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Short Communication

Removal of Phenolic Compounds from Industrial Wastewater by Activated Carbon

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Abstract. Phenol and its derivatives were removed by the physical treatment process of adsorption from pharmaceutical industrial wastewaters at the laboratory scale. The adsorption relationship between different doses of activated carbon and the concentrations of the phenolic compounds adsorbed was studied with respect to time. Determination of phenol concentration was carried out before and after adsorption on activated carbon by the red colour reaction spectrophotometerically. In this reaction, 4-aminoantipyrine acted as a colouring agent, potassium ferricyanide as an oxidant, and ammonium hydroxide-ammonium chloride as the buffer solution. During the present studies, the adsorption process using activated charcoal resulted in the reduction of phenol from 315 mg/l to 0.1 mg/l.

Keywords: phenol adsorption, industrial effluents, activated carbon, wastewater treatment, pharmaceutical effluents

Wastewater treatment is considered to be an integral part of any industrial process design. The environment protection agencies in different countries, including Pakistan, place significant emphasis on the removal of toxic substances from industrial wastes prior to their discharge from the treatment plants into water bodies (Lenore *et al.,* 1998). Pharmaceutical industries generate large volumes of organic wastes in their effluent discharges. Among these are phenols and related compounds, which are potentially toxic to aquatic life. These compounds create an oxygen demand in the receiving waters and have the unique property of tainting the taste of fish, if present at the concentration of 0.1-1.0 mg/l (Verchurren, 1977). The chlorinated derivatives of phenols impart taste to drinking water, when present in even minute concentrations. The potential sources of phenols in industrial effluents are the municipal sewage, bunker fuel cooking plants, pharmaceuticals, and petroleum industries (Guard *et al.,* 1975). Phenol is nevertheless extensively used as a medicinal fungicide, in textiles, and in the synthesis of organic products, particularly phenolic resins. It is, therefore, necessary to develop a quick and efficient method to remove phenolic compounds whenever these are generated as wastes.

A variety of physical treatment technologies have been developed for the wastewater streams, such as activated carbon adsorption, air and steam stripping, chemical precipitation, ion exchange, and membrane separation (Nukatsuka *et al.,* 2000). Activated carbon adsorption, which is essentially a proven technology to reduce pollution in industrial wasterwater, has been investigated for the removal of phenols generated as wastes during industrial processing. Most of the organic substances, such as phenols and their derivatives, are readily adsorbed onto activated carbon (Kang *et al.,* 2000).

The main purpose of the present study was to reduce the amount of phenol in pharmaceutical industry effluents upto the discharge limit of phenols in the effluents within the National Environment Quality Standards in force in Pakistan (NEQS, 1993). The method uses the ability of activated carbon to adsorb phenolic compounds.

For the determination of phenol concentration, many analytical techniques are available, which include chromatographic (Faust *et al.*, 1971), metal adsorption (Alam *et al.,* 1999), and spectrophotometeric (Merck, 1976). In the present work, the spectrophotometeric method was used for the determination of phenol in the range of 0.1-1.0 ppm. The laboratory-scale physical treatment observations, upon the removal of phenol from pharmaceutical industrial effluents, are presented in Tables 1 and 2.

The industrial wastewater, prior to treatment, was adjusted to pH 7-8 and temperature to 32-35 °C. The wastewater was pretreated to remove suspended solids, oil and grease, particularly to avoid excessive pressure drop, which is a problem sometime created in the presently reported physical treatment procedure. Nine samples of wastewater (100 ml each) were then contacted with a range of nine different concentrations (0.05-5.0 g) of powdered activated charcoal as the adsorbent. The mixture was manually swirled. The flasks were agitated on a flask shaker for 80 min. Following agitation, the samples were filtered through Whatman filter paper # 42. The residual phenol concentration was determined by the development of

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a red coloured complex, produced on reaction with 0.2 % aqueous 4-amminoantipyrine reagent. The red colour end-product was plotted against the similarly treated phenol standard solutions of known concentrations and observations were recorded at 470 nm (Merck, 1976), using UV-vis Specord 200 Analytic Jena AG spectrophotometer. Standard phenol solutions were made by dissloving various concentrations of 0.1 to 0.01 g phenol (Merck) in one liter distilled water.

The observations on various characteristic parameters, after treatment of the pharmaceutical industrial effluent, are given in Table 1. The concentrations of oil and grease, biochemical oxygen demand (BOD) and chemical oxygen demand (COD), in the wastewater were 40, 395 and 1310 mg/l, respectively. The concentration of phenol in wastewater was 315 mg/l, which after adsorption on activated carbon was reduced to 0.1 mg/l. Therefore, the treatment resulted in achieving the safe discharge limit within the NEQS (NEQS, 1993).

For the development of an efficient carbon adsorption process, pH and temperature are the two most important physical parameters to be controlled. During the present study a range of pH 6-8 was selected. It was observed that increase of pH decreased the adsorption of phenol. This, in turn, required lighter concentration of powdered activated carbon. The best results were obtained at pH 7.8 at 32 °C. It was also noted during the experimental studies that a small volume of highly contaminated effluent required higher concentration of carbon dose in the treatment process, as has been reported previously (Teng *et al.,* 1999).

It was also observed that for efficient removal of phenol by activated carbon, 70-80 min contact time was generally adequate for the adsorption of phenol from the pharmaceutical industrial wastewater. The results reported in Table 2 show that the phenol concentration in the effluent water was re-

Table 1. Characterization of the pharmaceutical industrial wastewater used for the adsorption of phenol, before and after treatment

Parameters	Wastewater sample		NEQS
	before treatment	after treatment	
pH	5.8	7.8	6-10
Conductivity (µs/cm)	4270	4070	
Temperature (°C)	28	32	40
Total organic carbon (mg/l)	415	139	
Suspended solids (mg/l)	92	< 5	150
Phenol (mg/l)	315	0.1	0.1
Oil and grease (mg/l)	40	< 5	10
COD	1310	475	150
BOD	395	110	80
Total dissolved solids (mg/l)	1185	885	3500
Chlorides (mg/l)	1011		1000
Sulphates (mg/l)	398		600
Total solids (mg/l)	1277		

NEQS = national environmental quality standards (NEQS, 1993); COD = chemical oxygen demand; BOD = biochemical oxygen demand

Table 2. The effect of activated carbon conentration and treatment time on the adsorption of phenol from the phenol industry effluent; various parameters of the treatment procedure were: 6-7% aqueous solubility of phenol, filtered wastewater sample volume of 100 ml at 32 °C and pH 7.8; best results obtained after 70 min agitation time, using 2.5 g activated carbon dose, observations recorded spectrophotometrically at 470 nm

Time (min)	Carbon dose (g)	Phenol remaining (mg/l)	Phenol adsorbed (mg/l)	Ratio of phenol adsorbed to activated carbon	Phenol adsorbed (%)
0	control	315.0			
5	0.05	295.0	20	40.0	6.34
10	0.1	241.0	74	74.0	23.49
20	0.2	177.0	138	69.0	43.80
30	0.3	89.0	226	75.3	71.74
40	0.5	15.0	300	60.0	95.23
50	1.0	1.50	313.5	31.4	99.52
60	1.5	0.20	314	20.9	99.70
70	2.5	0.01	315	12.6	99.99
80	5.0	0.06	315		99.99

duced from 315 mg/l to 0.1 mg/l. Maximum adsorption target (99.99%) was achieved at 2.5 g activated carbon dose within 70 min at pH 7.8 and the temperature of 32 °C.

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