ADSORPTIVE PROPERTIES OF CDE CHARCOAL CLOTH

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Summary

Data are reported for the adsorption of vapours and solutes on to charcoal cloth, under both dynamic and equilibrium conditions. BET N_2 areas are in the range 900 to 1660 m^2/g and saturation capacities are high, varying with the activity. In dynamic adsorption larger capacity at penetration is attributed to a rapid rate of adsorbate/solid interaction.

Introduction

CDE charcoal cloth is a new, high activity adsorbent in the form of a robust, flexible woven cloth composed entirely of charcoal (1, 2). It is produced in the form of 60 cm wide rolls in the CDE experimental plant, the degree of activation being varied to suit the requirement. This paper summarises the results of measurements of the adsorptive properties both under equilibrium and dynamic conditions. Physical properties are described in a further paper to this Conference.

Charcoal Activity

The adsorptive activity of the charcoal cloth may be varied as required during manufacture, and a range of samples are reported on here. To provide an assessment of activity, heats of wetting (3) in benzene and silicone fluid (2 cP) have been measured and are quoted for comparative purposes. Such data provide a measurement of not only the accessible surface area of carbons but also of molecular sieving (4), silicone fluid (molar vol. 433) being a much larger molecule than benzene (molar volume 80).

In practical situations, adsorbed moisture will influence adsorption behaviour; in certain cases measurements have therefore been made both with dry charcoal and with charcoal equilibrated with air at 80% RH (for brevity, "moist" charcoal). Where comparative data for granular charcoal is included, the results refer to two high quality nutshell charcoals (graded 14 x 25 BSS) of medium and high activity, referred to here as "granular" A and B.

Equilibrium Adsorption

Surface Areas

BET surface areas derived from $N_2/77^oK$ isotherms on numerous cloth samples taken from the experimental production runs gave BET areas in the range 900 - 1660 m^2/g. Typical examples are shown below.

Sample	Sil.2 HOW	BET Surface Area
Charcoal Cloth 1	113 j/g	1660 m^2/g
Charcoal Cloth 2	44 j/g	1350 m^2/g
Granular A	80 j/g	870 m^2/g

Pore Size

The heats of wetting (Table 1) showed the molecular sieve effect usually observed with charcoals (5). The increase in pore size arising from further activation was also clear, Cloth 146 having been subjected to the greater activation.

TABLE 1. Molecular Sieve Properties

Wetting liquid	Molar Volume ml mol^{-1}	Heat of Wetting j/g Cloth 107	146
Methanol	40.5	84	86
Chlorobenzene	101.7	67	72
Dekalin	154	42	60
Sil.1 cP	288	12	54
Sil.2 cP	433	5	43

Vapour Adsorption at Saturation Vapour Pressure

The adsorption of benzene, chlorobenzene and carbon tetrachloride at saturation vapour pressure have been measured by exposing dried, weighed samples to the respective liquids in an enclosure until equilibrium was observed. The results, given in Table 2, show that substantial amounts of vapour are adsorbed, spanning the range of good commercial charcoals. The Gurvitsch rule is followed, and volumes adsorbed rise with increasing activity.

Vapour Adsorption under Dynamic Adsorption Conditions

Vapour concentrations in the 1 to 10 mg/l range in air, set up by standard methods, were passed through layers of charcoal cloth held in a suitable jig. Effluent concentrations were measured by use of a calibrated CDE halogen detector or by an FID equipment. Experiments were made with both dry and moist air over an air velocity range of 0.5 - 8.0 cm/s.

In all cases the usual linear variation of penetration time T (and hence weight adsorbed w at penetration) with the weight of charcoal cloth W (or number of layers) was observed. It was found that $w = FCT = N_o(W - W_c)$ where F = volume flow, c = influent concentration, W_c = critical bed and N_o = equilibrium uptake.

For the adsorption of chlorobenzene, styrene, halothane and carbon tetrachloride on dry cloth W_c was small, corresponding to less than one layer (0.5 mm) of cloth. Increase in the moisture content of the cloth led to an increase in the critical bed to 2 to 4 layers, depending on the system. The value of N_o was unchanged for the strongly adsorbed chlorobenzene (b.p. 132°C), but was reduced for halothane (b.p. 56°C). Critical flow rate and critical concentration were also small, being nearly zero for dry cloth. In consequence, beds consisting of more than 5 layers (0.25 cm deep) showed a notable constancy of the amount adsorbed when flow and concentration are varied. Change in cloth activity around the average had only a minor influence on the general behaviour.

Experiments with only 1 and 2 layers show that appreciable removal of vapour occurred even in such shallow beds. Thus for the system 0.5 mg/l styrene, velocity 2 cm/s, 2 layers (1 mm) moist charcoal cloth, penetration times of 24 and 68 min were recorded at penetration levels of 1% and 10% respectively.

TABLE 2. Vapour Adsorption at Saturation Vapour Pressure

Charcoal	Heat of Wetting joule/g		% Vapour adsorbed w/w			Vapour adsorbed cc/g		
	Benzene	Sil.2 cP	Benzene	Carbon Tet.	Chloro-benzene	Benzene	Carbon Tet.	Chloro-benzene
Cloth P57 (1)	105	19	35.4	62.2	43.1	0.404	0.391	0.390
Cloth P57 (4)	120	123	67.3	127.8	86.9	0.767	0.804	0.786
Cloth P66	96	88	45.8	81.7	57.0	0.522	0.514	0.514
Cloth P68	69	10	29.2	52.9	36.8	0.333	0.333	0.333
Cloth P69	69	72	44.7	75.9	55.0	0.510	0.477	0.499
Granular A	130	80	-	63.5	47	-	0.40	0.43
Granular B	155	125	-	101.0	68	-	0.63	0.62

Comparison with Granular Charcoal

Experiments measuring the penetration times of chlorobenzene with granular charcoal and charcoal cloth show that under identical conditions (concentration 9 mg/l, velocity 8 cm/s, 80% RH) the main difference lay in the critical bed depth, which was in the weight ratio of 1:5. Thus the weight of granules required to give T = 10 min was 250% greater, and for T = 30 min 175% greater, than that of charcoal cloth of similar activity.

In experiments with the anaesthetic halothane (6) (concentration 43 mg/l), a 3.7 cm depth of dry granules gave the same penetration time as 1 cm (20 layers) of dry charcoal cloth at flow rates of 1 to 4 cm/s. With moist charcoal, at a linear velocity of 1 cm/s the % uptake on charcoal cloth was 300% greater, and at a linear velocity of 4 cm/s 200% greater than on granules.

Adsorption from Aqueous Solution

(a) Equilibrium uptake

The adsorption isotherms for adsorption of phenol, acetic acid and dimethoate (an insecticide) from aqueous solution were measured for both charcoal cloth and a granular charcoal. The isotherms for the two charcoals were very similar, showing that the charcoal activities were the same. Rates of adsorption were also measured and a first order rate constant (K) calculated. With both phenol and acetic acid, K was 1.6 min^{-1} for the charcoal cloth, but only 0.1 min^{-1} for the granules. For the larger dimethoate molecule, K for cloth was 0.012 min^{-1} and 0.0011 min^{-1} for the granules. Thus the rate of adsorption on charcoal cloth was more than an order of magnitude the greater.

(b) Dynamic adsorption

The removal of phenol (concentration 50 g/l) from a solution flowing through a 2 cm diameter column of charcoal was measured by following the change in effluent concentration with time (7). Experiments were made with 2 g charcoal cloth, 2 g and 7 g granular charcoal. When the effluent concentration had risen to 1/1000 of the influent concentration, the weights adsorbed by the three columns were calculated as: 2 g charcoal cloth column: 37% w/w; 2 g granular column: zero; 7 g granular column:17% w/w.

In experiments at two further influent concentrations, equilibrium adsorption on charcoal cloth was also calculated from extended experiments: these values corresponded closely with those determined in the earlier equilibrium experiments.

Discussion

Under equilibrium conditions CDE charcoal cloth has the properties of an adsorptive carbon, exhibiting molecular sieving and capacity depending on the extent of activation. The capacity of high activity charcoal cloth exceeds that of good commercial granular charcoals. However, the small critical bed for charcoal cloth found in all dynamic adsorption experiments indicates a high rate of adsorption in comparison with granular charcoals, a conclusion borne out by rate measurements in solution. To this is attributed the large adsorptions observed at initial penetration of test vapour or solutes. In dynamic adsorption the influence of pre-adsorbed moisture is notably less than with granular charcoal.

References

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