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Evaluation of optimal activated carbon from an agricultural waste for the removal of para-chlorophenol and 2,4-dichlorophenol

Zaharaddeen N. Garba[a,b], *Afidah Abdul Rahim*[a,*]

[a] *School of Chemical Sciences, Universiti Sains Malaysia, 11800 Penang, Malaysia*
[b] *Department of Chemistry, Ahmadu Bello University, P.M.B. 1044, Zaria, Nigeria*

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ABSTRACT

The most ideal conditions for preparing activated carbon from *Prosopis africana* seed hulls (PASH-AC) were investigated using sodium acetate (CH_3COONa) as an activating agent. The prime conditions applied for the activated carbon preparation from PASH were activation temperature of 795 °C, activation time of 62 min and IR of 2.46. The optimal PASH-AC was mesoporous with reasonably high surface area of 1085.92 m^2/g which gave good adsorption capacities of 347.47 and 380.75 mg/g for PCP and 2,4-DCP, respectively. The adsorption data were modelled using Langmuir, Freundlich and Temkin adsorption isotherms; the equilibrium adsorption of both PCP and 2,4-DCP on PASH-AC obeyed Langmuir model, pseudo-second-order kinetics was the order that best described the two adsorption processes.

1. Introduction

Due to increasing water demand globally, considerable attention was given to recovery, recycle and reuse of waste water. Thousands of chemical contaminants are present in waste water; many are of organic origin with chlorophenols among them. Chlorophenols (CPs) are a group phenols comprising one or more covalently bonded chlorine atoms (Fan et al., 2015) with their toxicity depending on the degree of chlorination and the position of chlorine atoms relative to the hydroxyl group (Czaplicka, 2004). Parachlorophenol (PCP) and 2,4-Dichloro phenol (DCP) were chosen as the adsorbates in this work because of their persistence in environment as well as being characterized as carcinogenic, having strong odour and inability to biodegrade easily (Ren et al., 2011; Zhou et al., 2014), therefore, removing them from the recycled water is very crucial.

Some of the treatment processes engaged for the removal of chlorophenols from waste water include adsorption (Gao et al., 2015), catalytic wet oxidation (Chaliha and Bhattacharyya, 2008), biodegradation (Steinle et al., 2000), ozonation and electrochemical degradation (Lim et al., 2013). Adsorption process has been proven globally as one of the best and most effective water treatment technologies (Foroughi-Dahr et al., 2015; Giraldoa and Moreno-Piraján, 2014). Its advantages in comparison to the other water treatment methods include simplicity in design, high adsorption capacity and fast adsorption kinetics with activated carbon being the most widely used adsorbent (Lee et al., 2015; Lladó et al., 2015). However, commercially available activated carbons are expensive due to the starting material involved in manufacturing them, for that there is an increasing attention in using cheap and readily available lignocelluloses materials as precursors for the preparation of activated carbon. *Borassus aethiopum* shells

* *Corresponding author*. Tel.: +60 46533888; fax: +60 46574854.
E-mail address: afidah@usm.my (A.A. Rahim) .

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(Garba et al., 2014), orange peel (Köseoglu and Akmil-Basar, 2015), palm date seed (Islam et al., 2015) and citrus peel (Dutta et al., 2011) are some precursors that were successfully transformed into activated carbons on a laboratory scale.

Another agricultural waste material with plausible chance of being a good precursor material for activated carbon productions are *Prosopis africana* seed hulls (PASH). Preliminary studies have reported PASH to contain high carbon and low ash content which makes it a good precursor material for preparing activated carbon. To the best of our knowledge no study has been done on the adsorption applications of optimal activated carbon from a novel PASH precursor using sodium acetate as chemical activating agent for the removal of any adsorbate.

Therefore, the inventive aspects of this work were the pre-treatment of PASH by impregnation with sodium acetate (CH_3COONa) and subsequently physico-chemical activation to produce mesoporous activated carbon (PASH-AC) which was subjected to textural and morphological studies. PCP and DCP were used as the adsorbates to evaluate the adsorption performance of the PASH-AC in aqueous solutions. Adsorption equilibrium, isotherms, kinetics, mechanism, thermodynamics and regeneration studies were considered.

2. Materials and methods

2.1. Adsorbates

The adsorbates (PCP and 2,4-DCP) were supplied by Sigma–Aldrich (M) Sdn Bhd, Malaysia. Deionized water was used to prepare their solutions. The basic information concerning the adsorbates is included in Table 1 (Vidic et al., 1993). Six different concentrations of the adsorbates were prepared, which are 30, 60, 100, 150, 250 and 350 mg/L. The concentrations were prepared by first dissolving 1 g of each adsorbate into 1 L volumetric flask and then were diluted appropriately to prepare the six series of concentrations.

2.2. Activated carbon preparation

The seed hulls of *P. africana* were collected locally from Nigeria as discarded agricultural wastes. They were washed with distilled water, dried at 105 °C for 24 h, ground using a locally made grinder and sieved into particle size of 200–500 μm to generate the precursor. Analytical grade chemicals/reagents were used in this work.

The activated carbon preparation procedure was referred to our previous work (Garba and Afidah, 2014) with little modifications. The pre-treated PASH was loaded in a stainless steel vertical tubular reactor placed in a tube furnace and the carbonization of the precursor was carried out by elevating the temperature from room temperature to 700 °C under purified nitrogen (99.99%) atmosphere with the flow rate of 150 mL min^{-1}. The carbonized material was then activated under CO_2 gas at a flow rate of 150 mL min^{-1} using similar reactor as used for carbonization under different temperatures and held for varying periods of time. The product was cooled to room temperature then washed with distilled water until a neutral pH was attained, oven dried and finally stored in an airtight container for further use.

The modifications include impregnating PASH with CH_3COONa as chemical activating agent. The optimum preparation conditions applied were 795 °C activation temperature, 62 min activation time and 2.45. A flow chart describing the activated carbon preparation procedure and its application in the CPs adsorption is shown in Fig. 1.

An analysis on activation technologies comparing activation methods for different substrates using diverse activating

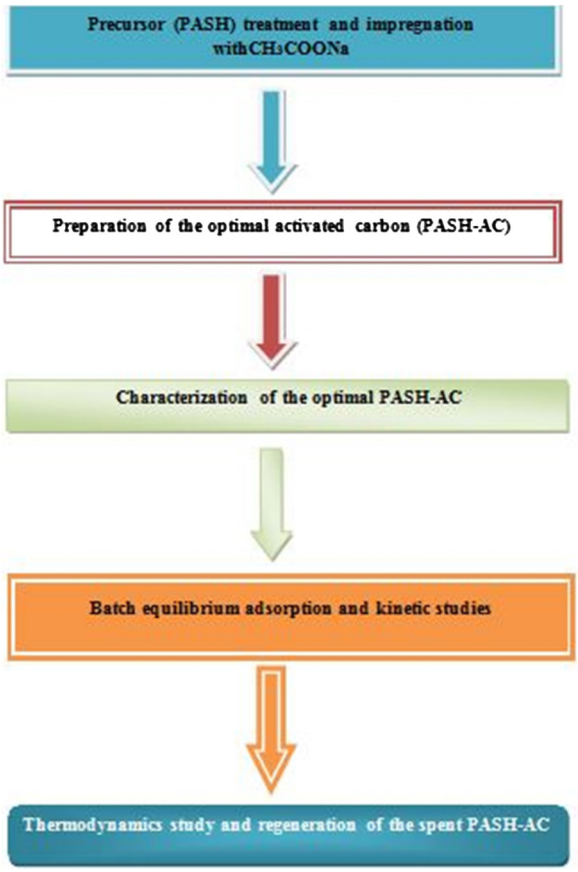
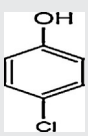
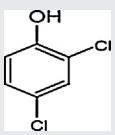


Fig. 1 – Flow chart diagram of the research activities.

Table 1 – Basic information concerning PCP and 2,4-DCP (Vidic et al., 1993).

Chlorophenols	Boiling point (°C)	pK_a	Aqueous solubility (g/L)	Molecular weight (g/mol)
	220	9.37	27	128.56
	210	7.90	4.5	163.00