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ADSORPTION STUDY OF MERCURY ON CHARCOAL

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After some of the mercury poisoning tragedies like Minamata disaster, containment of mercury pollution has become an environmental concern worldwide. Among the different approaches like cementation, ion exchange to remove inorganic mercury ion from waste waters, adsorption is a noteworthy technique due to its simplicity and cheapness. The present adsorption study is done with mercuric nitrate solution in the range of 100 to 900 mgl^{-1} using activated charcoal powder, (E.Merck), activated coconut shell, charcoal and commercial wood charcoal. The shape of the adsorption isotherm obtained reveals multilayer theory of adsorption. Among the three carbon materials mentioned, activated coconut charcoal shows the highest degree of adsorption. At 500 mgl^{-1} initial mercury, coconut charcoal gives 64 mg per gm of adsorbent at *p*H 2. Wood charcoal without specific adsorption treatment shows an adsorption of 24 mg per gm of adsorbent. Though increase of acidity decreases the adsorption capacity, a capacity of 24 mg per gm is found at 0.5 *p*H corresponding to 0.32 N compared to 42 mg per gm at 2 *p*H corresponding to 0.01 N.

Keywords: Mercury pollution/adsorption of ionic mercury/activated carbon

INTRODUCTION

Water pollution exists today in many parts of the world. The problem is increasing day by day around industrial and urban centres. Water effluents that carry different metals are let out into nearby rivers causing contamination of surface waters. Most of the metals are toxic. These toxic metals change the biological systems into inflexible and irreversible conformations leading to deformity in the body and finally to death [1]. There are different methods for the removal of these toxic metals present in water and among them adsorption is a notable one. Presence of mercury and its salts in industrial effluents is a worldwide problem causing industrial health hazards [2,3]. Mercury pollution which was responsible for the notorious Minamata disaster in Japan has been noticed in two places in waters and sediments of the Thana Creek in Mumbai (Bombay) and the Rushikulya river in Orissa in India. The scope of this work covers evaluation of different carbon materials for the adsorption of ionic mercury from solution.

EXPERIMENTAL

The adsorption study is done with mercuric nitrate solution in the range of approximately 100 mg/l to approximately 900 mg/l concentration. Mercuric oxide is dissolved in minimum quantity of nitric acid and the solution diluted to the required extent for obtaining different concentrations. The solution contains only mercury as the metallic ion. As adsorbents, activated charcoal (laboratory grade MERCK), activated coconut charcoal, wood charcoal (commercial grade) are employed. The activated coconut charcoal particles are irregular in shape and the approximate size falls between 700-800 micrometers. The particle size of the other powders range from 50 to 80 mesh (180-300 micrometres).

Each trial consisted of 70 ml of the mercury containing solution, agitated with 0.5 g of the adsorbent for a period of about 15 minutes and then the slurry filtered. The filtrate is analysed for the unadsorbed quantity of mercury from which the quantity adsorbed is found.

Apart from (the adsorption done in) an agitated vessel (adsorption in), a packed column containing the adsorbent is

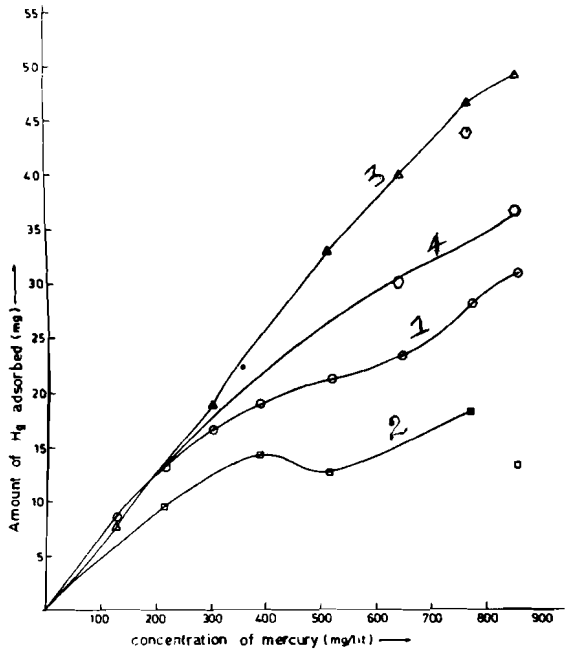

Fig.1: Effect of concentration of mercury on adsorption capacity
(1) Activated charcoal (Lab grade Merck)
(2) Wood charcoal (further powdered)
(3) Activated coconut charcoal
(4) Activated coconut charcoal (further powdered)

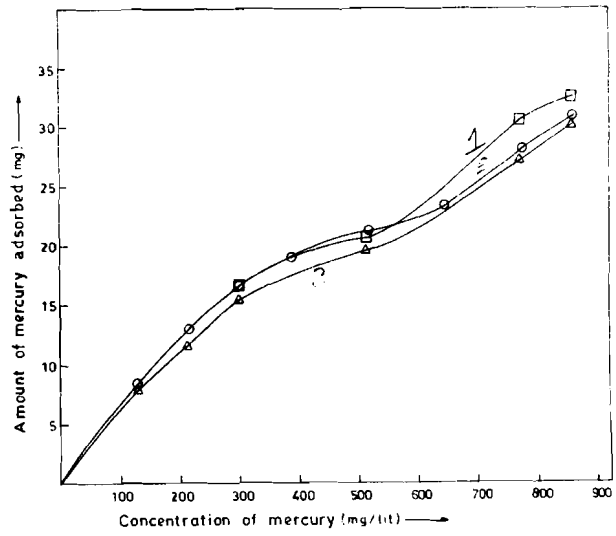

Fig.2: Effect of temperature on adsorption capacity (activated charcoal)
(1) 191 K (2) 302 K (3) 323 K

also used. Estimation of mercury is done by the replacement method of EDTA analysis using copper-PAN as indicator.

RESULTS AND DISCUSSION

Effect of concentration

Results of the investigations varying the initial concentration of mercury in solution from 100 mgl^{-1} to 900 mgl^{-1} keeping the quantity of adsorbents as 0.5 g in all cases is presented in Fig. 1. It can be readily inferred that the adsorption capacity of the adsorbent increases with the concentration of the metal ion in solution in all cases. This is in conformity with the general theory of adsorption [4]. Out of the different adsorbents used, activated coconut charcoal is found to possess the maximum adsorption capacity which is found to be 97.98 mg of Hg/g of adsorbent. Though the particle size of the activated coconut charcoal is much bigger than the laboratory grade activated charcoal (hence lower apparent surface area) the adsorption capacity of the former is found to be higher. Further powdered coconut charcoal whose particle size is reduced to that similar to laboratory grade one, does not show betterment in adsorption. It is considered probable that the activation property is affected during the powdering process. The commercially available wood charcoal (powdered) without any specific activation treatment shows notable adsorption capacity. The nature of the adsorption isotherm as shown in Fig. 1 reveals fairly clearly a pattern similar to Type II or Type IV of the adsorption isotherm model. Type II-V come under multilayer adsorption phenomena contrast to Type I which is unimolecular layer adsorption postulated by Langmuir. In the former, the amount of adsorption keeps on rising and is attributed to the formation of additional layers of physically adsorbed molecules. These adsorption isotherms are generally reported for gas on solid surface. However, the similarity observed between such adsorption and the present study where metal ion is adsorbed on solid surface, on the pattern of the isotherms is brought out here. The similarity in the pattern can suggest multilayer adsorption for mercury on carbon surface.

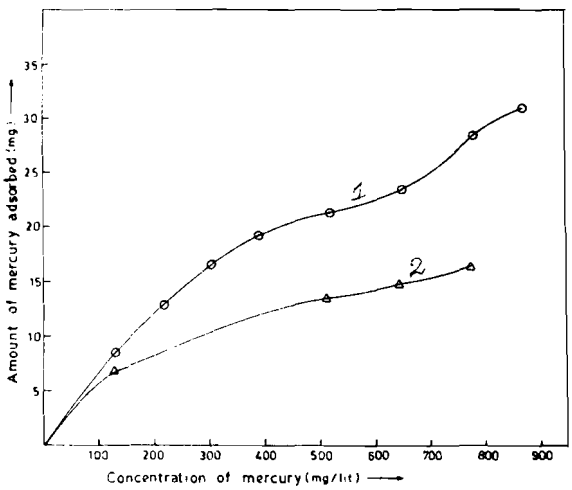

Fig.3: Effect of acidity on adsorption capacity (varying mercury concn) (1) 2 PH (2) 1 PH.

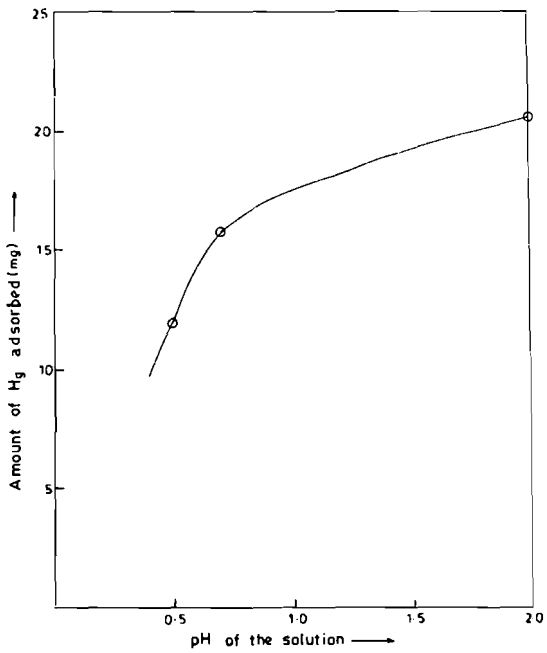

Fig.4: Effect of acidity on adsorption capacity (fixed mercury concn at 500mgl^{-1}

Effect of temperature

Temperature is considered as one of the important parameters in adsorption studies. It is known from the study of gaseous adsorption that, lower the temperature, higher is the adsorption [4]. This behaviour is also seen in the case of mercury adsorption on activated charcoal. Three temperatures are tried and the results are plotted in Fig. 2. Though the temperature effect within the range of study is not much pronounced, the general trend of adsorption capacity reducing with increase of temperature is seen. The weakening of the attractive forces between mercury and the activated charcoal surface (and between adjacent adsorbed mercury) as the temperature is increased leads to lowering of adsortpion. Thus, if the mercury is regarded as distributed between the adsorbed layer and the mercuric nitrate solution in a partition equilibrium, the position of equilibrium is displaced in favour of the mercuric nitrate solution as the temperature rises.

Effect of acidity

In addition to mercury, the waste water generated from certain industries may contain acids and thereby decrease the *p*H of the effluents [1]. With reference to this, the effect of hydrogen ion concentration on the adsorption of mercury is studied varying the *p*H of the solution by the addition of sulphuric acid and the results are plotted in Figs. 3-4.

The extent of adsorption is found to decrease with the increase of acidity. But it is not affected drastically. It can be seen at a *p*H of 0.5 corresponding to an acid concentration

TABLE I: Rate of adsorption

Adsorbent	:	0.5g of Laboratory grade activated charcoal
Volume of the solution	:	70ml
Temperature	:	303 K
Concentration of Mercury	:	514 mg/l
*p*H of the solution	:	2
Amount of Hg taken (mg)	:	36

Time Minutes	Amount of Hg remaining in the soln (mg)	% Removal from solution
5	16.85	53
10	16.16	55
15	15.14	58

TABLE II: Adsorption of mercury on activated coconut charcoal in a column

Quantity of adsorbent	:	0.5g
Rate of flow	:	3.24 ml/min
Concentration of mercury in feed solution	:	71.43 mg/l
Temperature	:	302 K

Duration minutes	Outgoing concentration mg/l	Quantity of Hg adsorbed mg	Quantity adsorbed per min mg/min
0-5	147	8.12	1.62
5-10	295	9.05	1.81
10-15	354	7.10	1.42
15-20	442	5.77	1.15
20-25	550	3.32	0.66
25-30	600	2.66	0.53
30-35	659	1.74	0.35
35-40	698	1.25	0.25

of 0.32 there is 58% of adsorption compared to a *p*H of 2 which correspond to 0.01 N.

Rate of adsorption

In all the previous experiments, the duration provided for adsorption is 15 minutes. In order to assess the rate of adsorption, lesser duration, viz. 5 minutes and 10 minutes are also tried and the results are presented in Table I. The results show that 92% of maximum adsorption is over within 5 minutes.

Adsorption done in column

The experiments pertaining to the effect of concentration, temperature etc. are hitherto done in an agitated vessel. In order to explore the possibility of making the process a continuous one, experiments are done using a packed column of the adsorbent (activated coconut charcoal) through which the solution is passed at a uniform rate using a metering pump. The results of the column experiments are presented in Table II.

The quantity of mercury adsorbed per gram of the adsorbent in the column for a total duration of 15 minutes is 48.54 mg. For the same duration, in an agitated vessel containing comparable mercury concentration in solution, 92.86 mg of mercury per gram of adsorbent was adsorbed. Generally, the adsorption capacity in column is found to be around 50% of that obtainable in agitated vessel.

CONCLUSION

The study undertaken to assess the ability of different forms of carbon to adsorb mercury ion from solution reveal: adsorption of mercury from solution follows the general rule that adsorption capacity increases with concentration of metal ion and is favoured by decrease of temperature. The commercially available wood charcoal (powdered) without any specific activation treatment shows notable adsorption capacity. Despite lower apparent surface area, activated coconut charcoal shows higher capacity of adsorption than the laboratory grade activated charcoal. The adsorption of mercury on laboratory grade activated charcoal in solution phase follows the multilayer theory of adsorption. The extent of adsorption is found to decrease with the increase of acidity. Notable adsorption is found with activated charcoal upto an acidity of 0.5 *p*H. Adsorption capacity is lower for treatment in a column compared to that in an agitated vessel.

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