Jurnal Rekayasa Kimia dan Lingkungan (Journal of Chemical Engineering and Environment)
Volume 15, Number 2, page 111-122, 2020
ISSN 1412-5064, e-ISSN 2356-1661
https://doi.org/10.23955/rkl.v15i2.13589

Characterization of Activated Coconut Shell Charcoal as a Zinc Absorbent for Used Oil Lubricant

Emi Erawati*, Haryanto, Neysa Wirantika Astuti, Annida Mitha Prasetyanti

Department of Chemical Engineering, Faculty of Engineering, Universitas Muhammadiyah Surakarta
Jl. A. Yani Tromol Pos I Pabelan, Kartasura, Surakarta, Jawa Tengah, Indonesia 57102
*E-mail: emi.erawati@ums.ac.id

Article History
Received: 02 May 2019; Received in Revision: 09 October 2019; Accepted: 04 July 2020

Abstract

Used oil lubricant containing zinc is dangerous for human health and the environment and is categorized as B3 waste (hazardous and toxic materials). Zinc separation can be performed by the adsorption method using activated coconut shell charcoal. This study aims to determine the efficiency of zinc adsorption on lubricating oil with particle size and percentage of solvent variations. Adsorbent characterization is estimated by the Langmuir and Freundlich equilibrium model, while kinetic adsorption is estimated by pseudo-first and pseudo-second order kinetic models. Coconut shells are heated at a temperature of 300^{o}C for one hour, and the results are soaked with HCl 25% for 18 hours. After the netralization process, charcoal is activated for three hours in a temperature of 500^{o}C and saved in closed storage. Activated coconut shell charcoal and a number of volumes of H_2SO_4 as a solvent are stirred together using oil lubricant with stirring speed variation for every sample for two hours. Samples are taken every 30 minutes for the destruction process using HNO_3 68% for two hours. The zinc concentrations before and after the absorption process are analyzed using Atomic Absorption Spectroscopy. The highest efficiency in the 0.5% v/v solvent and the particle size of -100 mesh variations ae 95.06% and 80.32%, respectively. The maximum adsorption power in the Freundlich isotherm is 5.35 g/g. Freundlich isotherm equilibrium and pseudo-second order are suitable methods to describe the characteristic evaluation of activated coconut shell charcoal and an adsorption kinetic model.

Keywords: adsoprtion, coconut shell, Langmuir, Freundlich, AAS

1. Introduction

Lubricating oil is important in mechanical activities. It serves to prevent and reduce wear because of the friction or mechanical contact. Motor oil is the biggest application of oil lubricant (Awad and Mohammed, 2014). Motor oil can experience deterioration caused by heat, oxidation, and fuel contamination. This has an impact on the other parts of the engine. The degree of degradation depends on the severity of the condition of the engine and the length of time of its use. Therefore, it is necessary to change lubricant oil periodically (Dai et al., 2016).

The increasing use of oil lubricant is simultaneous with the increasing total of motor vehicles. Used oil lubricant consists of 20% zinc and 4–5% lead. The content of zinc in used lubricating oil can cause pollution. The sources of pollutant zinc are generated from industries, such as general industry and mining, plating, fertilizers, paper products, and fibers (Parmar and Thakur, 2013). Zinc is an anorganic material that sometimes causes problems to the environment. Pollution comes from the contamination of mining or industrial waste. Zinc waste can cause death to plants, invertebrate animals, and fish when the concentration is higher than 1 ppm. In order to prevent zinc pollution before releasing it into the environment, it must be treated using lubricant oil.

Various regenerative technologies are used to generate reusable lubricant by the following five methods, namely acid/clay; distillation; solvent de-asphalting; Thin Film Evaporation (TFE) with hydrofinishing, TFE with clay finishing, and TFE with solvent finishing; TDA with clay finishing and Thermal De-Asphalt (TDA), with hydrofinishing process (Jafari and Hasanfour 2015). The first step of acid/clay process is the addition of sulfuric acid into the used lubricant oil. The product is namely dehydrated waste oil. Acid sludge is separated by deposition. The colloid, organic acid, foreign and wave substrances are removed by porcelain and aluminum silicate as the types of clay. The end of the process is filtering process for getting reusable oil (Kajdas, 2000).

The second method is distillation process. The process is relatively same with acid/clay process. The processes step is dehydration and removal of light, vacuum distillation, and clay finishing (Kajdas, 2000).

The third method is solvent de-aspalting process. This process uses dehydration and removal of light, vacuum distillation, solvent extraction, centrifugation, stripping, vacuum distillation, and clay finishing. Many researchers using solvent for treatment used lubricant oil such as propane (purity 95%) (Rincón et al., 2003), MEK methyl-ethylketone (Alhamed and Al-Zahrani, 1999) and chloroform (Lee et al., 2007). On the other hand, Kim et al. (2003) studied the use of bentonite, SBS polymer, sodium hydroxide, and the lime as solvent. Another researcher using n-hexane for purification used lubricating oil (Hasanpour et al., 2013).

The fourth method is TFE. Steps of the TFE process is dehidration removal of oil, vacuum, hydrofinishing, and filtering. The aim of hydrofinishing is to remove nitrogen, hydrogen, and sulphure compounds.

The fifth method is popular with the name of solvent extraction hydrofinishing. This process uses combination between solvent extraction and hydro-finishing. Solvent is used for eliminating foreign substance and hydrofinishing for fortifying oil quality. Two processes are combined for eliminating sulfur, nitrogen, and oxygen (Hsu et al., 2009). The fifth method is famous with TDA with hydrofinishing process and TDA with hydrofinishing. In the process, liquid petroleum gas (LPG) condensate and stabilized condensate (SP) are used as extraction solvents. The extracting process is continued with the clay treatment using clay material (Hamad et al., 2005). Table 1 describe differences between regenerative technologies for the used lubricant oil.

In addition, adsorption technique is also commonly applied to remove zinc metal in the used lubricating oil (Labied et al., 2018). Adsorption is a method of waste management that utilizes the ability of certain solids to bind certain substances from the solutions and bring them to the surface (Li et al., 2017). The parameters studied to optimize the use of non-conventional adsorption in waste management are adsorbate and adsorbent characteristics, adsorbent concentration, contact time, pH of solution, adsorbate concentration, particle size, and thermodynamic parameters (Bazrafshan et al., 2016). In previous studies, the absorption of zinc with clay waste as an adsorbent resulted in pH, adsorbent concentration, and contact time influencing greatly the adsorption rate.

Other researchers have studied zinc adsorption using precipitated calcium carbonate. The results of these studies show that the Langmuir isotherm is the suitable model for zinc adsorption, with a correlation coefficient of 0.541. This correlation coefficient is less than the maximum because the correlation coefficient value is relatively small. Adsorption without activation of an adsorbent gives less-than-optimal results, with a k value and adsorption power lower than those in adsorption by activation.

Researches about adsorption process of the used lubricating oil has been explored by some researchers by combining the perfluoroethylene oxide and perfluoro-methylene oxide (Ikenaga et al., 2007), silica (SiO_2), alumina (Al_2O_3), silica–alumina (SiO_2–Al_2O_3) supported iron oxide (Fe_2O_3) catalysts (Bhaskara et al., 2004), graphite (Yao et al., 2016), bentonite (Oduola and Okwonna, 2016).

Table 1. Regenerative technologies for the used lubricant oil (Unnisaa and Hassanpourb, 2017)

No.	Regenerative Technologies	Energy Requirement	Industrial Scale	Economic Cost	Residual Oil Sludge	Hazardous Waste
1.	Distillation	High	Large industries	Low	Much	VOCs
2.	Solvent de-asphalting	High	Large industries	High	Much	VOCs
3.	TFE with hydrofinishing	High	Large industries	High	Little	VOCs
4.	TFE with clay-finishing	High	Large Industries	High	Little	VOCs
5.	TFE with solvent finishing	High	Large industries	High	Little	VOCs
6.	Solvent extraction hydrofinishing	High	Large industries	High	Little	VOCs
7.	TDA	High	Large industries	High	Little	VOCs
8.	Acid/clay	Low	Small industries	Low	Much	VOCs

In this research, coconut shells are used as absorbent. The advantages of coconut shells as an adsorbent are that they have excellent natural structure and low ash content (Song et al., 2014). Coconut shells will be burned before turning into charcoal; then, they will be activated with HCl for 18 hours to make the reagent experience an expansion of the surface area and able to bind the lead maximally.

Hlaing et al. (2011) have used coconut shells as adsorbents on artificial waste comprising of Pb, Cd, and with various masses of the adsorbent, resulting in the increase of metal ion removal as the increase of adsorbent mass, but with the decrease of absorption capacity. Research conducted by Oduola and Okwonna (2014) shows that activated ukpor clay (bentonite) can reduce metal ions obtained in the waste oil with their highest values, such as Ca (804 mg/L), Pb (398 mg/L), and Zn (222 mg/L), to 3.6 mg/L, 5.6 mg/L and 0.01 mg/L, respectively.

This research studies activated carbon of coconut shell charcoal as an adsorbent for adsorption liquid for waste consiting of Zn^{2+}. The effect of particle size and percentage of solvent on the adsorption capacity of Zn have been evaluated. Based on these studies, Freundlich and Langmuir isotherm models were used to fit the equilibrium data. Finally, the adsorption kinetic model using pseudo-first-order and pseudo-second-order were investigated.

Adsorption Isotherm Modeling

The adsorption model used is the Langmuir and Freundlich isotherm (Habeeb et al., 2017). The Langmuir isotherm is expressed by Equations of (1) – (4) (Habeeb, et al., 2017).

$$C_\mu = \frac{bC_e C_{\mu_{mak}}}{1+bC_e} \quad (1)$$

$$\frac{1}{C_\mu} = \frac{1+bC_e}{bC_e C_{\mu_{mak}}} \quad (2)$$

$$\frac{C_e}{C_\mu} = \frac{1+bC_e}{bC_{\mu_{mak}}} \quad (3)$$

$$\frac{C_e}{C_\mu} = \frac{1}{bC_{\mu_{mak}}} \quad (4)$$

The plot Ce/Cμ to Ce is conducted using regression linear equation with *slope* $1/C_{\mu mak}$ and *intercept* $1/b \cdot C_{\mu mak}$ to obtain $C_{\mu mak}$ and b value.

where,

C_μ : Solute concentration (adsorbate) on the surface of the pore wall at equilibrium

C_e : The concentration of solute (adsorbate) in the fluid at equilibrium

$C_{\mu mak}$: Maximum solute concentration on the surface of the pore wall at equilibrium

b : Langmuir constant

While the Freundlich isotherm equation is expressed by Equations of (5) – (7) (Habeeb et al., 2017):

$$C_\mu = k\,C_e^{\frac{1}{n}} \quad (5)$$

$$\log C_\mu = \log k + \log C_e^{\frac{1}{n}} \quad (6)$$

$$\log C_\mu = \log k + \frac{1}{n} \log C_e \quad (7)$$

A plot of log Cμ versus log Ce is conducted with regression linear equation to obtain 1/n as slope and log k as intercept. The magnitude of $1/n < 1$ indicates the favorability of the adsorption process.

where,
k: adsorption capacity
n: adsorption intensity

Kinetics Modelling

The rate constants were interpreted by using pseudo-first-order and pseudo-second-order models.

Pseudo-First-Order Kinetics Model

The reaction rate constant using a pseudo-first-order kinetic model was proposed by (Yuh-Shan, 2004) which is revealed by Equation 8.

$$\frac{dC_\mu}{dt} = k_1 + (C_e - C_\mu) \quad (8)$$

where:

t : Time

k_1 : The constant absorption of one pseudo-order absorbtion constant

Integration with the boundary conditions t = 0, C_μ = 0 and t = t, C_μ = C_μ; then, the equation becomes Equation 9.

$$\ln (C_e - C_\mu) = \ln C_e - k_1 t \quad (9)$$

If a plot of ln (C_e - C_μ) is applied to t, we will obtain k_1 and C_e values.

Pseudo-Second-Order Kinetics Model

The reaction rate constant using a pseudo-second-order model is expressed by using Equation (10).

$$\frac{dC_\mu}{dt} = k_2\left(C_e - C_\mu\right) \tag{10}$$

By integrating the limit state (t = 0, C_μ = 0, and t = t, C_μ = C_μ), then the equation (10) becomes Equation (11) (Tan et al., 2008).

$$\frac{t}{C_\mu} = \frac{1}{k_2 C_e^2} + \frac{1}{C_\mu}t \tag{11}$$

where:
k_2: pseudo two order reactions contanta (g/mg)

2. Material and Methods

2.1 Materials

Used oil lubricant was used as raw material which was collected from the motor vehicle repair shops around Surakarta, Central Java, Indonesia. Coconut shells were collected from the traditional market around Surakarta, Central Java, Indonesia. HNO_3 (Merck Millipore), HCl (Merck Millipore), distilled water, H_2SO_4 (Merck Millipore), standard solution Zn (Merck Millipore), and Whattman 42 were chemicals used in this research.

2.2 Preparation of Absorbent

Coconut shells were cleaned and broken into smaller size and dried in an oven at 100°C for 1 hour. After drying process, the coconut shells were put into furnace with a temperature of 300°C for one hour for the charcoaling process. In these temperature, coconut shell charcoal does not turn to ash because coconut shell has a low ash content. Besides, it is not burned at its maximum temperature, which is 1500°C (Tinga et al., 2016). Adsorbents at room temperature were pounded and filtered using 149 µm sieve. One hundred gram adsorbent was soaked into HCl 25% 250 mL for 18 hours (Bath et al., 2012). The result of the marinades was filtered and washed with distilled water to reach the neutral pH. The marinades were put into a furnace at a temperature of 500°C for 3 hours for the activation process. Activated adsorbents were stored in the desiccator for 0.5 hours.

2.3. Adsorption Experiment

Used oil lubricant as much of 400 mL, 10 g adsorbents, and various percentage of H_2SO_4, namely 0% v/v, 0.5% v/v, 1% v/v, and 2% v/v were put into glass flask with volume of 600 ml, mixed using magnetic stirrer in the speed of 10 for 2 hours. Every 30 minutes (0, 30, 60, 90, and 120 minutes), the filtrate was taken as much of 50 mL. Then, it was transferred to 100 mL Erlenmeyer flask which had been labeled. The same procedures were repeated in the particle size variations, such as -20 + 40 mesh, -40 + 60 mesh, -60 + 100 mesh, and -100 mesh.

2.4. Sample Analyzing

Used oil lubricant had experienced adsorption (filtrate) in the various percentages of solvent and particle size of destruction process before being analyzed using Atomic Absorption Spectroscopy (AAS). Filtrate in the Erlenmeyer flask was added with 5 mL HNO_3 68%; then, it was heated on electrical stove with constant temperature for 2 hours. In the first 1 hour, 5 mL HNO_3 68% was added again. After heating, the result of destruction was cooled to room temperature. The filtrate was filtered using Whatman 42 paper. The digestion product was diluted with HNO_3 in a 100 mL volumetric flask and shaken until homogeneous. The filtrate was filtered and analyzed using AAS Shimadzu AA-6650.

3. Results and Discussion

3.1 Coconut Shell Charcoal

The coconut shell charcoal has a particle size of 149 µm before being used as adsorbent and analyzed using Indonesian Industrial Standard Number 0258-79. The adsorbent test results are shown in Table 2.

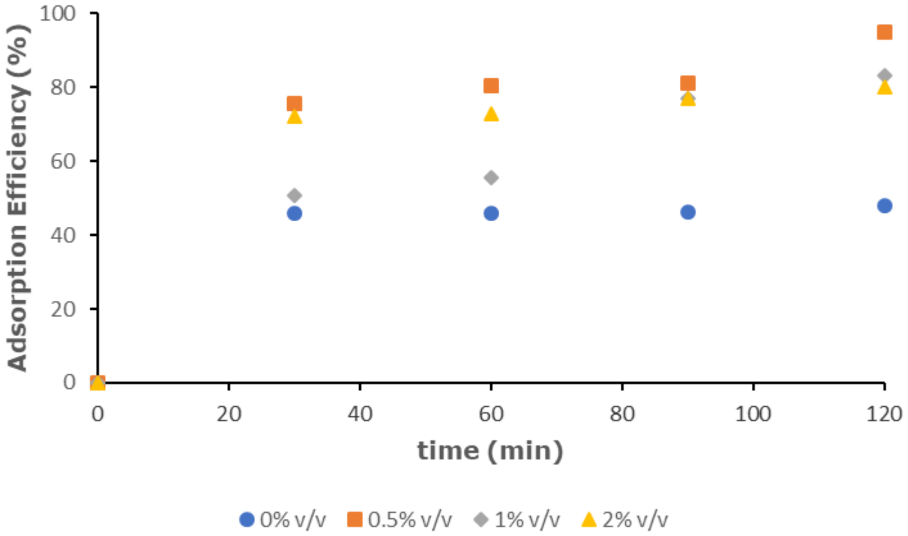
Table 2. Coconut shell adsorbent specification

No.	Characteristics	SII 0258-79	Adsorbent
1.	The missing part is heating 950°C	Max. 15%	5.69%
2.	Moisture Water	Max. 10%	1.01%
3.	Ash content	Max. 2.5%	0.98%
4.	Carbon content	Min. 80%	93.3%

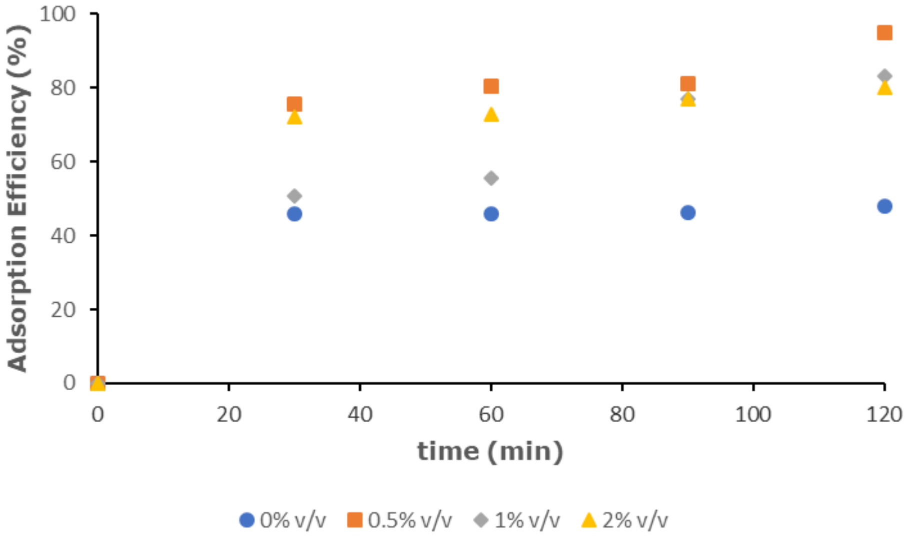
Based on Table 2, coconut shell adsorbent in the particle size of 149 µm is proper to be used for adsorbing the used oil lubricant.

3.2 Absorption Profile

Figure 1 describes the relationship between time versus percentage efficiency in the percent solvent and particle size variations. Equilibrium adsorption time is the time when adsorption capacity to Zn is not changing or in constant condition. Based on Figure 1, the time for adsorption of the used lubricant oil using activated coconut shell charcoal is 120 minutes. It is compared to 60 minutes using bentonite (Oduola and Okwonna, 2016).



(a)

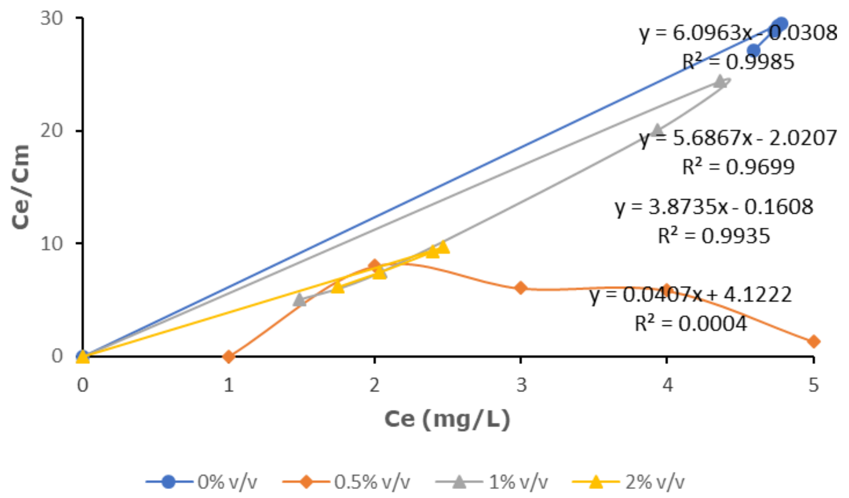


(b)

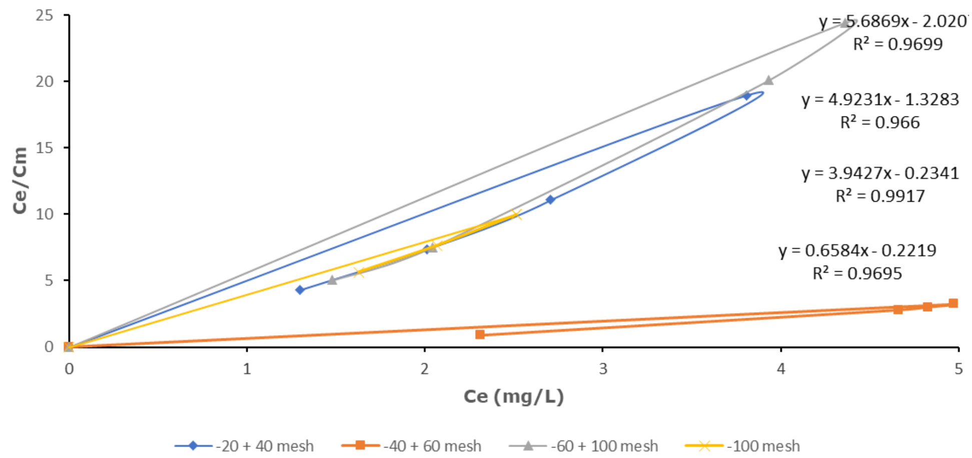
Figure 1. Adsorbtion efficiency in the variation (a) % solvents, (b) particle size.

3.3 Isotherm kinetics

A standard solution was prepared at various zinc concentrations, namely 0, ½, 1, 1 ½, and 2 ppm. Based on the plot, the relationship between concentrations and the adsorbance results in calibration curve. The calibration curve equation is y = 0.127x + 0.0101 with value of R^2 is 0.9949. The equation becomes the target for calculating the sample absorbance that had been read using AAS. The relationship between the metal ion concentration after adsorption and the adsorption solute concentration consisting of zinc metal for Langmuir isotherm is presented in Figure 2 in the variation (a) solvent % and (b) particle size.



(a)



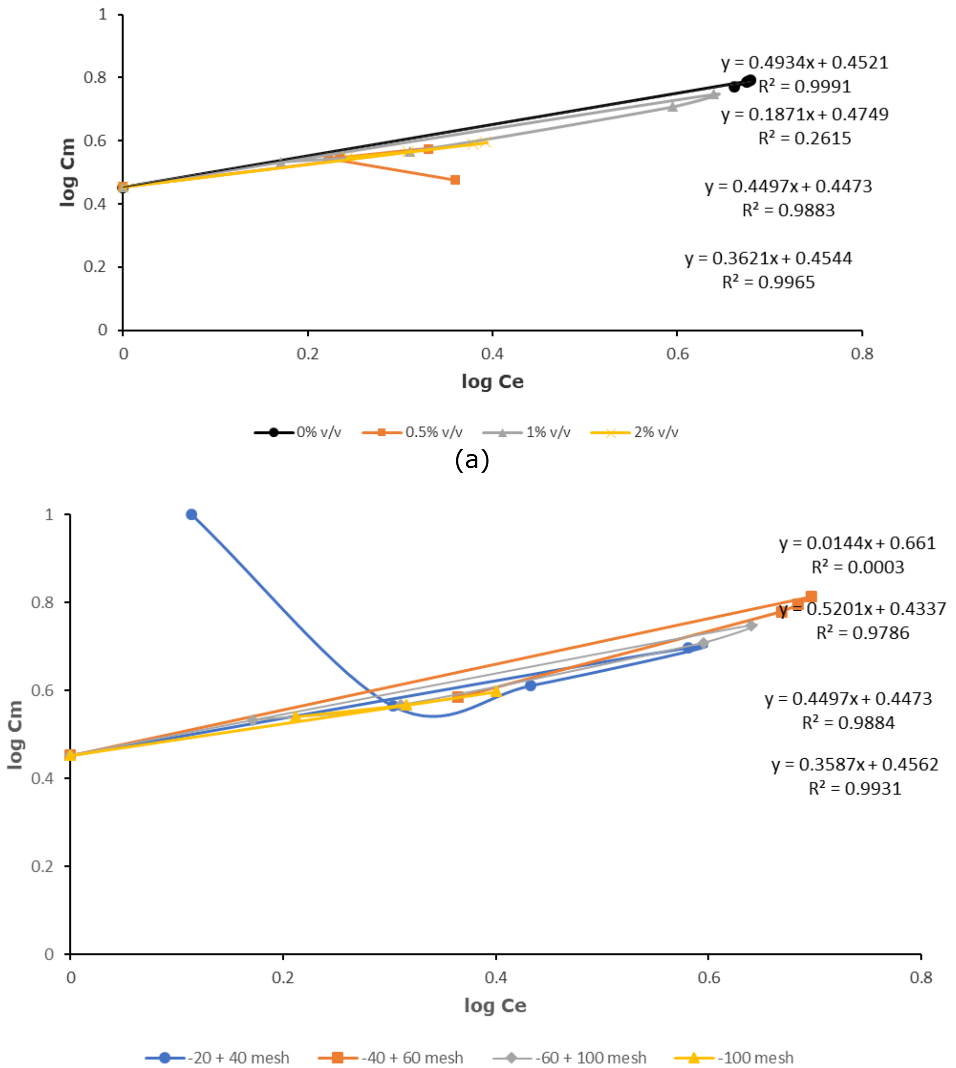
(b)

Figure 2. Langmuir adsorption isotherm of used oil lubricant variation (a) solvent %, (b) particle size.

Based on linear regression equation in Figure 2 (a) and Figure 2 (b), it was obtained $C_{\mu mak}$ and b values as shown in Table 3 and Table 4. Tables of 3 and 4 summarize all the constants and correlation coefficient of two isotherms used. In the Langmuir equation, $C_{\mu mak}$ shows adsorption capacity level in the metal zinc. Based on Table 3, the more solvent percent is added, the more absorption capacity will increase. Based on Table 3 the adsorption capacity will increase with the smaller grain size. On the other hand, in the Freundlich isotherm, the relationship between metal ion concentration after adsorption and adsorption solute concentration on the Zn metal-containing solution for the Freundlich isotherm can be seen in Figure 3 in the variation solvent concentration (a) and particle size (b).

Based on Figure 3 (a) and Figure 3 (b), the k value, n in the variation percent of solvent and particle size can be seen in Table 4. Table 4 shows the Freundlich parameter. The plot of log C_m versus log C_e gives a straight line with slope 1/n. Parameter to illustrate adsorption capacity is k and n values. If the equilibrium adsorption Freundlich constant (k) is bigger, then adsorption capacity will be better.

Based on Table 4, the highest adsorption capacity in the equilibrium concentration 0.5% v/v is 5.35 g/g while in the smaller particle size, the adsorption capacity will decrease. 1/n is symbolized absorption capacity, the greater the adsorption capacity (1/n), the smaller the affinity of coconut shell charcoal to absorb the used oil.



(a)

(b)

Figure 3. Freundlich adsorption isotherm in the variation of solvent percent (a) and particle size (b).

Table 3. Langmuir isotherm model parameters and correlation coefficients

No.	Percent *solvent* (% v/v)	B	Cμmax	R^2	Regression linear equation
1	0.0	197.93	0.164	0.9900	Y=6.0963x-0.0308
2.	0.5	9.8×10^{-3}	24.57	0.0004	Y=0.0407+4.1222
3.	1.0	2.81	0.176	0.9600	Y=5.6867-2.0207
4.	2.0	24.89	0.258	0.9900	Y=3.8735x-0.1608
Particle size (mesh)					
5.	-20+40	3.70	0.203	0.9600	y=4.9231x-1.3283
6.	-40+60	2.94	0.153	0.9600	y=6.5838x-2.2189
7.	-60+100	2.81	0.176	0.9600	y=5.6869x-2.0207
8.	-100	16.84	0.250	0.9900	y=3.9427x-0.2341

Table 4. Freundlich isotherm model parameters and correlation coefficients

No.	Percent Solvent (% v/v)	K	n	R^2	Regresion linear equation
1.	0.0	0.34	2.03	0.99	Y =0.4934x+0.4521
2.	0.5	0.32	5.35	0.26	Y =0.1871x+0.4749
3.	1.0	0.34	2.22	0.98	Y=0.4497x+0.4473
4.	2.0	0.34	2.76	0.99	Y=0.3621x+0.4544
Particle sizes (mesh)					
1.	-20+40	0.34	2.57	0.97	Y=0.3889x+0.4582
2.	-40+60	0.36	1.92	0.97	Y=0.5201x+0.4337
3.	-60+100	0.34	2.22	0.98	Y =0.4497x+0.4473
4.	-100	0.34	2.78	0.99	Y=0.3587x+0.4562

Lubricant oil adsorption using coconut shells as adsorbent with R^2 value in the Langmuir equilibrium is 0.0004 to 0.99, while in Freundlich equilibrium is 0.26–0.99. The value of R^2 in the Freundlich equilibrium model is larger than the Langmuir equilibrium model.

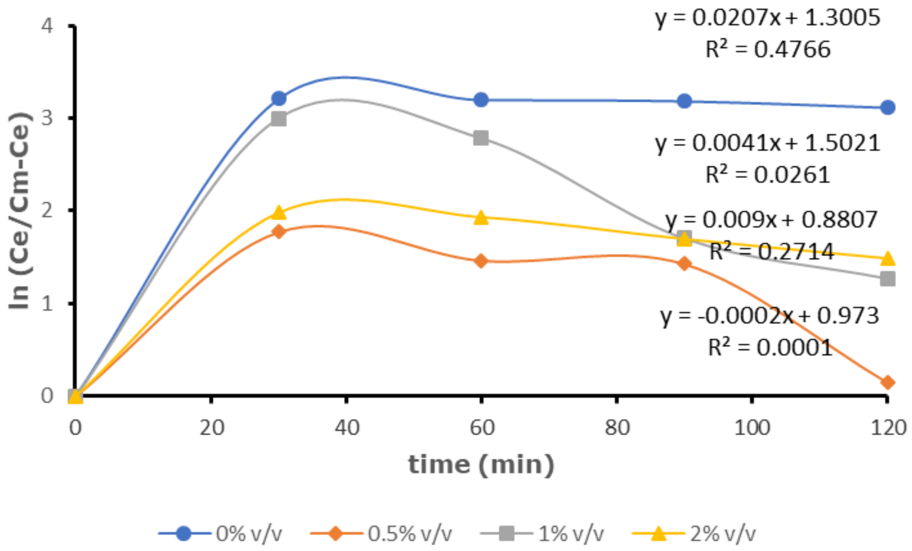
Table 5. Langmuir and Freundlich parameters in some researchers.

Researchers	Adsorbent	Langmuir B ($L \cdot g^{-1}$)	Langmuir $C\mu_{mak}$ ($g \cdot g^{-1}$)	Freundlich ln k (g/g)	Freundlich 1/n
Hu et al.	Nano PE	0.0843	6.8	3.353	0.3540
(2017)	Mikro PS	0.1424	5.2	3.105	0.4790
Shella et al.	Zn (II)	0.7530	357	2.220	0.7400
(2012)	Cd (II)	1.8100	384	11.77	0.5052
	Hg (II)	4.6900	714	17.32	0.5966

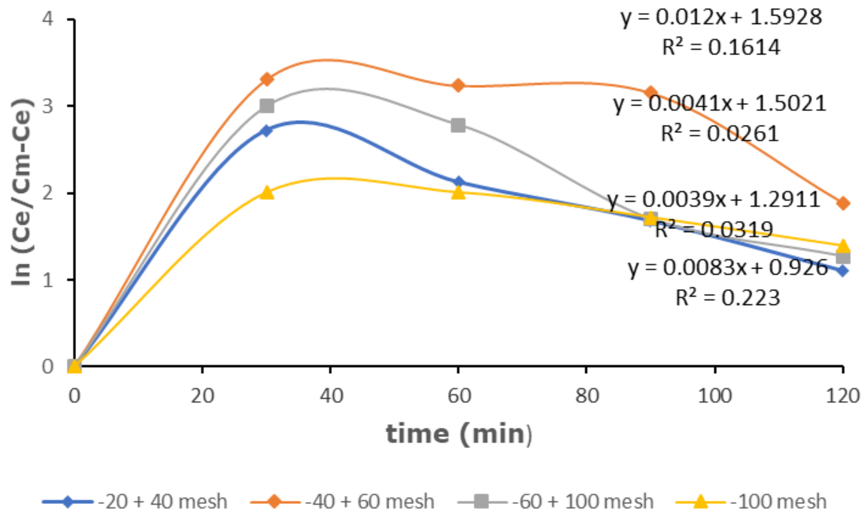
This shows that the process of adsorption of the used oil using coconut shell charcoal is more suitable when approached with the Freundlich equilibrium model. Tables of 4 and 5 describe n constant between 2.71 to 2.98. However, the constant is in the range of 1.0–10.0, the constant shows that adsorption process better runs in the varioues particle sizes and solvent percent.

3.4. Adsorption Kinetics

The reaction kinetics is predicted using pseudo-first and second-order kinetics. The relationships between the changed concentration and the time are shown in Figures of 4 and 5. Figure 4 (a) shows that first-order kinetic data in the range of 0–120 minutes. The total metal Zn concentration increases to time. Figure 4 (b) describes that adsorption processs is effective in the interval 0 to 30 minutes while in the interval 60 to 120 minutes, desorption process is more dominant than adsorption because metal Zn concentration increases.

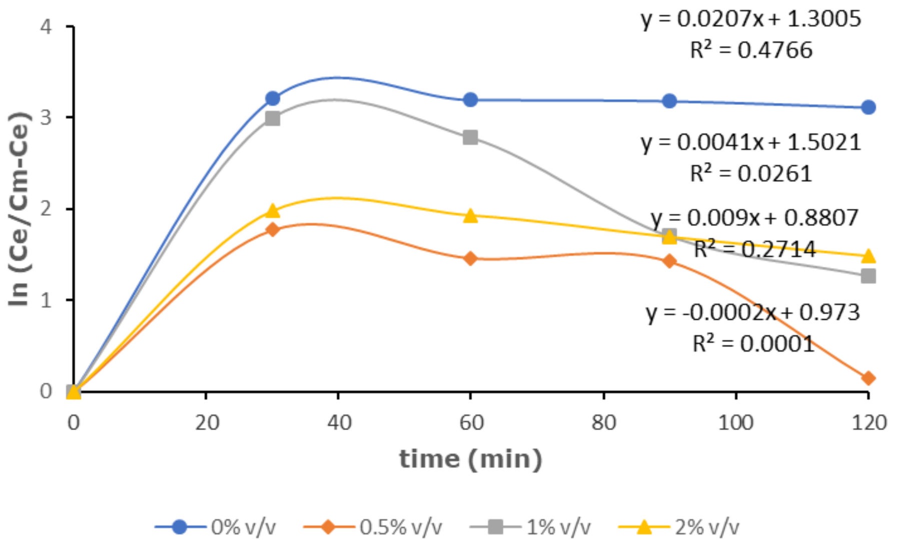


(a)

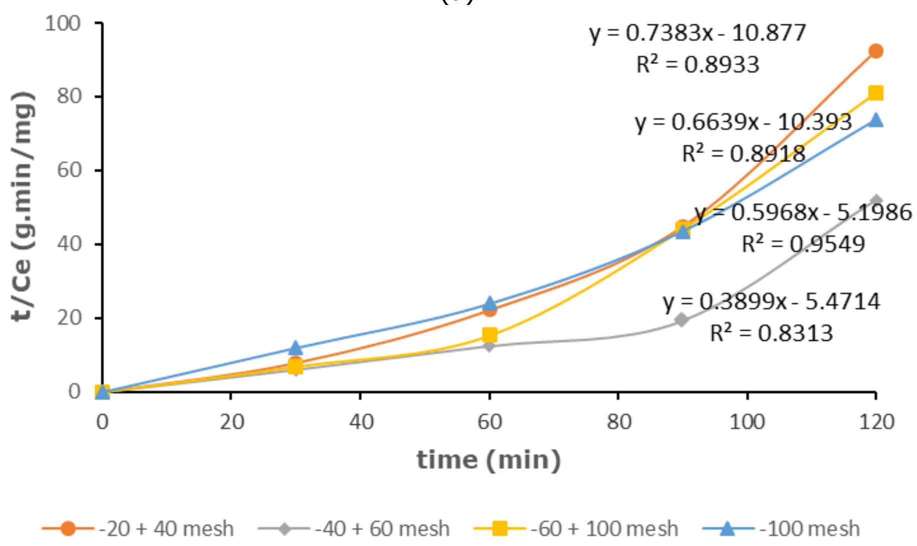


(b)

Figure 4. Pseudo-first-order kinetics for adsorption used oil lubricant in the variation (a) solvent percent and (b) particle sizes.



(a)



(b)

Figure 5. Pseudo-second-order kinetics for adsorption used oil lubricant (a) solvent percent (b) particle size.

Table 6. Pseudo first and second-order kinetic model parameters in the percent solvent and particle size variations.

No.	Percent solvent variations (% v/v)	First-order		Second-Order	
		k_1 (min^{-1})	R^2	k_2 (g/mg. min^{-1})	R^2
1.	0.0	0.0207	0.47	0.24156	0.99
2.	0.5	0.0021	0.01	0.09115	0.67
3.	1.0	0.0041	0.02	0.04241	0.89
4.	2.0	0.0090	0.27	0.08283	0.97
	Particle size variations				
5.	-20+40	0.0039	0.03	0.05	0.89
6.	-40+60	0.0120	0.16	0.02	0.83
7.	60+100	0.0041	0.02	0.04	0.89
8.	-100	0.0083	0.22	0.068	0.95

Based on Figure 5 (a), at the various solvent percentages using the second-order kinetic model in the range of 0–120 minutes, metal Zn concentration increases every time. The phenomena show that desorption is more dominant than adsorption process. On the other hand, Figure 5 (b) at the various particle sizes has the same phenomena as the solvent percent desorption, which is more dominant than adsorbtion process.

Pseudo-second-order kinetic reaction is more suitable for illustrating the adsorption process of zink because the value of correlation coefficients are in the range of 0.67–0.99 compared to pseudo-first-order kinetic, namely in the range of $3x10^{-2}$–0.47 (Table 6). While reaction rate constant in the range of 0.23–5.69 is bigger than that of the used oil adsorption using bentonite, expanded graphite, and microplastic.

Researches about used oil adsorption have been conducted by some researchers using adsorbent bentonite, expanded graphite, and microplastic. The adsorption constant in the pseudo-first and second-order can be seen in Table 7.

Table 7. Adsorption constant in the pseudo-first and second-order.

No.	Researcher	Adsorbent	k value Pseudo First-Order (min^{-1})	R^2	Pseudo second -order ($g/mg·min^{-1}$)	R^2
1.	Oduola and Okwonna (2016)	Bentonite	0.004	0.89	0.089	0.93
2.	Yao et al. (2016)	Expanded graphite	0.504	0.89	0.0006	0.99
3.	Hu et al. (2017)	Nano PE	0.045	0.66	8.57	0.99
	Song et al. (2014)	Mikro PS	0.077	0.78	6.86	0.99

Conclusions

Activated coconut shell charcoal can be used as an adsorbent for oil lubricant consisting of metal ion using adsorption process. By using coconut shell active charcoal as a used oil adsorbent, it can increase the value of activated charcoal which has only a waste material without economic value. On the other hand, activated coconut shell charcoal can reduce the environmental pollution caused by the used lubricant oil. Isotherm Freundlich equilibrium model is more suitable to describe reaction equilibrium than isotherm Langmuir which is the maximum adsorption power of 5.35 g/g. The reaction constant rate in the first-order and second-order reaction are 0.0207 min^{-1} and 0.24156 $g/mg·min^{-1}$, respectively.

Acknowledgment

The authors acknowledge the Institute for Research and Service, Universitas Muhammadiyah Surakarta that has funded the research through the Competitive Regular Research scheme (PEREKOM) with the Competitive Regular Research Agreement No. 132.6 / A.3-III / LPPM / IV / 2018.

References

Awad, A.N. and Mohammed, S.S. (2014) A study of enhancement of the properties of lubricant oil, *American Journal of Chemical*, 4, 68–72.

Alhamed, Y.I.S. and Al-Zahrani, A.A. (1999) Techno-economical Evaluation of Oil Recovery and Regeneration of Spent Bleaching Clay, *JKAU: Eng. Sci*, 11,2, 115–126.

Bazrafshan, E., Amirian, P., Mahvi, A., Ansari-moghaddam, A. (2016) Application of adsorption process for phenolic compounds removal from aqueous environments: a systematic review, *Global NEST Journal*, 18, 146–163.

Bhaskara, T., Uddin, M.A., Muto, A., Yusaku Sakata, Y., Omura, Y., Kimura, K. Yasuhisa Kawakami, Y. (2004) Recycling of waste lubricant oil into chemical feedstock or fuel oil over supported iron oxide catalysts, *Fuel*, 83, 9–15.

Dai, W., Kheireddin, B., Gao, H., Liang, H. (2016) Roles of nanoparticles in oil lubrication, *Tribology International Journal*, 102, 88–98.

Habeeb, O.A., Kanthasamy, R., Abdelgawad, G., Ali, M., Mohd, R. Bin, Yunus, Olalere, O. A. (2017) Kinetic , isotherm and equilibrium study of adsorption of hydrogen sulfide from wastewater using modified eggshells. *IIUM Engineering Journal*, 18, 13–25.

Hamad, A., Al-Zubaidy, E., Fayed, M. E. (2005) Used lubricating oil recycling using hydrocarbon solvents*, Journal of Environmental Management,* 74 (2), 153–159.

Hassanpour, M., Jafari, A.J., Gholami, M., Farzadkia, M. (2013) Feasibility study of recycling and converting acidic sludge to bitumen in used motor oil refining industries, *Journal of Health in The Field*, 5 (2), 7-16.

Hlaing, C. S., Kyu, K. K., Win, T. (2011) Removal of some toxic heavy metals by means of adsorption onto biosorbent composite (Coconut Shell Charcoal - Calcium Alginate) beads, *University Research Journal*, 4, 237–251.

Hu, J.Q., Yang, S.Z., Guo, L., Xu, X., Yao, T., Xie, F. (2017) Microscopic investigation on the adsorption of lubrication oil on microplastic, *Journal of Molecular Liquid,* 227, 351–355.

Hsu, Y. L., Lee, C. H., Kreng, V. B. (2009) Analysis and Comparison of Regenerative Technologies of Waste, *Wseas Transactions on Environment and Development,* 5, 295–309.

Ikenaga, E., Kobata, M., Kim, J. J., Wakabayashi, A., Nishino, Y., Tamasaku, K., Sakane, Y., Ishikawa, T., Komiya, S., Kobayashi, K. (2007) Study of adsorption process states for lubricant molecule using hard X-ray photoemission spectroscopy, *Journal of Electron Spectroscopy and Related Phenomena*, 156–158, 336–339.

Jafari, A. J. and Hasanfour, M. (2015) Analysis and comparison of used lubricants, regenerative technologies in the world, *Resources, Concervation, and Recycling*, 103, 171–191.

Kajdas, C. (2000) Major Pathways for Used Oil Disposal and Recycling. Part 2, *Tribotest Journal*, 7 (1), 137–153.

Kim, Y. S., Jeong, S. K., Yoon, W. L., Yoon, H. K., Kim, S. H. (2003) Tar-formation kinetics and adsorption characteristics of pyrolyzed waste lubricating oil, *J. Anal. Appl. Pyrolysis*, 7, 19–33.

Labied, R., Benturki, O., Eddine Hamitouche, A. Y., Donnot, A. (2018) Adsorption of hexavalent chromium by activated carbon obtained from a waste lignocellulosic material (Ziziphus jujuba cores): Kinetic, equilibrium, and thermodynamic study, *Adsorption Science Technology Journal*, 1, 1–34.

Lee, S.H., Lee, S., Kim, D.Y., Kim, J. (2007). *Degradation characteristics of waste lubricants under different nutrient conditions. Journal of Hazardous Materials, 143 (1-2), 65–72.*

Li, T., Chen, C., Jin, Q., Zhao, J., Tang, X., Zhu, Y. (2017) Evaluation and prediction of water resources based on AHP, *Environmental Research Letters,* 51, 1–7.

Oduola, M. K. and Okwonna, O. O. (2016) Kinetic modelling of the adsorption treatment of waste lubricating oil using activated ukpor clay, *International Journal of Engineering Reasearch and Science,* 2, 113-123.

Parmar, M. and Thakur, L. S. (2013) Heavy metal, Cu, Ni and Zn: toxicity, health hazard and their removal techniques by low cost adsorbent : A Short Overview. *Internationl Journal Plant, Animal and Enviromental Science*, 3, 143–157.

Rincón, J., Cañizares, P., García, M. T., Gracia, I. (2003) Regeneration of Used Lubricant Oil by Propane Extraction. *Industrial & Engineering Chemistry Research,* 42 (20), 4867–4873.

Shella, T., Nayaka, Y. A., Visvanatha, R., Basavanna, S., Ventakesha, T. G. (2012) Kinetics and thermodynamics studies on the adsorption of Zn(II), Cd(II) and Hg(II) from aqueous solution using zinc oxide nanoparticles. *Powder Technology,* 217, 163-170.

Song, C., Wu, S., Cheng, M., Tao, P., Shao, M., Gao, G. (2014) Adsorption studies of coconut shell carbons prepared by KOH activation for removal of lead(ii) from aqueous solutions, *Journal Environmenta*, 6, 86-98.

Tan, I. A. W., Ahmad., A. L., Hameed, B. H. (2008) Adsorption of basic dye on high-surface-area activated carbon prepared from coconut musk: equilibrium, kinetic, and thermodynamic studies, *Journal of Hazardous Material,* 154, 337–346.

Tinga, T. L., Jayaa, R. P., Hassana, N. A., Yaacoba, H., Jayantib, D. S., Ariffin, M.A.M. (2016) A Review of Chemical and Physical Pro of Coconut Sheell in Asphalt Mixture, *Jurnal Teknologi (Sciences & Engineering*), 78 (4), 85–89.

Unnisaa, S.A. and Hassanpourb, M. (2017) Development circumstances of four recycling industries (used motor oil, acidic sludge, plastic wastes and blown bitumen) in the world, *Renewable and Sustainable Energy Reviews*, 72, 605–624.

Yao, T., Zhang, Y., Xiao, Y., Zhao, P., Guo, L., Yang, H., Li, F. (2016) The effect of environmental factors on the adsorption of lubricating oil onto expanded graphite, *Journal of Molecular Liquids*, 218, 611–614.

Yuh-Shan, H. (2004) Citation review of Lagergren kinetic rate equation on adsorption reactions, *Scientometrics*, 59 (1), 171–177.