp. 30ºC; Adsorbent Dosage: 3.0 g/100 ml; Contact Time: 120 mins; rpm: 120)

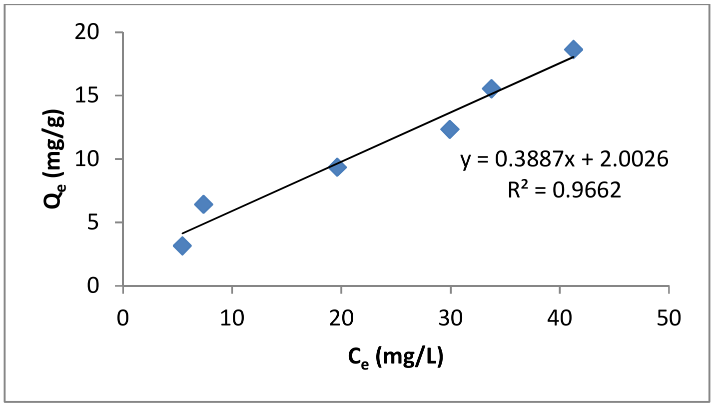

Fig. 3. Henry adsorption isotherm for the removal of cyanide ions
(Process Conditions: pH: 10; Temp. 30ºC; Adsorbent Dosage: 3.0 g/100 ml; Contact Time: 120 mins; rpm: 120)

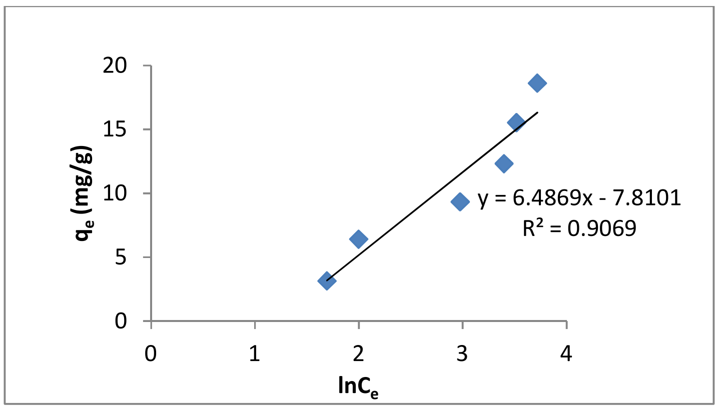

Fig. 4. Slygin-Frumkin (Temkin) adsorption isotherm for the removal of cyanide ions
(Process Conditions: pH: 10; Temp. 30ºC; Adsorbent Dosage: 3.0 g/100 ml; Contact Time: 120 mins; rpm: 120)

3.2 Kinetics Models for Cyanide Ions Adsorption on to Shea Butter Seed Husk Carbon Black

To find out a suitable kinetic model for explaining the cyanide ions adsorption process Pseudo-First Order Model, Pseudo-Second Order Model and Intra Particle Diffusion Model were tested. The various values for the parameters present in the models used such as R^2 and others are presented in Table 5.

Kinetic parameters for the above model equations are computed from the slope and intercept of the respective Figs. 5-7 as stated below and are reported in Table 5 along with the values of correlation coefficients (R^2). From Table 5, it is crystal clear that Pseudo - First Order Model, Pseudo-Second Order Model and Intra Particle Diffusion Model shows R^2 value of 0.821, 0.999 and 0.904 respectively. From the values calculated, it will be deduced that, Pseudo – Second Order Model best describes the kinetics of adsorption of cyanide ions by Shea Butter Seed Husk carbon black with the highest value of R^2 to be 0.999 as against others.

Table 5. Kinetic model parameters and their values for the various adsorption models

Models	Parameters	Values
Pseudo-First Order	C_o (mg/l)	100
	R^2	0.821
	q_e (mg/g)	2.793
	K_1 (min^{-1})	0
Pseudo-Second Order	C_o (mg/l)	100
	R^2	0.999
	q_e (mg/g)	3.257
	K_2 (g/mg/min)	0.093
Intra Particle Diffusion	C_o (mg/l)	100
	R^2	0.904
	K_i (mg/g/min$^{-1/2}$)	0.053
	C (mg/g)	2.628

The performance of the present SBSH Carbon Black bio-adsorbent was compared with other literature reports on cyanide ions removal using various bio-adsorbent from wastewater either domestic or industrial effluent at various operating conditions is presented in Table 6. The various operating condition values presented in Table 6 shows that since the operating conditions have different values, it will be difficult to compare the performance accurately. But, for the present bio-adsorbent from the values presented seems to have high effective performance compared to the others.

Table 6. Comparison of percentage removal and other operating parameters on cyanide ions bio-sorption for this research work and other literatures

Adsorbent	Cyanide compound	Initial cyanide concentration (mg/L)	Dosage (g/L)	Contact time (min)	pH	Temp (ºC)	Cyanide removal (%)	Reference
Cu-II impregnated Carbon	KCN	500	8 - 80	5 - 15	10.5	30	99.56	[23]
Activated Carbon	NaCN	102	1.5	20	10	25	-	[24]
Rice Husk Ash	NaCN	80	0.5	60	7 - 8	40	33.9	[25]
Raw/Heat Activated Sepiolite	$[Cu(CN)_3]^{2-}$	100	0.5	90	8	20-22	40 - 90	[26]
Coal Fly Ash	KCN	20	40	48	9	30	82	[27]
Almond Shell	NaCN	100	20	90	7	30	91.5	[28]
SBSH Carbon Black	KCN	100	30	120	10	30	94.56	This Research work

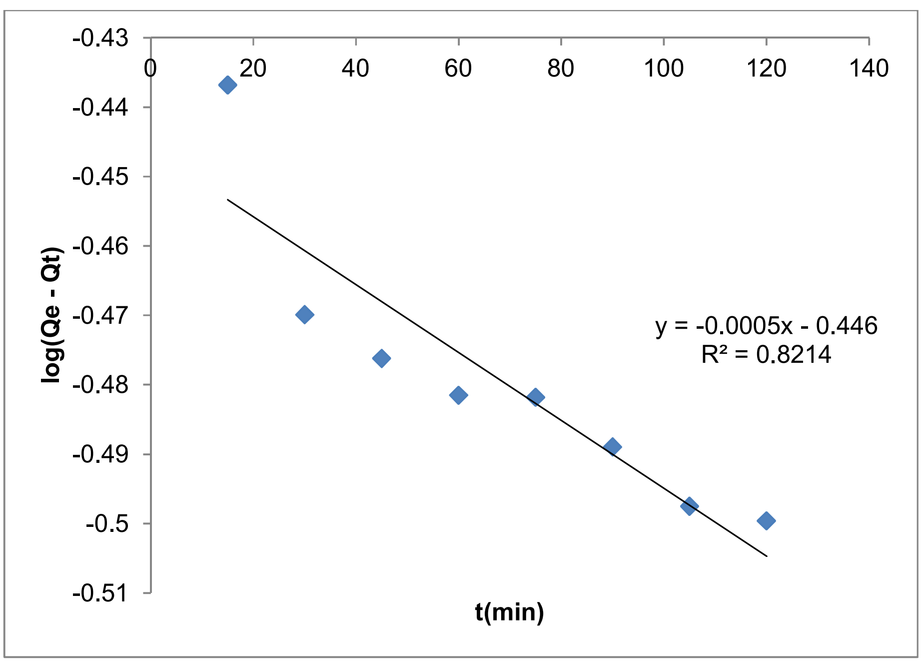

Fig. 5. Pseudo-first order model for the removal of cyanide ions by SBSH carbon black
(Process Conditions: pH: 10; Temp. 30ºC; Adsorbent Dosage: 3.0 g/100 ml; ICC: 100 mg/L; rpm: 120)

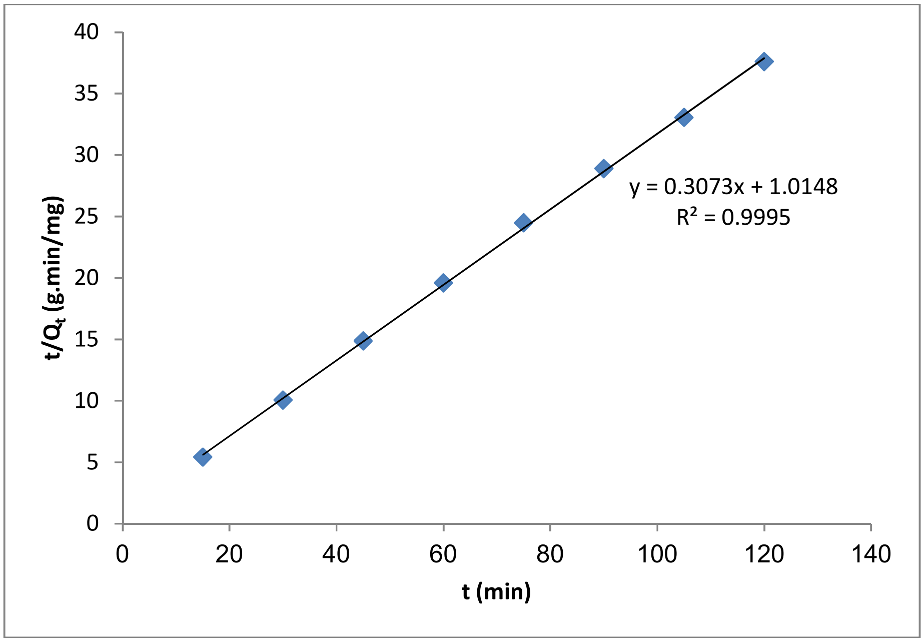

Fig. 6. Pseudo-second order model for the removal of cyanide ions by SBSH carbon black
(Process Conditions: pH: 10; Temp. 30ºC; Adsorbent Dosage: 3.0 g/100 ml; ICC: 100 mg/L; rpm: 120)

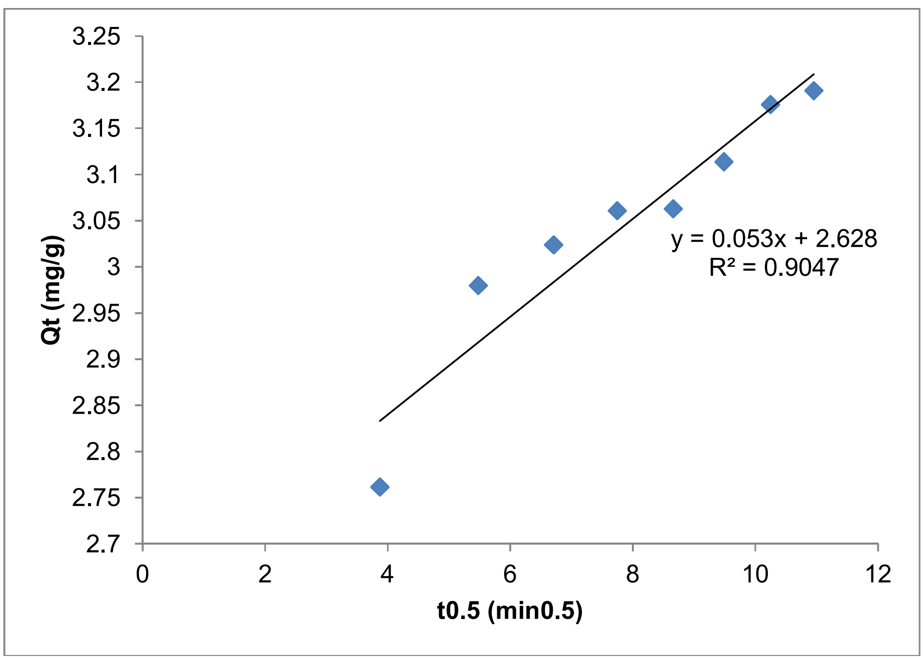

Fig. 7. Intra particle diffusion model for the removal of cyanide ions by SBSH carbon black
(Process Conditions: pH: 10; Temp. 30ºC; Adsorbent Dosage: 3.0 g/100 ml; ICC: 100 mg/L; rpm: 120)

4. CONCLUSION

From the result and discussion, it showed doubtlessly the effectiveness of the prepared and activated adsorbent in the decontamination of wastewater bearing cyanide ions. The maximum sorption capacity of the adsorbent was seen to emerge at about 94.56% cyanide removal at 100 mg/L concentration with adsorbent dose of 3.0 g/100 ml. The equilibrium and kinetic studies showed a greater adsorption capacity of cyanide ion from aqueous solution. The equilibrium and kinetic stage adsorption by Henry Isotherm and Pseudo-second Order Model are more accurate for the cyanide ions removal by the SBSH carbon black as adsorbent. Hence, the adsorption study behaviour of modified Shea butter seed husk carbon black adsorbent shows its potential ability in the treatment of wastewater (effluent) bearing cyanide ions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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