

Preparation of high yield activated carbon for purification of water using Polyethyleneterephthalate (PET) as primal matter

Prajwal Erappa K, Suhas B G, Taran N

Kendriya Vidyalaya, GITB Press Campus, Siddhartha Nagar, Mysuru- 570011

abstract

A waste-treat-waste approach had been used to absorb the contaminants from aqueous solution. Polyethylene terephthalate (PET) is expanded polystyrene form. It is used in all over the world because of its affordability, The projects possess the preparation of Activated carbon (ACs) from PET as a primal matter to produce a novel type of ACs that is an extremely effective purification media. PET is the most common thermosoftening resin. It is 90% carbon, but the process of turning it into ACs is difficult. In this paper waste PET is used because it is one of the serious post consumer plastic waste that have created lots of serious environmental problems. The ACs is currently made from wood or coal which adds considerable cost for manufactures and we hypothesized that by using pet as input material we could save both money and environment. The ACs prepared in this paper was PET by activation method using Potassium Hydroxide.

The Brunauer-Emmett-Teller (BET) aims to explain the physical absorption of gas molecules on a solid surface serves as a basis of important analysis. This technique is used to measure specific surface area of the materials. BET surface area reach upto 1002 m² g⁻¹ with KOH at most. The degrees of macroporosity are large in KOH. By United States Environmental Protection agency, ACs if applied optimal way, it is one of the best technology available for lead removal via absorption. The lack of clean water is the major problem in third world countries and by converting to ACs by PET, solving two problems with just one solution which is by converting a environmental problem into a environmental solution.

Production of activated carbons from solid wastes is one of the most environment-friendly solutions by transforming negative-valued wastes to valuable chemicals. In this work, waste of Poly-ethyleneterephthalate (PET) bottles was chosen because it is one of the serious post-consumer plastic wastes that caused lots of environmental problems. The activated carbon studied in this paper was prepared from PET wastes by a two-step physical activation method under N₂ and CO₂ atmosphere, respectively. In this study, an improved method was investigated to prepare high surface activated carbon. The characteristics of a typical commercial activated carbon were also measured and compared. It was found that the activated carbon had a well-developed micro pore structure and BET surface area about 2010 m²/g prepared from PET wastes at 975° C and 240 min holding time of activation stage and 800° C and 60 min holding time in carbonization stage. This carbon has 62% burn-off and 2.23 nm average pore diameter with a total pore volume of 0.93 cm³/g using N₂ adsorption at 77K. In addition, activated carbon produced was evaluated for its ability to remove phenol aqueous solution in a batch process. The results revealed that prepared activated carbon is expected to be an economical product for phenol removal for wastewater treatment.

Keywords: High surface activated carbon, PET waste, Physical activation.

1. Introduction

Activated carbons are widely used as commercial adsorbent with an immense field of applications. They can be produced virtually from any organic precursor^{1–3}. Although activated carbon (AC) was still one of the most significant adsorbents from an industrial point of view, the development of appropriate methods to produce them and the understanding of their porous structure continues.

Activated carbon with high surface area has been widely used in a variety of industry applications, which include separation/purification of liquids and gases, recovery of solvents, removal of toxic substances and removal of organic pollutants from drinking water and as catalysts or catalyst support. As environmental pollution is becoming an increasingly serious problem, the need for high surface area activated carbon is growing. This high surface area largely depends on the type of precursor and production method. Understanding the

development of these properties is crucial in the design of adsorbents.

Activated carbons with high specific surface area can be prepared from a variety of carbonaceous materials such as coal, nutshell, wood, agricultural wastes or industrial wastes.³⁻⁷ There are two main methods for the preparation of activated carbon using physical or chemical activation. Physical activation is a two-step process which requires carbonization material followed by activation at the elevated temperature in the presence of oxidizing gases. In the chemical activation process the precursors are impregnated with dehydrating chemicals in a single step. However, chemical activation requires a complex recovery and recycles of the activating agent, which generates liquid discharge that demands furthermore effluent treatment. Physical activation process is widely adopted industrially for commercial production owing to the simplicity of the process and the ability to produce activated carbons with well developed micro porosity. The existing method of preparing activated carbon is given under table 1.

Textural properties of the activated carbons prepared from PET by physical activation methods. Values reported in the literature.

Activati ng	Carbonization temperature/ Treatment time/		Activation temperature/	<i>SBE</i> <i>T</i> /	<i>V_{mi}</i> /	<i>V_{me}</i> /	<i>V_T</i> /	Reference
agent	°C	°C	min	m ² g ^{−1}	cm ³ g ^{−1}	cm ³ g ^{−1}	cm ³ g ^{−1}	
CO ₂	800	975	240	790	-	-	0.666	Esfandiari et al. (2012)
Steam	700	900	90	1254	-	-	e	Laszlo et al. (1999)
H ₂	-	800	5-8	950	0.36	-	0.60	Sych et al. (2006)
SO ₄ /steam	750	900	-	1190	-	-	0.62	Laszlo et al. (2001)
Steam	750	900	90	1443	0.65	-	0.70	Podkoscielny and Laszlo (2007)
H ₂	-	825	5-8	1030	0.36	-	0.60	Kartel et al. (2006)
SO ₄ /steam	-	925	e	2468	0.90	0.236	1.087	Parra et al. (2004b)
CO ₂	800	975	240	2010	-	-	0.93	Ali et al. (2011)
Steam	750	900	90	1170	0.425	-	0.625	Laszlo and Szucs (2001)

Methodology

Physical Activation-

The activated treatment in steam was performed by using a horizontal series furnace. It was made up of two cylindrical furnace connected horizontally. The first one operating at 250°C for water vaporization and second one for activation. Using a pump, water flow was continuously propelled towards the vapourisation furnace and steam was carried out by a N₂ atmosphere until highest desired temperature. Once this was done the system was allowed to cool down to room temperature under inert N₂ atmosphere and so obtained products were weighed and stored in airtight container. The operational conditions for the preparation of the ACs by physical activation with steam are summarized in table 2.

Chemical Activation-

The preparation of ACs by the chemical activation method, KOH:PET ratio was 2:1, by weight i.e., For example 1 gram of PET to 2 grams of KOH and uniformly mixed. The sample was introduced to the series heating furnace. The thermal treatments were carried out in a horizontal cylindrical furnace (300 mm length and 75 mm diameter). The temperature was increased at a rate of 10°C under inert N₂ atmosphere until highest desired temperature. After cooling, the samples were subjected to washing with base of 0.1 mol/L aqueous NaOH solution, then with water with certain temperature (80°C) until the rinsed water showed neutral pH. The samples were dried at 120°C for 24 h and stored in air-tight containers. Again, the operational conditions are listed in Table 2.

Physical activation with steam				Chemical activation with KOH		
T/°C	Steam flow/mL min ⁻¹	t/h	Yield/%	T/°C	t/h	Yield/%
600	8.33	1	17.05	700	1	30.07
700			16.95	800		28.45
750			17.90	850		24.62
800			15.60	850	0.25	27.80
850			9.40		0.5	27.90
875			9.20		1	28.45
900			7.75		2	32.00

Results

The preparation of Activated carbon (ACs) from Polyethylene terephthalate (PET) as a primal matter with excellent yield was successful for a great extent. The ACs were carbonized, activated and was then saturated with certain chemicals and were employed in an acidic solution. The finest condition of preparation of activated carbons obtained was when activated by KOH with temperature of 850 C and with an activation time of 120 minutes (2-hours).

Let us notate activated carbon obtained by the activation method of 900C for one hour as VT 900, and activated carbon obtained with activation method from KOH by activating with 850C for 2 hours as HT850, and a determinant activated carbon obtained from store as D.

The elemental analysis was performed only for samples VT900 and HT850, i.e., those that exhibited the best textural properties. summarizes the elemental analysis data together with the ash content obtained for these samples. The elemental analysis data show that the carbon content is very high for both samples, which is a desirable property for ACs. The same happens to the ash content, which is very low in the two AC samples and very similar to the ash content obtained for the commercial activated carbon (sample D). The ash contents of these ACs make them suitable to be used in water and wastewater treatments as well as in medicine and pharmacy. As indicated above, the ash content of the PET precursor is extremely low, if any. Hence, the presence of a certain amount of ashes in samples VT900 and HT850 is justified on the basis of the occurrence of traces of inorganic matter in the PET precursor associated to remarkable mass losses (as suggested by the low yield values, see Table 2) as a consequence of the gasification of carbon atoms during the process of preparation of the samples.

Elemental and immediate analyses of some selected samples.

%	VT900	HT850	D
C	90.30	75.50	-
H	0.90	1.90	-
N	0.0	0.0	-
S	0.0	0.0	-
Ash	1.12	1.30	1.1

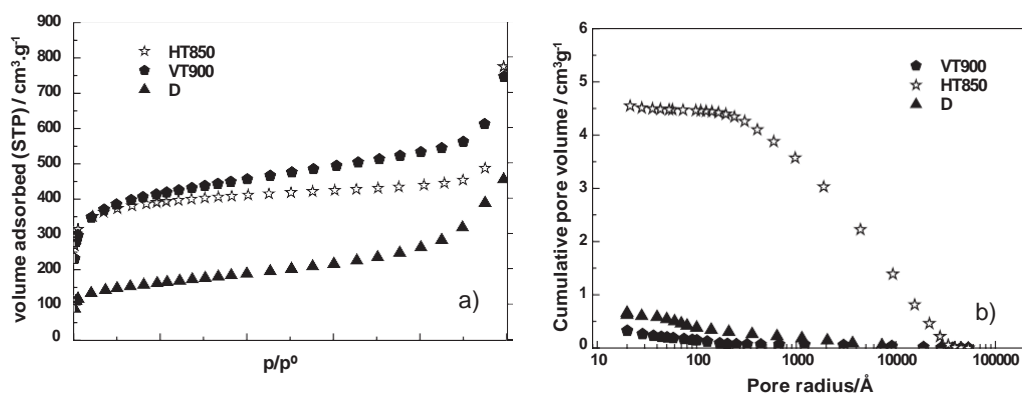
N₂ adsorption isotherms

For comparison purposes, Fig. 3a) includes the adsorption isotherms of the samples showing the best textural properties among all the samples prepared by physical activation with steam or chemical activation with KOH as well as for the commercial activated carbon (i.e., samples VT900, HT850 and D, respectively). The shape and relative position of the isotherms denote that both of the samples prepared from PET exhibit a better developed microporosity than sample D. Contrary to microporosity, the development of mesoporosity is larger for D than for VT900 and HT850. Regarding the porosity distribution in the region of micropores, it is quite similar for VT900 and HT850 and different for D. Thus, it becomes clear that microporosity is made up of wider pores for VT900 and HT850 than for D making it more efficient in absorption of contaminants than commercial available activated carbon.

Mercury porosimetry

Samples VT900, HT850 and D have also been analyzed by mercury porosimetry. Graphical representations of cumulative pore volume vs. pore radius obtained for the samples are shown in Fig. 3 b). It is worth noting that sample HT850 exhibits a remarkably larger development of macroporosity in comparison with samples VT900, D and consists of a wide range of pore sizes. However, samples VT900 and HT850 are less mesoporous carbons than sample D.

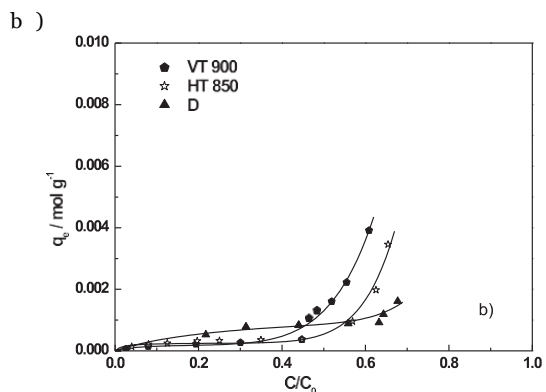
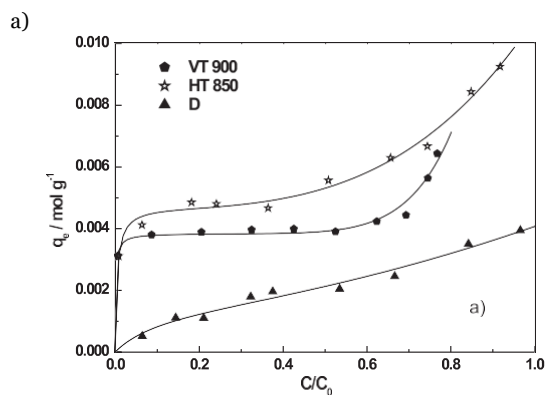
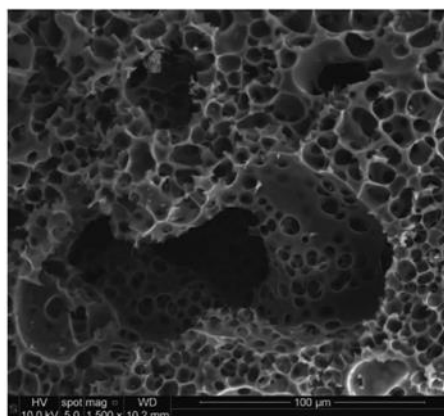
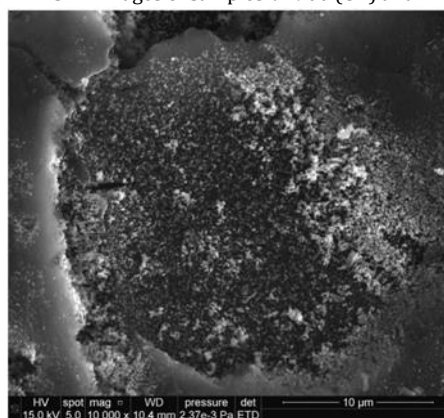
Fig. 3. N₂ adsorption isotherms at -196°C (a) and mercury intrusion curves (b) for samples VT900 and HT850



Absorption equilibrium isotherm.

The absorption equilibrium isotherms plots obtained for all of the systems studied in this paper are depicted. The experiment shows that in terms of absorption capacity, P-nitro phenol (PNP) in a mono-component solution by the three ACs. The adsorption isotherms of VT900 and HT850 exhibit very steep initial track. It is a very great indicative that it is highly efficient to remove Fe(3) ions from the polluted solutions.

SEM images of samples VT900 (UP) and HT850 (Down).



Adsorption isotherms of PNP and/or Fe(III) by the selected samples: a) PNP; b) Fe(III);

Textural properties of the activated carbons prepared from PET by physical and chemical activation methods. Values calculated from Hg intrusion curves and He density measurements.

Sample	V_{me-p} (cm ³ /g)	V_{ma-p} (cm ³ /g)	t_{Hg} (g/cm ³)	t_{He} (g/cm ³)	V_T (cm ³ /g)	V_T^{δ} (cm ³ /g)
VT900	0.27	0.07	0.56	1.98	1.28	1.08
HT850	0.24	4.33	0.17	1.76	5.31	5.16
D	0.42	0.24	0.69	2.09	0.97	0.98

Conclusions

The commercialization of this PET based ACs it must because it is the counter measure for the developing water crisis in India as well as the plastic pollution which have adverse effect over the environment The PET based ACs can be effectively used large scale projects as purifying the polluted river such as Gangas and Yamuna by collecting the plastic in there. The results confirm that PET based ACs is expected to be an economical adsorbent of contaminants from aqueous solutions. Yes we have ended up creating and developing a safe and innovative solution for a global environmental problem.

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