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Sorption of Styrene from Aqueous Solution using Electrospun EPDM Fibers

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Abstract: *The ability of electrospun EPDM fibers to remove styrene from aqueous solution was reported in this study. The effects of various experimental parameters, such as initial styrene concentration, srobent dosage, and temperature, were investigated using a batch-sorption technique. The optimum conditions for removal of styrene were found. Experimental and theoretical analyses showed that the swelling process was rapid and could reach equilibrium within a short time. The experimental studies revealed that electrospun EPDM fibers have the potential to act as an alternative sorbent to remove styrene from aqueous solutions.*

Keywords: *Electrospun EPDM Fiber (EEF); oil sorbent; styrene solution*

1. INTRODUCTION

Styrene, an environmental hormone and carcinogen, can exist and accumulate in the environment for a long time. It is found the accumulated styrene amount has surpassed the water self-purification capacity. Therefore, it is urgent to take effective measures to remove styrene from water.

In recent years, various sorbents were widely applied to sorb organic liquids. According to Park J. K. *et al.*[1] the rubber is a good sorbent for organic compounds. Researchers [2-5] have conducted batch sorption test on organic liquids by using sorbents based on rubber. However, there has been limited research on the feasibility of using electrospun EPDM fiber (EEF) in organic contaminants clean up and there are few reports in treatment of environmental hormones spilled on water, particularly for styrene.

The aim of this study is primarily to investigate the feasibility of using EEF to remove styrene from water and provide useful information on treatment of environmental hormones. The influences of several process parameters such as initial styrene concentration, sorbent dosage and temperature on EEF are explored. The sorption kinetics of styrene from aqueous solution onto EEF is further evaluated by kinetic models.

2. EXPERIMENTAL

2.1 Materials and Characterizations

Styrene (C8H8) is of chemical grade, and is used as the representative environmental hormones in this study. EPDM were kindly provided by Kumho EP Rubber Co. Ltd.

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The main procedure for the preparation of EEF is similar to those previously described in our earlier paper. [6]

The surface morphology of the EEF was viewed under a scanning electron microscope (SEM, JEOL JSM-5600LV, Japan). The average fiber diameter was calculated based on SEM images using Photoshop 7.0 software.

2.2 Method

The effects of experimental parameters are studied in a batch mode of operation. Styrene solution of known concentration were taken in a 150ml Screw-cap conical flask with a known amount of sorbent and was agitated in a thermostat rotary shaker at a speed of 200rpm. At various time intervals, the flasks were successively removed, the remaining concentration of styrene in solution was measured on a Perkin-Elmer UV-visible spectrophotometer model 550S at a wavelength of 297nm.

3. RESULTS AND DISCUSSION

3.1 Scanning Electronic Microscopic (SEM) Analyses

Figure1 shows that the randomly oriented fibers ranging from 400nm to 1.8 μm in diameter formed a nonwoven mat. The fibrous materials are different from the conventional textile fabrics. These fibrous webs, which contain small pores, facilitate the transport of liquids into the sorbents and retain the liquids after sorption. It can be seen that the EEF nonwoven mat possess properties like high porosity, micro-scaled pore

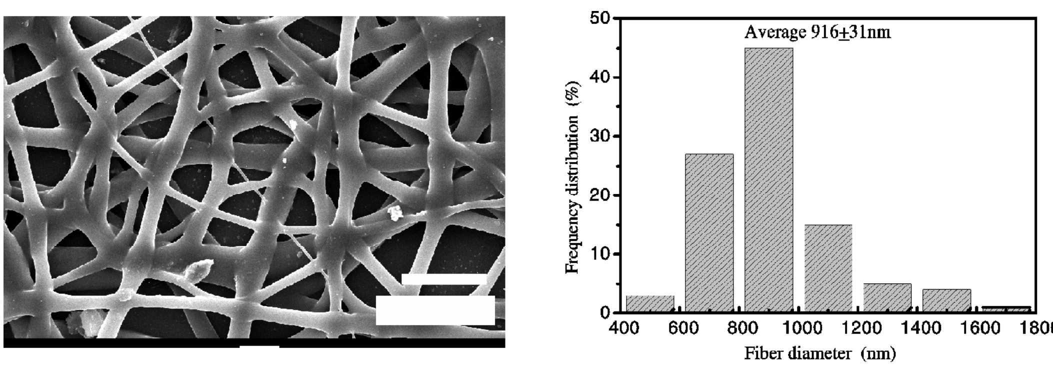

Figure 1: SEM Image of EEF and Size Distribution of Fiber Diameters

size, high interconnectivity of the interstitial space, good morphology stability and controllable mat thickness, and above all, the nano-scaled fiber diameter give rise to an increased surface area to volume ratio. These properties make the EEF appears to be an ideal sorbent for organic liquids sorption.

3.2 Effect of Initial Concentration on Sorption

The effect of initial concentration (10, 40, 70 and 100mg/l) for the removal of styrene were carried out at 293K for 60 min. From figure 2, on changing the initial concentration from 10 to 100 mg/l, the percentage styrene removal decreased from 92.3% to 71.23% and the amount of styrene sorbed increased from 9.23 to 71.23 mg/g in the same concentration range. The removal of styrene was dependent on the initial concentration since the amount of styrene sorbed increased with increase in initial concentration. A similar trend was reported for the sorption of aromatic hydrocarbons through filled natural rubber. [7]

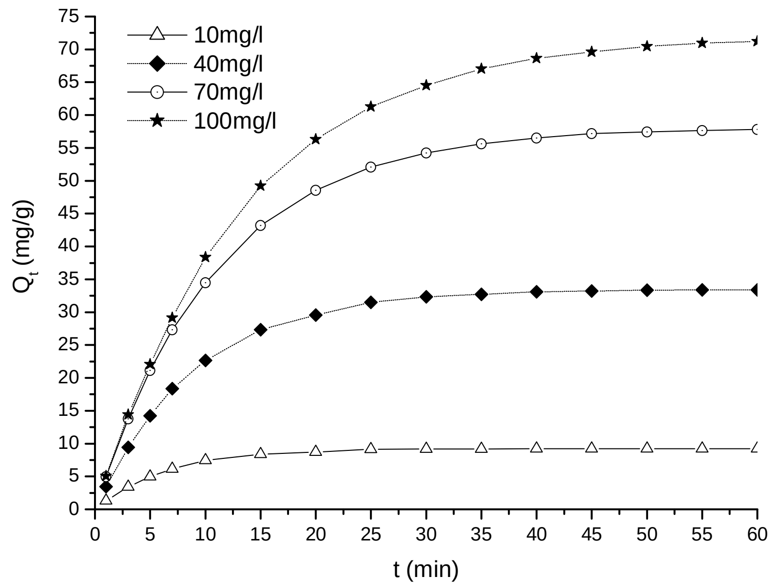

Figure 2: Effect of Initial Concentrations (T = 293K)

In this study, Lagergren pseudo first-order, pseudo second-order models [8] were used to analyze the sorption kinetic date. The values of rate constants obtained from the kinetic models for the styrene-sorbent system were given in Table 1.The best-fit model was selected based on the linear regression correlation coefficient, values. It was found that the Pseudo first-order kinetic constant, and Pseudo second-order kinetic constant, decreased with increasing of the initial styrene concentration. The experimental data fitted well with the first-order kinetic model (?) which suggested the swelling process is rapid can reach equilibrium within a short time. This result also fell well with Fick's Law.

Table 1
Sorption Kinetic Model Rate Constants at Different Initial Concentrations

Parameter	*Pseudo first-order*		*Pseudo second-order*	
C_0 (mg/1)	*K_1 (min^{-1})*	*R_1^2*	*K_2 (g/mg*min))*	*R_2^2*
10	0.155	0.994	14.945	0.818
40	0.116	0.999	3.250	0.824
70	0.097	0.998	1.487	0.828
100	0.83	0.999	0.773	0.880

3.3 Effect of Sorbent Dosage on Sorption

It can be seen from Figure 3, the percentage styrene removal increased from 71.23% to 98.32% with an increase in sorbent concentration from 1 to 10 g/l whereas the amount of styrene sorbed per unit of sorbent mass decreased from 71.23 to 9.83 mg/g in the same sorbent concentration range. This was due to the fact that as the dosage of sorbent was increased, there was less commensurate increase in sorption of the sorbent. [9]

The calculated kinetic parameters at different sorbent dosages were listed in Table 2.

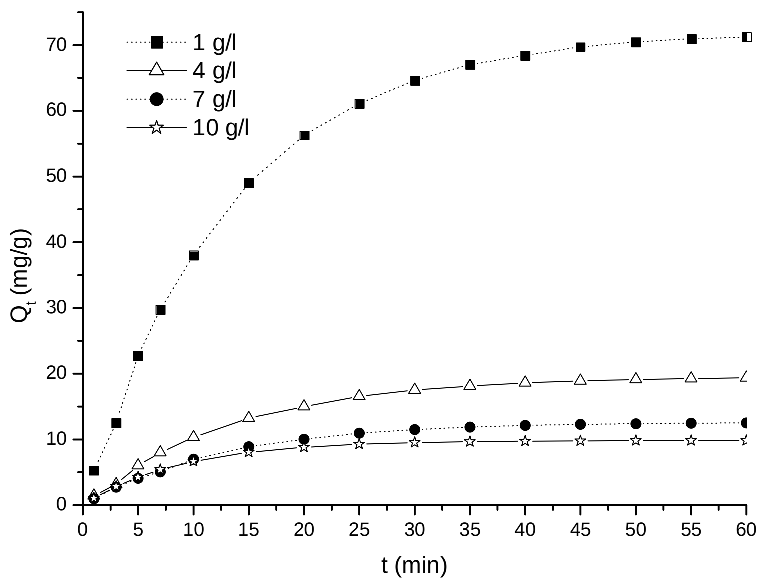

Figure 3: Effect of Sorbent Dosage on Styrene Sorption onto EEF

Table 2
Sorption Kinetic Model Rate Constants at Different Sorbent Dosage

Parameter	*Pseudo first-order*		*Pseudo second-order*	
m_s *(g/1)*	K_1 *(min^{-1})*	R_1^2	K_2 *(g/mg*min))*	R_2^2
1	0.046	0.989	0.409	0.932
4	0.075	0.999	0.384	0.939
7	0.081	0.992	0.472	0.929
10	0.113	0.995	1.326	0.892

3.4 Effect ofTemperature

The removal of styrene onto EEF was studied at 10, 20, 30 and 40? to determine the sorption isotherms and thermodynamic parameters. It is observed from Figure 3 that the amount of sorbed styrene onto EEF increased from108.45 to 125.15mg/g by increasing the temperature of the styrene solution from 10 to 40?. Similar trends were also observed for the aqueous phase sorption.[10]

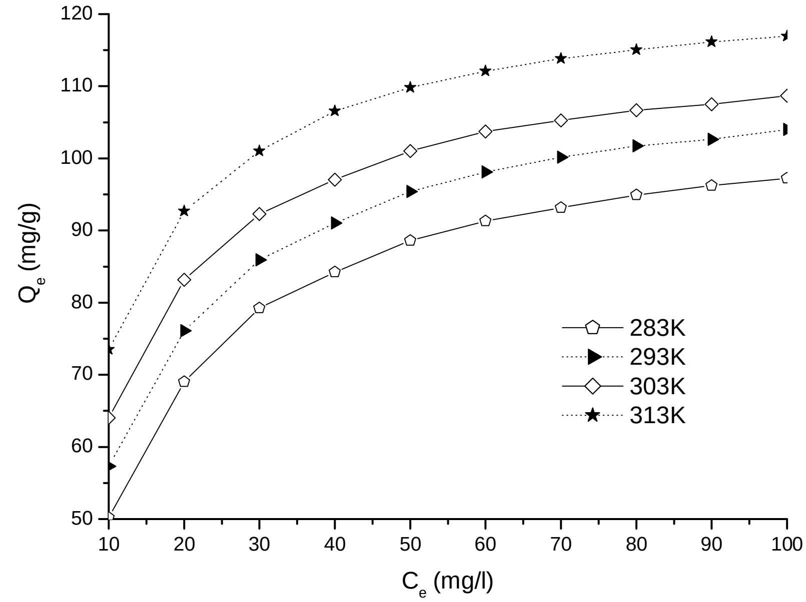

Figure 3: Effect of Temperature on Sorption

Analysis of the sorption equilibrium data is important to optimize the design of sorption system. Langmuir(with three different linear forms) and Freudilich[11]were tested in this work. Table 4 displays the results of the calculated isotherm constants at different temperatures. isotherm model was found to best fit the experimental data over the whole concentration range as indicating from the high values of the correlation coefficients ($R^2 > 0.99$). Similar trends were reported for the model's minimal deviation from the fitted equation resulting in the best error distribution.[12]The values of Langmuir and Freundlich constants were found to increase with increasing temperature.

Table 4
Isotherm Parameters Obtained using Linear form at Different Temperatures

Isotherm	*T (K)*	*283*	*293*	*303*	*313*
Langmuir-1	Q_m (mg/g)	108.45	114.28	117.64	125.15
	K_L (l/mg)	0.087	0.100	0.120	0.141
	R^2	0.999	0.999	0.999	1
Langmuir-2	Q_m(mg/g)	109.17	112.10	119.33	123.30
	K_L (l/mg)	0.085	0.109	0.110	0.140
	R^2	0.993	0.992	0.990	0.987
Langmuir-3	Q_m (mg/g)	108.85	114.25	117.84	125.20
	K_L (l/mg)	0.086	0.100	0.119	0.142
	R^2	0.999	0.999	0.999	0.999
Freundich	$1/n$	0.271	0.245	0.216	0.190
	K_F (mg/g)(l/mg)$^{1/n}$	29.48	35.23	41.97	50.73
	R^2	0.968	0.970	0.966	0.965

CONCLUSIONS

In this study, evaluation of EEF as an effective sorbent to styrene was carried out. the sorption kinetics of styrene on the EEF was studied in a batch mode operation for the parameters initial styrene concentration, sorbent dosage and temperature. The results showed that sorption of the styrene increased with increasing in initial styrene concentrations while it decreased with increasing in sorbent mass. The sorption equilibrium isotherms were analyzed by Langmuir, and Freundlich isotherm equations. The Langmuir isotherms provided the better correlations for the styrene onto EEF. The maximum styrene sorption capacity on EEF at 40? was 125.15mg/g. The results of the present investigation showed the EEF is a potentially useful sorbent for the sorption of styrene and such environmental hormones.

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