CARBONISATION-ACTIVATION SYSTEM FOR THE PRODUCTION OF BIOCHAR AND ACTIVATED CARBON FROM OIL PALM KERNEL SHELL

NAHRUL HAYAWIN ZAINAL; ASTIMAR ABDUL AZIZ; NOR FAIZAH JALANI and ROPANDI MAMAT

785

MPOB INFORMATION SERIES • ISSN 1511-7871 • JULY 2018

MPOB TT No. 637

The demand of activated carbon is increasing every year for many industrial applications such as water purification media, pollutant-gas adsorbent and catalyst support. Recently, many researches are focusing on the production of activated carbon from renewable resources and one of it is the palm kernel shell (PKS). One of the important application of PKS activated carbon is as bio-adsorbent for palm oil mill effluent (POME) polishing treatment (Nor Faizah *et al*., 2016).

The preparation of activated carbon involves two main stages; (i) the preparation of charcoal via carbonisation process and (ii) the activation of the charcoal. These two processes are normally carried out separately and it involves two different industry. The carbonisation process is basically the heating of raw material at temperature between 300°C-500°C, whereby volatiles are derived out during the process (Smisek and Cerney, 2009). The carbon content is enriched an initial porosity and some ordering in the carbon structure is formed. Some of the carbonisation technologies have been introduced earlier (Astimar *et al*., 2011; 2015; 2016). The activation process is to further enhance the carbon structure, either into making the carbon more porous or more crystalline. In this stage, the charcoal is subjected to higher temperature, between 850°C-950°C, and simultaneous physical activation by applying steam treatment (Rugayah *et al*., 2014). The activation of the charcoal enhances the adsorption characteristics via formation of highly porous and large surface area of the carbon. To reduce the production cost of activated carbon, it is important to develop a system that can combine these two processes of carbonisation and activation.

NOVELTY

A patented system of a double insulated carbonisation-activation reactor was developed in order to produce activated carbon with high yield and surface area (*Figure 1*). The carbonisation of PKS at 400°C, followed by steam activation at 500°C-1000°C continuously in the same reactor, with steam flow rate of 12.80-18.17 litre min^{-1} had improved the activated carbon surface area from 305 ± 10.2 m^2 g^{-1} to 935 ± 36.7 m^2 g^{-1} and gave a high yield of 30% within 7 hr retention time with a low gaseous emission. The activated carbon produced was successfully applied as bio-adsorbent for the treatment of POME final discharge with the reduction of TSS, COD, colour and BOD up to 90%, 68%, 97% and 83%, respectively; which comply with the standard set by Department of Environment, Malaysia (DOE).

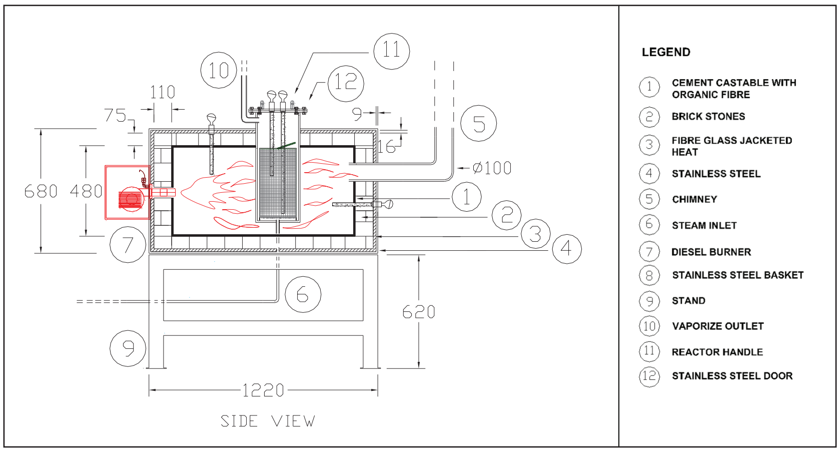

Figure 1. Schematic diagram of the double insulated carbonisation-activation reactor system.

ISSN 1511-7871
9 771511 787001

BENEFITS

The carbonisation-activation system was designed to enable the activation stage to be continuously conducted after carbonisation without stopping the operation. This design makes the feeding of the substrate and uploading of the activated carbon from the reactor easier as compared to conventional reactor. In comparison with other activated carbon, the PKS activated carbon produced from this system showed significantly higher surface area as compared to previous study and other reported data that used oil palm biomass as feedstock material (*Table 1*). More importantly, *Table 1* clearly shows that the surface area had increased rapidly with the increase of the activation temperature to reach a maximum value of 935-987 $m^2 g^{-1}$ at 900°C.

On the application of the produced PKS for the polishing treatment of POME final discharge, it was found that it can effectively reduce the BOD, COD, TSS and colour with maximum percentages of 83%, 68%, 90% and 97%, respectively at an optimum bio adsorbent dosage of 40 g $litre^{-1}$ (*Table 2*). The bio adsorbent of PKS activated carbon can be directly used in polishing treatment of POME by varying the dosing and later can be recycled as soil conditioner or regenerated.

TABLE 1. CHARACTERISTICS OF ACTIVATED CARBON PRODUCED FROM OIL PALM BIOMASS

Type of biomass	Carbonisation conditions	Activation conditions	Type of reactor	Retention time (min)	Yield (%)	Surface area ($m^2 g^{-1}$)	References
Oil palm mesocarp fibre	600°C/0.5 hr	600°C/0.5 hr	Furnace	60	-	494	(Ibrahim *et al*., 2017)
Oil palm kernel shell	300°C/0.5 hr	800°C/1 hr	Tube furnace	90	22.00	584	(Hidayu and Muda, 2016)
Date palm seed	800°C/2 hr	800-1000°C/2 hr	Tubular furnace	240	28.00	666	(Reddy *et al*., 2012)
Oil palm trunk	500°C/3 hr	500°C/3 hr	Quartz horizontal tubular reactor	480	<20	1800	(Hussein *et al*., 2001)
Oil palm kernel shell	400°C/3 hr	900°C/4 hr	Carbonisation-activation	420	30.00	935-987	This study

TABLE 2. COMPARISON OF DIFFERENT BIO-ADSORBENT MATERIAL AT DIFFERENT DOSAGE WITH REMOVAL EFFICIENCY OF POME FINAL DISCHARGE

Bio-adsorbent material	Concentration (Mg $litre^{-1}$) / Removal efficiency (%)				References
	BOD	COD	TSS	Colour	
Oil palm mesocarp fibre	-	300 mg $litre^{-1}$/70%	15 mg $litre^{-1}$/88%	-	(Ibrahim *et al*., 2017)
Oil palm kernel shell	-	132-1008 mg $litre^{-1}$/75%	-	38-4708 ADMI/76%	(Nor Faizah *et al*., 2016)
Banana peel	97%	100%	100%	96%	(Mohammed and Chong, 2014)
Industrial-grade alum	-	10 mg $litre^{-1}$/98%	2 mg $litre^{-1}$/99%	-	(Othman *et al*., 2014)
Rice husk	-	41%	-	88%	(Kutty *et al*., 2011)
Oil palm kernel shell	5.1 mg $litre^{-1}$/83%	189 mg $litre^{-1}$/68%	18 mg $litre^{-1}$/90%	80 ADMI/97%	This study
Standard discharge limit	100 mg $litre^{-1}$	-	200 mg $litre^{-1}$	100 mg $litre^{-1}$	(DOE, 1982)

ECONOMIC FEASIBILITY

The estimated fixed cost for the production of PKS activated carbon is RM 890 000 based on the capacity of 4 t month^{-1}.

TABLE 3. ECONOMIC ANALYSIS OF CARBONISATION-ACTIVATION TECHNOLOGY

Economic analysis	Value
Net present value (NPV)	RM 220 241
Internal rate of return (IRR)	26%
Payback period	3 yr
Benefit cost ratio (B:C)	1.46

Note: This economic feasibility will be more profitable if the system is installed by the palm oil millers using their PKS operating using excess energy and steam available.

REFERENCES

Astimar, A A and Ropandi, M (2011). Charcoal from palm kernel shells (Hollow plinth carbonisation furnace system). *MPOB Information Series No. 494*.

Astimar, A A; Ropandi, M and Nahrul Hayawin, Z (2015). Continuous carbonisation system for the production of charcoal from oil palm biomass. *MPOB Information Series No. 569*.

Astimar, A A; Nahrul Hayawin, Z; Ropandi, M; Fazliana, A H and Nor Faizah, J (2016). Charcoal production from PKS using microwave carbonisation system. *MPOB Information Series No. 596*.

DOE (1982). Environment Quality Act 1974-Envi-Ronment Quality (Prescribed Premises) (Crude Palm Oil)(Amendment) Regulations 1982. http://www.doe.gov.my/portalv1/wp-content/plugins/download-attachments/accessed on 22 May 2017.

Hidayu, A and Muda, N (2016). Preparation and characterisation of impregnated activated carbon from palm kernel shell and coconut shell for CO_2 capture. *Procedia Eng, 148*: 106-113.

Hussein, M; Abdul Rahman, M; Yahaya, A; Taufiq-Yap, Y and Ahmad, N (2001). Oil palm trunk as a raw material for activated carbon production. *J. Porous Mater. 8*: 327-334.

Ibrahim, I; Hassan, M A; Abd-Aziz, S; Shirai, Y; Andou; Ridzuan, M; Amiruddin, A and Ali, M (2017). Reduction of residual pollutants from biologically treated palm oil mill effluent final discharge by steam activated bioadsorbent from oil palm biomass. *J. Clean. Prod. 141*: 122-127.

Kutty, S; Ngatenah, S; Johan, N and Amat, K (2011). Removal of Zn (II), Cu (II), chemical oxygen demand (COD) and colour from anaerobically treated palm oil mill effluent (POME) using microwave incinerated rice husk ash (MIRHA). *Int. Conf. Environ. Ind. Innov. 12*: 90-94.

Mohammed, R and Chong, M (2014). Treatment and decolorisation of biologically treated palm oil mill Eefflluent (POME) using banana peel as novel biosorbent. *J. Environ. Manag. 132*: 237-249.

Nor Faizah, J; Astimar, A; Noorshamsiana, A; Hassan, W and Nahrul Hayawin, Z (2016). Application of palm kernel shell activated carbon for the removal of pollutant and colour in palm oil mill effluent treatment. *J. Earth Environ. Heal. Sci. 2*: 15-20.

Othman, M; Hassan, M; Shirai, Y; Baharuddin, A; Ali, A and Idris, J (2014). Treatment of effluents from palm oil mill process to achieve river water quality for reuse as recycled water in a zero emission system. *J. Clean. Prod., 67*: 58-61.

Reddy, K; Al Shoaibi, A and Srinivasakannan, C (2012). Activated carbon from date palm seed: Process optimisation using response surface methodology. *Waste Biomass Valoriz, 3*: 149-156.

Rugayah, A F; Astimar, A A and Norzita, N (2014). Preparation and characterisation of activated carbon from palm kernel shell by physical activation with steam. *J. Oil Palm Res., Vol. 26(3)*: 251-264.

Smisek, M and Cerny, S (1970). Active Carbon: Manufacture, Properties and Application. Elsevier Publishing Co., London.

For more information, kindly contact:

Head of Corporate Implementation
and Consultancy Unit, MPOB
6, Persiaran Institusi,
Bandar Baru Bangi,
43000 Kajang, Selangor, Malaysia
Tel: 03-8769 4574
Fax: 03-8926 1337
E-mail: tot@mpob.gov.my
www.mpob.gov.my