Removal of *Bisphenol-A* Endocrine Disruptor by Adsorption on Activated Carbon Derived from Waste Leathers

R. Anbu[1] and A. Udaya[2]

Department of Chemistry, Poompuhar College (Autonomous), Melaiyur (Affiliated to Bharathidasan University, Tiruchirappalli 620 024, T.N., India

ABSTRACT

The goal of this study is to determine the ability of activated carbon derived from waste leather from the leather industry to adsorbed bisphenol-A, an endocrine disruptor, from aqueous solution. The functionalized activated carbon was found to have the best adsorption capacity at acidic pH. The weak vander Waals force of attraction between the activated carbon's surface and bisphenol-A The kinetics of adsorption were found to fit well with a pseudo second-order reaction. Langmuir, freundlich, DKR, and the Elovich models were used to correlate equilibrium isothermal data. Adsorption was observed, and there were no remarkable changes after three hours. The effect of particle size revealed that the smallest one adsorbs more due to the availability of a large number of surface areas. The minimum initial concentration of the adsorbate favoured high adsorption. The process was endothermic, feasible, and spontaneous. Nearly 90% of adsorptions in an acidic medium were found. Overall, it was found that the activated carbon derived from waste leather could be a new sustainable chemical technology for water purification.

Introduction

Endocrine disrupting chemical substances (EDCs) are natural or synthetic compounds that have the ability to cause changes in endocrine aspects of the body and to interact with an infinite number of nuclear receptors and hormone receptors associated with endocrine and steroid hormones (USEPA; Washington, DC, USA: 2000). One of the most identified rising EDCs is bisphenol A, a critical herbal chemical used as a monomer in the manufacturing of polycarbonate plastics, epoxy resins, and flame retardants (Zeng *et al.*, 2006*)*, The worldwide manufacturing of bisphenol A is about eight million tonnes per year. This massive amount of bisphenol A manufacturing and processing is to blame for the excessive presence of this substance in the environment. Wastewater treatment plants, for example, inadvertently release bisphenol A into effluents when you reflect on the fact that they are no longer in the establishment designed to deal with such chronic and xenobiotic resources Huang Y.Q *et al.*, (2012), found that the awareness of bisphenol A is greater in industrial and business areas than in different regions, affecting the first-class of rivers and lakes shut to these areas. Moreover, the latest research by way of Yamamoto *et al.* (2001) has proven that bisphenol A can attain values of up to 17.2 mg/L in landfill leachates, in all likelihood due to the presence of plastic debris. High bisphenol A concen-

S478

Eco. Env. & Cons. 28 (October Suppl. Issue) : 2022

trations have also been found in sewage treatment plant influents and effluents of waste paper recycling vegetation (up to 370 g/l), river water in Germany (up to 0.8 g/l) (Heemken *et al* 2001), waste water in Ontario (up to 149 g/l) (Peart *et al.*, 2002), and bottled water in France (0.07–4.21 g Drinking water treatment technologies are frequently unable to remove the entire amount of bisphenol A present in supply waters (Kleywegt *et al.*, 2011), As a result, there is a high risk of long-term exposure of humans to this compound. In this direction, several studies have been carried out to look at the correlation between bisphenol A publicity and health results. These studies show that this compound can increase the risk of cancer in specific ovarian, breast, and prostate cancers (Rochester J.R., 2013 *et al.*,), as well as a variety of metabolic issues such as obesity, endometrial hyperplasia, recurrent miscarriages, and polycystic ovary syndrome (Di Donato *et al.*, 2017). Other extraordinary issues related to bisphenol A publicity are cardiovascular disease, altered immune machine activity, diabetes in adults, infertility and precocious puberty (Rees-Clayton *et al.*, 2011), Several technologies, such as coagulation, floculation, sedimentation, filtration (Joseph *et al.*, 2012), carbon nanomaterials (CNMs) (e.g., carbon nanotubes (CNTs) (Joseph *et al.*, 2011), and graphene oxides (GOs) For bisphenol A removal, membrane filtration, ultraviolet (UV) irradiation (Duan *et al.*, 2017), organic methods (Wang G *et al.,* 2006), and superior oxidation strategies (Rivas *et al.,* 2008), (Rivero, *et al.,* 2014), have been studied for bisphenol A removal. Therefore, effective, extra-sustainable techniques are sought to dispose of such contaminants from water and wastewater (Ioannou-Ttofa *et al.*, 2016). Physical adsorption is normally regarded as a wonderful technique for the elimination of these kinds of natural molecules in aqueous media, provided that the adsorbents have giant handy inside and/or exterior surfaces. In this regard Nakanishi *et al.*, (2002), studied the adsorption traits of bisphenol A on herbal adsorbents produced from a variety of wooden chips. (Asada T *et al.*, 2004*)*, confused that the porous carbon produced by way of bamboo ought to be a fascinating adsorbent for the elimination of bisphenol A from aqueous solution. Yoon *et al.*, (2003), discovered that the effective adsorption of six types of activated charcoal powder (PAC) to bisphenol A ranges from 31% to >99% with activated carbon dosages of 5 and 15 mg/l. Also, Lazim

et al., (2015), discovered that coir pith eliminated 72% of bisphenol A, achieving the maximum adsorption capability of 4.308 mg/g, observed through durian peel (70%, 4.178 mg/g) and coconut shell (69%, 4.159 mg/g).

Materials and Methods

Preparation of endocrine disruptors

Bisphenol-A had been chosen as the endocrine disruptor for the adsorption research in the previous work. with a concentration of 1000 mgL^{-1} were prepared by dissolving the required quantity of substances. The test solutions are prepared by suitable dilution of this solution. The pH of the solutions had been adjusted by the addition of a 0.1 M solution of HCl or NaOH.

Preparation of the adsorbent

Activated carbon of waste leathers (ACWL) accumulated from the leather-based industries, Pallaavaram area in Chennai, India, have been washed, dried, powdered and sieved to 0-63 µ particle size. This powder is dried at 105 °C for 12 hrs in an oven and they are saved in apolymer bottle. This powdered adsorbent used to be introduced with HCl of 0.1 M solution for 24 hrs and then filtered and washed with double distilled water. Once more it is dried in a oven at 105 °C for 12 hrs and saved in polymer bag.

Determination of Carbon Characteristics

The activated carbon samples have been characterised by the use of an FT-IR Shimadzu spectrophotometer. XRD and SEM have been used to study the surface morphology of the adsorbents.

Proximate Analysis of Carbon

Activated carbon samples have been prepared from the waste leather collected by the leather industry. About 500 gm of samples have been amassed in an airtight aluminium container. Samples for proximate analysis have been pulverised to a mesh dimension of 100 and dried for 12 hours in a desiccator. For proximate evaluation of the dedication of moisture content, unstable matter, ash content material, and constant carbon laid down. (The Indian Standard IS: 1350 (Part-I)-1984 (Nnaji, *et al.*, 2017) was used).

Ultimate Analysis

The ultimate evaluation of activated carbon is used for the determination of carbon, hydrogen, sulphur, nitrogen, and ash as observed in gaseous products for the entire combustion. The trendy technique is defined in (IS: 1350, phase II-2000). (Nnaji *et al.*, 2017). The quantity of warmth generated at some point during the combustion of a unit of weight of an activated carbon pattern is described as its calorific value. Activated carbon calorific values and their traits have been decided in accordance with IS: 1350–1974 and 1975 in a bomb calorimeter.

Adsorption Experiments

The adsorption experiments were conducted at 30 °C, with the pH of the solutions adjusted with 0.1M HCl and 0.1M NaOH. A known amount of adsorbent was added to the pattern and allowed sufficient time for adsorption equilibrium. The batch experiments have been carried out in Erlenmeyer glass flasks of 100 ml capacity. To assist mixing of the options with the adsorbents, the combination had to be shaken in a mechanical shaker (Remi make) at an appropriate (100-300) rpm for three hours. Then the mixture was filtered and the remaining endocrine disruptor concentration was determined in the filtrate using Spectro UV-Vis Double Beam UVD-3500, a Labomed. Inco photometer at a suitable max. The effect of various parameters on the rate of the adsorption process was observed by varying the mesh dimension of the adsorbent, contact time (t), initial concentration of endocrine disruptors (Co), adsorbent dose, initial pH of solution, and temperature. The solution volume (V) was kept constant at 50ml. The endocrine disruptor adsorption (%) at any instant of time was determined by the following equation:

Adsorption of endocrine disruptors (%) = (Co–Ce) 100/Co

Where

Co is the initial concentration and

Ce is the concentration of the endocrine disruptors at equilibrium.

To increase the accuracy of the data, each experiment was repeated three times, and average values were used to draw the graphs.

Adsorption isotherms

Adsorption research has been conducted at distinct initial concentrations, ranging from 10 mg/L1 to 60 mg/L1, at the most efficient pH, for a contact time of 180 min. at room temperature. From the information obtained, the mechanism of adsorption used to be studied by the utility of four isotherm equations, particularly those of Langmuir (eq: 1), Freundlich (eq: 2), Redlich-peterson (eq: 3) and Dubinin-Kaganer-Radushkevich (DKR) (eq: 4), and corresponding parameters have been calculated from their respective graphs.

$$Ce/X = 1/K*KL + Ce/ K \qquad .... (1)$$
$$KL = b* q0$$
$$\log qe = \log KF + 1/n \log Ce / \quad .... 2)$$
$$qe = KR Ce / (1+bRCe\beta) \qquad .... (3)$$
$$\log qe = \log Xm – \beta\varepsilon2/2.303 \qquad .... (4)$$

Adsorption kinetics

The amount of adsorption of endocrine disruptors used to be decided at more than a few time intervals, particularly 10, 20, 30, 40, 50, and 60 min. The information had been fed into 4 specific kinetic models, and the equilibrium adsorption capacities and different beneficial parameters had been calculated. They are Lagergren's pseudo-first order kinetics (eq:5), pseudo-second order kinetics (eq:6), Elovich kinetics (eq:7), and the intra-particle diffusion model (eq:8).

$$\log (qe-qt) = loqe – k1t/2.303 \qquad .... (5)$$
$$t/qt = 1/k2.qe2 + t/qe \qquad .... (6)$$
$$qt = 1/\beta \ln \alpha\beta + 1/® \ln t — ....(7)$$
$$qt = kp . t1/2 —(8) \qquad ....(8)$$

The adsorption thermodynamics

Four vital thermodynamic parameters have been deduced for the adsorption process, specifically the alternate Gibbs free energy (Go, eq:9), enthalpy changes (Ho, eq:9), and change in entropy (So, eq:10). as well as the activation energy (Ea, eq: 11).

$$\Delta G^o = - RT \ln Kc = –H^o - T''S^o — \qquad ..9)$$
$$\ln Kc = - \Delta H^o/ RT + ''S^o/ R \qquad .. 10)$$
$$\log K = \log A – (Ea / 2.303RT) \qquad .. (11)$$

Results and Discussion

Proximate Analysis

The effects of proximate evaluation for moisture, volatile matter, fixed carbon, and ash are given in Table 1.

S480

Eco. Env. & Cons. 28 (October Suppl. Issue) : 2022

Table 1. Proximate Analysis of Activated Carbon

	Moisture %	Ash%	Carbon%	Volatile matter%
ACWL	1.3	3.2	91.2	4.3

Fixed Carbon

The fixed carbon content material of activated carbon, aside from moisture and ash, is 91.2%. The constant carbon values rely generally on the C and O values in the activated carbon. It is well understood that the FC content material will increase as the activated carbon rank improves (Maharani *et al.,* 2010), Liu *et al.,* 2008).

Ultimate Analysis

The consequences of the analysed parameters Carbon, hydrogen, nitrogen, sulphur, and oxygen are tabulated. The consequences of every factor are mentioned in detail.

Carbon dioxide (CO_2)

The carbon content of the collected activated carbon samples from the learning area is 86.54 wt. %.The excessive concentrations of C are usually attributed to vitrinite macerals (Huang, Y *et al*., 2014). It is additionally well recognised that the C content material in activated carbon will increase step by step with the growing activated carbon rank in Table 3 (Mohammadi *et al*., 2010).

Oxygen

The oxygen content in the samples was 8.5% by weight. The lower O content is a characteristic of high-quality activated carbons (Liu, *et al*., 2008), (Nomanbhay *et al*., 2005).

Effect of particle size

The relationship of adsorption capability to particle dimension is based upon two criteria: (i) the chemical shape of the endocrine disruptor and its chemistry; and (ii) the intrinsic attribute of the adsorbent (its crystallinity, porosity, and tension of the polymeric chains). The increase in adsorption capability with lower particle measurement suggests that the bisphenol A preferentially adsorbed on the outer surface and did no longer wholly penetrate the particle due to the steric hassle of the massive endocrine disruptor (Nnaji *et al*., 2017). The impact of the adsorbent's size of particle measurement used to be studied in the range of 0-200 microns particle dimension (0-63, 63-125, 125-200) for checking the most adsorption of Bisphenol A, and the smallest particle dimension (0-63) was proven to be fantastic for adsorption (92.76), as particles with the smallest dimension give the largest surface numbers and the outcomes are proven in. Fig. 1a.

Effect of adsorbent dosage

The adsorbent dosage is an essential parameter that influences the extent of endocrine disruptor uptake from the adsorbate and hence the impact, as proven in Fig. 1b. It was evident that the quantity of endocrine disruptor uptake would increase from 67.55% with 50 mg of adsorbent up to 90.45% with 200mg of adsorbent. Prior to that, it is obvious that the percentage elimination of Bisphenol A will increase as the adsorbent dosage increases from 50 mg to 200 mg due to the restricted availability of the wide variety of adsorbing species for a fantastically large quantity of surface sites on the adsorbent at greater dosages of adsorbent. (Liu *et al*., 2008),

Effect of pH

The uptake of Bisphenol A will increase from 31.66% to 91.00% when the pH increases from pH 1 to pH 5. After that, the ability of adsorption decreases barely in pH varies from 6 to 9. The minimal adsorption determined at low pH (pH 1) may also be due to the fact that the greater attention and greater mobility of H^+ ions existing favoured the preferential adsorption of hydrogen ions in contrast to the endocrine disruptor bisphenol A. (Huang, *et al.*, 2014). This potential means that at greater H^+ concentration, the biosorbent surface turns into a more positively charged surface, such that the enchantment between biomass and endocrine disruptor cations is reduced. In contrast, as the pH increases, more negatively charged floors will become accessible, consequently facilitating increased Bisphenol A removal. It is typically agreed that the sorption of endocrine disruptors will increase with increasing pH (Fig.1c) as the endocrine disruptor species end up much less secure in the solution. However, at greater pH values (pH 7, pH:8, and pH:9), there is a deep minimise in the adsorption capacity. This is due to the incidence of bisphenol A precipitation.

Effect of contact time

The impact of contact time on the adsorption of

Bisphenol A on activated carbon of waste leathers (ACWL) is proven in figure 1d. Adsorption increases as contact time adsorption increases and is highest (94.6%) at 3 h. Figure 1d displays that the curve is clean and continuous, Bisphenol A to saturation, suggesting feasible monolayer coverage of the endocrine disruptor on activated carbon of waste leather (ACWL). 68.6% adsorption has taken place in 30 minutes of contact time with the adsorbent, which shows the effectivity of activated carbon from waste leathers (ACWL) as an adsorbent. More time is required for the attainment of equilibrium. In this study, all the batch experiments were carried out for a time interval of 180 minutes (Nomanbhay *et al.*, 2005).

Effect of initial concentration

Adsorption ability decreases from 92.33% to 80.05% as the endocrine disruptor concentration increases from 10 to 60 mg l^{-1}. The electrostatic interplay between the endocrine disruptor bisphenol A and the absorbent energetic sites is limited to higher concentrations. Moreover, this can be defined by the reality that fewer adsorption sites have been included as the endocrine disruptor attention decreases. Besides, decrease the initial concentrations of bisphenol A to increase the affinity of the endocrine disruptor bisphenol A toward the lively sites. (Begum *et al.*, 2013). Adsorption occurs most when the initial concentration of the endocrine disruptor bisphenol A is 10 mg/l. As the concentration increases, all the adsorption sites are crammed up and there are still unabsorbed endocrine disruptor molecules. As a

Fig.1a

Fig1b

Fig 1c

Fig 1d

result, the reduction in adsorption is proven Figure 1e. This end result is in favour of solely monolayer coverage and suggests the Langmuir isotherm model. Since 92.33% adsorption happens when the initial concentration used to be 10 mgl^{-1}, the activated carbon of waste leathers (ACWL) seems to be a very high-quality adsorbent in eliminating even traces of bisphenol A.

Adsorption isotherms

Isotherm parameters, evaluated from the linear plots of equations (1-4), are illustrated in Table 2 (Fig.2a, b, c, d). The K_L (sorption equilibrium constant) for the Langmuir isotherm, i.e., 3.361 mg/g, indicated the excessive adsorption potential of the adsorbent towards Bisphenol A adsorption. This is in turn supported with the aid of the values of the dimensionless separation component (R_L), which is much less than one. The R^2 (correlation coefficient) value of 0.915 indicated that the Langmuir isotherm is suitable for explaining the bisphenol A adsorption. (Desta, *et al.*, 2013), The R^2 cost calculated for the Freundlich isotherm used to be observed to be 0.997, indicating that the experimental information can be defined by the Freundlich isotherm. The K_F (ultimate adsorption capacity) price, as calculated from the Freundlich isotherm, was 3.4914. The values of the Freundlich constant, n, are plenty larger than one, implying that the adsorption system is ruled with the aid of physisorption alone. The R^2 value calculated for the Redlich-Peterson isotherm was discovered to be 0.99, indicating that the experimental records can be defined through the Redlich-Peterson isotherm. The unit cost as calculated from this isotherm was 0.2 (Weber *et al.*, 1974).

The Dubinin–Kaganer–Radushkevich (DKR) equation was once adopted to describe the single-solute adsorption isotherms. The R^2 value calculated for the DKR isotherm was once determined to be 0.959, indicating that the experimental records can be defined by the DKR isotherm poorly. The value, as calculated from this isotherm, was 1.663. The values of the desorption constant,, in the Redlich-Peterson and the Dubinin-Kaganer-Radushkevich isotherms are a measure of the desorption constant. Its values are much less than one, indicating beneficial adsorption. (Imamoglu *et al.*, 2008) The sorption coefficient in the DKR isotherm is a treasured parameter to distinguish between physisorption and chemisorption. Lower values endorse physisorption more.
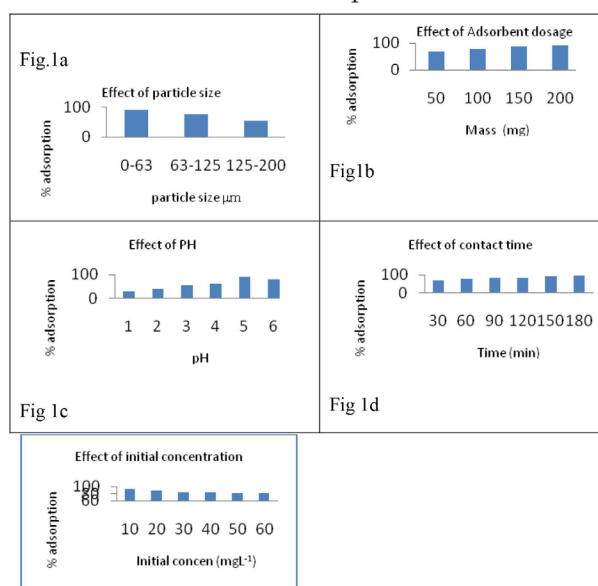
S482

Eco. Env. & Cons. 28 (October Suppl. Issue) : 2022

Table 2 and Figure 2(a,b,c,d)
Isotherm parameters for the adsorption of Bisphenol A using *ACWL* at 30°C,
pH: 5.0, Adsorbent dosage: 150mg, Initial concentration: 10 mgL^{-1}

Langmuir parameters	K_L = 3.361	q0 = 24.096	b_L = 0.1394	R^2 =0.915
Freundlich parameter	K_F =3.4914	n =1.8416	-	R^2 = 0.997
DKR parameters	â = 1.663	b =0.894	q0 =7.839	R^2 = 0.959
Redlich Peterson parameters	â= 0.200	K_R =1.255	b_R =5	R^2 = 0.99

2a

2b

2c

2d
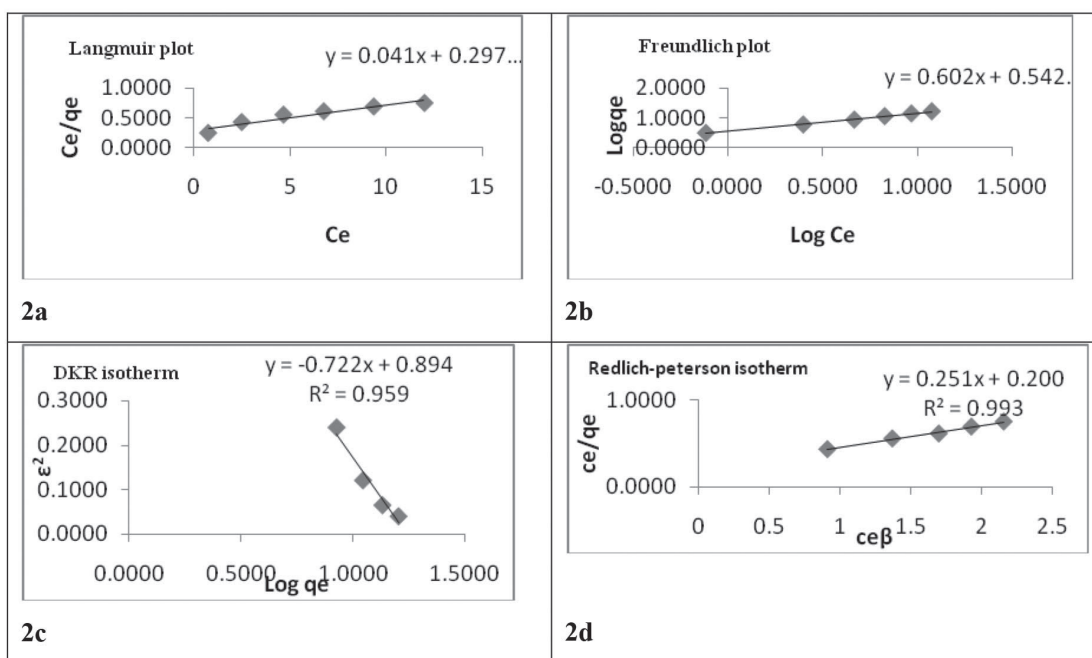
Kinetics study

The R^2 values for the pseudo second order kinetics indicate excessive precision, suggesting that II order kinetics is a first-class fit (Lee *et al.*, 2002), Table 3 and Figures (3a, b, c, d).

The effect of temperature

The percentage of Bisphenol A adsorption was used to be studied as a feature of temperature in the range of 30-60 °C. It used to be found that adsorption yield increased with an increase in temperature. For a 50-ppm preliminary concentration of endocrine disruptor solution, the minimal adsorption was 84.23 percent at 30°C and the most adsorption was 90.91% at 60 °C. The impact of temperature on the proportional adsorption of Bisphenol A on activated carbon of waste leathers (ACWL) is proven in Fig.4. This is solely natural due to the fact that an increase in temperature offers the vital strength for the endothermic method of adsorption, Bisphenol A,

to an increase in the speed of the process. The factor to be favoured is that even at room temperature, adequate (more than 81.31%) adsorption has taken place. This, in turn, confirms the adsorbent's efficacy in the removal of the toxic endocrine disruptor bisphenol (Chowdhury *et al.*, 2012).

Thermodynamic parameters

The thermodynamic parameters for the adsorption of the endocrine disruptor bisphenol A on activated carbon of waste leathers (ACWL) are given in Tables.4(a, b). For the adsorption of Bisphenol A on activated carbon of waste leathers (ACWL), the free
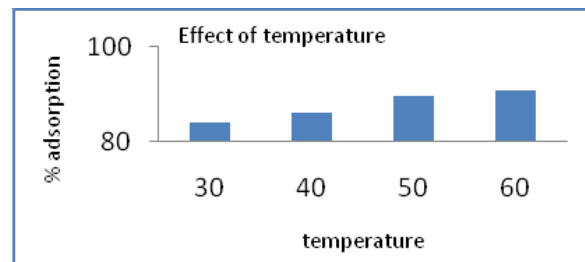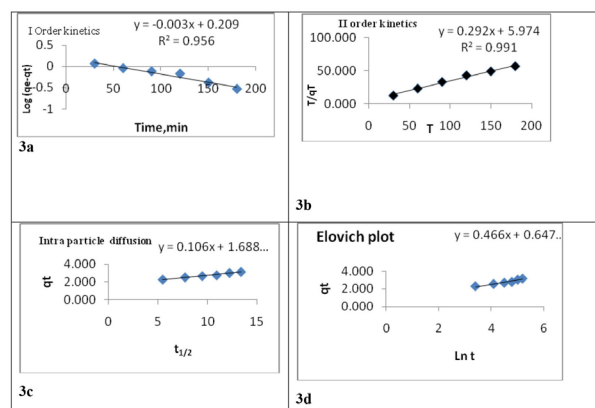
Table 3 and Figure (3a,b,c,d)
Kinetic parameters for the adsorption of Bisphenol A
ACWL at 30 ℃, pH: 5.0, Adsorbent dosage: 150mg,
Initial concentration: 10 mgl⁻¹

I order	0.956
II order	0.991
Int part diff	0.978
Eolvich model	0.944

3a

3b

3c

3d

energy values are all terrible, confirming that the procedure is spontaneous even at room temperature (Guo *et al.*, 2019). The entropy value is wonderful and explains the increase in randomness of the process. The endothermic nature of the adsorption system is evident from the positive values of enthalpy change. Presumably, the randomness factor (TSo) overcomes the energy factor (Hᵒ) and makes the normal procedure spontaneously go negative. Activation energies for the adsorption of Bisphenol A on an adsorbent were once calculated using the Arrhenius equation (eq11), plotted in Fig. 5 (a, b) and tabulated in Table.4 (a, b). The activation strength received in this case points out that bodily forces are involved in the sorption mechanism and sorption feasibility.

FT-IR Study

The FT-IR spectra of activated carbon samples be-

fore and after adsorption are shown in Fig. 6(a, b).The spectra provide evidence for the presence of adsorbates on the adsorbent's surface. The most notable variations amongst them are the top intensities. The carbon has marked variations in the intensities of almost all the absorption bands, reflecting that the density of corresponding purposeful companies fluctuates a lot. After adsorption, some peaks vanish due to desorption in the adsorbate and a few peaks are barely shifted to greater or decreased wave numbers due to electrostatic forces. There are no new peaks after adsorption testing, and the absence of the formation of new compounds is tested. As can be inferred from the figures, the adsorption frequencies are nearly equal, and it is presumed that the purposeful corporations have been no longer affected due to adsorption, which solely endorses that physisorption has taken place. As can be inferred from the figures, the adsorption frequencies are nearly identical, and it is presumed that the practical companies have not been affected due to adsorption, which solely endorses that physisorption has taken place (Momilovi *et al.*, 2011).

SEM analysis

Scanning Electron Microscopy (SEM) was used to examine the surface morphology of activated carbon from waste leathers (ACWL) before and after adsorption, and the corresponding SEM micrographs


Fig 6a   Fig 6b
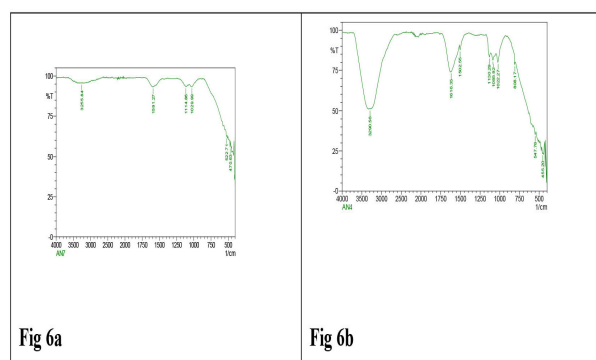
Tables 4(a,b). Figure 5(a,b)
Thermodynamic parameters for the adsorption of Bisphenol A on *(ACWL)*,pH: 5.0, Adsorbent dosage: 150 mg,
Initial concentration: 10 mgl⁻¹

"G⁰	"H⁰	"S⁰	Log₁₀ Ka	1/T
-1453.83	19.14714	57.44143	0.250514	0.003299
-'1929.15	-	-	0.321.802	0.003193
-2889.5	-	-	0.467081	0.003095
-3335.08	-	-	0.522927	0.003002

S484

Eco. Env. & Cons. 28 (October Suppl. Issue) : 2022

were acquired at an accelerating voltage of 20 kV at 10000 magnification and are shown in Figures 7(a, b).At such magnification, the activated carbon of waste leather (ACWL) particles confirmed the hard surface area inside which micropores had been definitely identifiable (Ayyappan, *et al*., 2005).
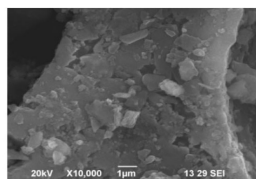

(7a)
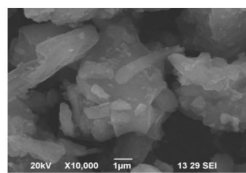
(7b)

XRD Pattern

The X-ray Diffraction Studies of the adsorbent, activated carbon of waste leathers (ACWL), before and after adsorption of the endocrine disruptor bisphenol A have been carried out using an X-ray Diffractometer 40KV/30mA, Model D/Max UL-TIMA III. Figures 8(a, b) depict the diffraction patterns. It is evident from the figures that there is no considerable difference in the spectra of the adsorbent before and after adsorption. This may also be due to the reality that adsorption does not alter the chemical nature of the surface area of the adsorbent. Adsorption is ruled by means of susceptible Van der Waals forces and is weakly in nature.

Conclusion

This work reviews the first utility of surface-functionalized activated carbon of waste leathers (ACWL) to eliminate bisphenol A, an endocrine disrupting chemical and precedence pollutant, from water. It was once discovered that pH extensively influences adsorption potential, with the best possible adsorption charges being discovered at pH 5. The functionalized cellulose fibre exhibited very excellent adsorption properties for bisphenol A, with 70% of the pollutant being adsorbed after 5 min of contact time. It was once found that the adsorbent machine can be effortlessly regenerated by using an easy and quick washing procedure, which lets it improve its adsorption capability by nearly one hundred percent. These findings highlight the technology's manageability for realistic software due to the abundant availability of activated carbon from waste leathers (ACWL) and the easily scalable procedure for activated carbon functionalization.
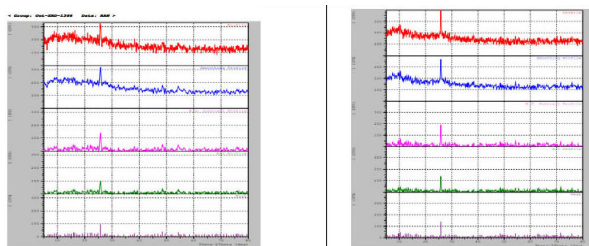
(7a)

(7b)

Other blessings of the ACWL are: (1) it's very effortless extraction manner, which offers a carbon with an excessive share of activated carbon (> 90%) and an extraordinarily low moisture content; and (2) its large adsorption properties.

Acknowledgement

References

Asada, T., Oikawa, K., Kawata, K., Ishihara, S. and Iyobe, T. 2004. Study of removal effect of bisphenol-A and B-estradiol by porous carbon. *J. Health Sci.* 50: 588–593. doi: 10.1248/jhs.50.588. [CrossRef] [Google Scholar]at: Google Scholar.

Ayyappan . R., Sophia. A. C., Swaminathan . K. and Sandhya . S. 2005. Removal of Pb(II) from aqueous solution using carbon derived from agricultural wastes. *Process Biochemistry*. 40 (3-4) : 1293–1299. View at: Publisher Site | Google Scholar.

Begum, K. and Alhaji, N. 2013. Adsorption efficiency of sawdust in activated and surface-modified forms - A comparative study. *Chemical Science Transactions*. 2(4): 1364-1369. DOI:10.7598/cst2013.689

Chowdhury, Z. Z., Zain, S. M., Khan, R. A., Rafique, R. F. and Khalid, K. 2012. Batch and fixed bed adsorption studies of lead (II) cations from aqueous solutions onto granular activated carbon derived from mangostana garcinia shell. *Bioresources*. 7(3) : 2895–2915, 2012.View at: Google Scholar

Colin, A., Bach, C., Rosin, C., Munoz, J.F. and Dauchy, X. 2014. Is drinking water a major route of human exposure to alkylphenol and bisphenol contaminants in France? *Arch. Environ. Contam. Toxicol.* 66: 86–99. doi: 10.1007/s00244-013-9942-0. [PubMed] [CrossRef] [Google Scholar]

de Oliveira, L.K., Moura, A.L.A., Barbosa, V., Parreira, R.L.T., Banegas, R.S., Caramori, G.F., Ciuffi, K.J. and Molina, E.F. 2017. Removal of the emerging con-

taminant bisphenol A by an ureasil-PEO hybrid membrane: Experimental study and molecular dynamic simulation. *Environ. Sci. Pollut. Res.* 24: 18421–18433. doi: 10.1007/s11356-017-9434-2. [PubMed] [CrossRef] [Google Scholar]

Desta, M. B. 2013. Batch sorption experiment: Langmuir and Freundlich isotherm studies for the adsorption of textile metal ions into teff straw (Eragostis tef) agricultural waste, *Journal of Thermodynamics* 375830. DOI: 10.1155/2013/37580

Di Donato, M., Cernera, G., Giovannelli, P., Galasso, G., Bilancio, A., Migliaccio, A. and Castoria, G. 2017. Recent advances on bisphenol-A and endocrine disruptor effects on human prostate cancer. *Mol. Cell. Endocrinol.* 457: 35–42. doi: 10.1016/j.mce.2017.02.045. [PubMed] [CrossRef] [Google Scholar]

Duan X.D., He X.X., Wang D., Mezyk S.P., Otto S.C., Marfil Vega R., Mills M.A., Dionysiou D.D. Decomposition of iodinated pharmaceuticals by UV254 nm-assisted advanced oxidation processes. J. Hazard. Mater. 2017;323:489–499. doi: 10.1016/j.jhazmat.2016.04.022. [PubMed] [CrossRef] [Google Scholar]

Guo, J., Song, Y., Ji, X., Ji, L., Cai, L., Wang, Y., Zhang, H. and Song, W. 2019. Preparation and Characterization of Nanoporous Activated Carbon Derived from Prawn Shell and Its Application for Removal of Heavy Metal Ions. *Materials.* 12: 24.

Heemken, O.P., Reincke, H., Stachel, B. and Theobald, N. 2001. The occurrence of xenoestrogens in the Elbe river and the North Sea. *Chemosphere.* 45:245–259. doi: 10.1016/S0045-6535(00)00570-1. [PubMed] [CrossRef] [Google Scholar]

Huang, Y.Q., Wong, C.K.C., Zheng, J.S., Bouwman, H., Barra, R., Wahlström, B., Neretin, L. and Wong, M.H. 2012. Bisphenol A (BPA) in China: A review of sources, environmental levels, and potential human health impacts. *Environ. Int.* 42: 91–99. doi: 10.1016/j.envint.2011.04.010. [PubMed] [CrossRef] [Google Scholar]

Huang, Y., Li, S., Chen, J., Zhang, X. and Chen, Y. 2014. Adsorption of Pb (II) on mesoporous activated carbons fabricated from water hyacinth using H3PO4 activation: Adsorption capacity, kinetic and isotherm studies. *Appl. Surf. Sci.* 293: 160–168.

Imamoglu, M. and Tekir, O. 2008. Removal of copper (II) and lead (II) ions from aqueous solutions by adsorption on activated carbon from a new precursor hazelnut husks. *Desalination.* 228: 108–113. [CrossRef]

Ioannou-Ttofa, L., Foteinis, S., Chatzisymeon, E. and Fatta-Kassinos, D. 2016. The environmental footprint of a membrane bioreactor treatment process through Life Cycle Analysis. *Sci. Total Environ.* 568: 306–318. doi: 10.1016/j.scitotenv.2016.06.032. [PubMed] [CrossRef] [Google Scholar]

Joseph, L., Flora, J.R.V., Park, Y.G., Badawy, M., Saleh, H. and Yoon, Y. 2012. Removal of natural organic matter from potential drinking water sources by combined coagulation and adsorption using carbon nanomaterials. *Sep. Purif. Technol.* 95: 64–72. doi: 10.1016/j.seppur.2012.04.033. [CrossRef] [Google Scholar]

Joseph, L., Zaib, Q., Khan, I.A., Berge, N.D., Park, Y.G., Saleh, N.B. and Yoon, Y. 2011. Removal of bisphenol A and 17á-ethinyl estradiol from landfill leachate using single-walled carbon nanotubes. *Water Res.* 45: 4056–4068. doi: 10.1016/j.watres.2011.05.015. [PubMed] [CrossRef] [Google Scholar]

Kleywegt, S., Pileggi, V., Yang, P., Hao, C., Zhao, X., Rocks, C., Thach, S. and Cheung P. 2011. Whitehead B. Pharmaceuticals, hormones and bisphenol A in untreated source and finished drinking water in Ontario, Canada, occurrence and treatment efficiency. *Sci. Total Environ.* 409:1481–1488. doi: 10.1016/j.scitotenv.2011.01.010. [PubMed] [CrossRef] [Google Scholar]

Lazim, Z.M., Hadibarata, T., Puteh, M.H. and Yusop, Z. 2015. Adsorption characteristics of bisphenol A onto low-cost modified phyto-waste material in aqueous solution. *Water Air Soil Pollut.* 226: 34–45. doi: 10.1007/s11270-015-2318-5. [CrossRef] [Google Scholar]

Lee H.B., Peart T.E., Gris G. and Chan J. 2002. Endocrine-disrupting chemicals in industrial wastewater samples in Toronto, Ontario. *Water Qual. Res. J. Can.* 37: 459–472. doi: 10.2166/wqrj.2002.030. [CrossRef] [Google Scholar]

Liu, X., Hu, Q., Fang, Z., Zhang, X. and Zhang, B. 2008. Magnetic chitosan nanocomposites: A useful recyclable tool for heavy metal ion removal. *Langmuir.* 25: 3–8.

Mohammadi, S.Z., Karimi, M.A., Afzali, D. and Mansouri, F. 2010. Removal of Pb (II) from aqueous solutions using activated carbon from Sea-buckthorn stones by chemical activation. *Desalination.* 262: 86–93.

Momèiloviæ . M., Purenoviæ. M., Bojiæ. A., Zarubica. A. and Randelovid, M. 2011. Removal of lead(II) ions from aqueous solutions by adsorption onto pine cone activated carbon. *Desalination.* 276 (1–3):. 53–59.View at: Publisher Site | Google Scholar.

Momèiloviæ . M., Purenoviæ. M., Bojiæ. A., Zarubica, A. and Randelovid, M. 2011. Removal of lead(II) ions from aqueous solutions by adsorption onto pine cone activated carbon. *Desalination.* 276 (1–3): 53–

Nakanishi A., Tamai M., Kawasaki N., Nakamura T. and Tanada S. 2002. Adsorption characteristics of bisphenol A onto carbonaceous materials produced from wood chips as organic waste. *J. Colloid Interface Sci.* 252: 393–396. doi: 10.1006/jcis.2002.8387. [PubMed] [CrossRef] [Google Scholar]

Nnaji, Chidozie and Emefu, S. 2017. Effect of Particle Size

on the Sorption of Lead from Water by Different Species of Sawdust: Equilibrium and Kinetic Study. *Bioresources*. 12: 4123-4145. 10.15376/ biores.12.2.4123-4145.

Nomanbhay, S.M. and Palanisamy, K. 2005. Removal of heavy metal from industrial wastewater using chitosan coated oil palm shell charcoal. *Electron. J. Biotechnol.* 8: 43–53

Ong . S., Yip . S., Keng . P., Lee . S. and Papaya . Y. H.2012. (*Carica papaya*) seed as a low-cost sorbent for zinc removal. *African Journal of Agricultural Research.* 7(5): 810–819, View at: Google Scholar

Rees-Clayton E.M., Todd M., Dowd J.B. and Aiello A.E. 2011. The impact of bisphenol A and triclosan on immune parameters in the U.S. population, NHANES 2003–2006. *Environ. Health Persp.* 119:390– 396. doi: 10.1289/ehp.1002883. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

Rivas F.J., Encinas A., Acedo B., Beltran F.J. Mineralization of bisphenol A by advanced oxidation processes. J. Chem. Technol. Biotechnol. 2008;84:589–594. doi: 10.1002/jctb.2085. [CrossRef] [Google Scholar]

Rivero M.J., Alonso E., Dominguez S., Ribao P., Ibañez R., Ortiz I. and Irabien A. 2014. Kinetic analysis and biodegradability of the Fenton mineralization of bisphenol A. *J. Chem. Technol. Biotechnol*. 89: 1228– 1234. doi: 10.1002/jctb.4376. [CrossRef] [Google Scholar]

Rochester J.R. Bisphenol A and human health: A review of the literature. Reprod. Toxicol. 2013;42:132–155. doi: 10.1016/j.reprotox.2013.08.008. [PubMed] [CrossRef] [Google Scholar]

Staples, C.A., Dorn, P.B., Klecka, G.M., O'Block, S.T. and Harris, L.R. 1998. A review of the environmental

fate, effects, and exposures of bisphenol A. *Chemosphere*. 36: 2149–2173. doi: 10.1016/S0045-6535(97)10133-3. [PubMed] [CrossRef] [Google Scholar]sulfurized steam activated carbon prepared from sugarcane bagasse pith," Industrial

US Environmental Protection Agency (USEPA) Report to Congress. USEPA; Washington, DC, USA: 2000. Environmental protection agency—Endocrine disruptor screening program. [Google Scholar]

Wang, G., Wu, F., Zhang, X., Luo, M. and Deng, N. 2006. Enhanced photodegradation of bisphenol A in the presence of â-cyclodextrin under UV light. *J. Chem. Technol. Biotechnol.* 81: 805-811. doi: 10.1002/ jctb.1513. [CrossRef] [Google Scholar]

Weber, T.W. and Chakravorti, R.K. 1974. Pore and solid diffusion models for fixed-bed adsorbers. *Aiche J.* 20: 228–238. [CrossRef]

Yamamoto T., Yasuhara A., Shiraishi H., Nakasugi O. Bisphenol A in hazardous waste landfill leachates. Chemosphere. 2001;42:415–418. doi: 10.1016/S0045-6535(00)00079-5. [PubMed] [CrossRef] [Google Scholar]

Yoon, Y., Westerhoff, P., Snyder, S.A. and Esparza, M. 2003. HPLC fluorescence detection and adsorption of bisphenol A, 17β-estradiol, and 17α-ethynyl estra-diol on powdered activated carbon. *Water Res.* 37 : 3530–3537. doi: 10.1016/S0043-1354(03)00239-2. [PubMed] [CrossRef] [Google Scholar]

Zeng, G.M., Zhang, C., Huang, G.H., Yu, J., Wang, Q., Li, J., Xi, B. and Liu, H. 2006. Adsorption behavior of bisphenol A on sediments in Xiangjiang River, Central-south China. *Chemosphere.* 65:1490–1499. doi: 10.1016/j. chemosphere. 2006.04.013. [PubMed] [CrossRef] [Google Scholar]