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EVALUATION OF THE QUALITY OF POWDERED ACTIVATED CARBON AS A SORBENT FROM AQUEOUS SOLUTIONS

The Polish and foreign methods for quality control of powdered activated carbon (PAC) as a sorbent from aqueous solution are discussed on the basis of literature data and experimental study. It has been suggested, that both the experimental procedure and the form in which the result are to be presented should be unified. The latter should be given as the value of the adsorption on the given carbon for each adsorbate under conditions of equilibrium with the solution. This should allow to obtain the data characterizing the investigated carbon unambiguously, which in turn, will facilitate the estimation of the quality of carbon and a right choice of sorbent for the given purification method.

Activated carbon is a valuable adsorbent used in water treatment. Its increasing importance is due to the ever increasing environmental pollution and growing requirements for water quality. The name "activated carbon" stands for several porous carbon preparations produced through decarbonization and activation of two substances differing from one another in origin and methods of activation. To estimate the adsorption capacity of carbon used as sorbent in contact with an aqueous phase several techniques are used. Some of them accepted "as standards" are employed to describe the characteristics of a given carbon. The tests of phenol adsorption are most frequently employed to evaluate the adsorptivity of activated carbon, since phenolic compounds belong to the most frequent water pollutants. Other testing methods consist in determining the adsorption properties of carbon for such substances as phenol, iodine, molasses, detergent, phenazone, indole etc. The given carbon is then characterized by a number or an index which determines its adsorptivity. In these cases the tests of adsorption are carried out under equilibrium conditions (static adsorption). Some of indices are based on the properties of carbon, i.e. other than adsorptive capacity, as for instance the chlorine number which characterizes the catalytic efficiency of carbon in the reaction between chlorine and water and the methylene number defining the amount of carbon which would discolour 0.15% of methylene blue solution during 5 minutes. This last test is based on statics as well as on kinetics of adsorption. The methylene number is used for grading medical carbons [4].

Tests based on static adsorption differ both in methods, presentation of results and in definitions of numbers. This creates difficulties connected with unambiguous assessments of quality of carbon and with a suitable choice of sorbent, e.g. when two different kinds of carbon are compared a higher value of the iodine number

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indicates the better one, whereas higher values of other numbers (such as the phenol, molasses or detergent) indicate lower adsorptive ability. The lack of unification is particularly apparent in the widely used testing method based on phenol adsorption. The phenol number used in Poland defines the quantity of phenol adsorbed on the carbon (percentage by weight) from the solution of a given concentration, it does not indicate, however, the concentration at equilibrium, that is why the results obtained are not fully comparable quantitatively. The most rational – considering the theoretical principles of adsorption — is the phenol test formulated in the "German Norm" [3]. The phenol number is then defined as the amount of phenol, in miligrams per 100 mg of carbon, when the equilibrium concentration of phenol remaining in solution is 1 mg/dm^3. The adsorption equal to or higher than 3.7%, found from the adsorption isotherm indicates that the given carbon is of good quality. According to [2] phenol number should be expressed by the amount of phenol (in mg) adsorbed by 1 g of carbon when the concentration of the solution changes from 1 mg/dm^3 to 0.01 mg/dm^3 (1 ppm to 10 ppb).

American Norm [1] gives the phenol number as the amount of carbon (in ppm) necessary to reduce the concentration of phenol standard solution from 100 ppb to 10 ppb. An attempt has been made by GOMELLA [5] who tried to estimate the adsorptivity of carbon with respect to several adsorbates and to combine the results in a single index called FINAD (F — phenol, I — iodine, N — indole, A — phenazone (antypiryne), D — detergent). These substance are representative of common pollutants found in potable water and wastewater. PAC is here described by a five digit number, in which every digit characterizes the quality of the carbon with respect to one adsorbate. The global number FINAD should, according to the author, describe the adsorptive ability of the carbon with regard to individual adsorbates. The adsorptive ability of PAC was studied for each adsorbate in different range of concentrations. The final equilibrium concentrations were: 0.01 mg/dm^3 for phenol, 0.025 mg/dm^3 for detergent, 0.1 mg/dm^3 for indole, and grams/dm^3 for iodine and phenazone indices. The ways in which the particular numbers were defined are also different. The phenol, detergent and indole numbers are defined as the amount of carbon which decreases the initial concentration to an exactly defined equilibrium concentration, while the iodine and phenazone indices give the amount of the adsorbate (in grams) adsorbed on 100 g of carbon.

The statement that the carbon which strongly adsorbs phenol adsorbs iodine or phenazone weakly is by no means justifed, since the adsorption of the latter compounds is examined in a quite different range of concentrations. The idea of studying the adsorption of various adsorbates is certainly correct because the magnitude of adsorption depends on the structure, composition and size of the adsorbate molecule. To obtain, however, comparable data the studies should be carried out in equimolar solutions of suitable concentrations. This principle has been fully confirmed in our results obtained from the experiments conducted for the adsorbates used in the FINAD method. The concentration ranged from 0.01 mg to grams/dm^3, including the equilibrium concentrations representative of all norms and testing methods. The investigations were carried out on several PAC obtained in our laboratory and on commercial samples. The results obtained were given in paper [6] submitted for publication. To illustrate the dependence of the adsorptivity on the concentration, two adsorption isotherms have been shown for two selected PAC, whose origins and way of activation were known, but whose surface areas were different. These carbons obtained in the laboratory from charcoal were activated with steam at 850 °C and denoted by A and B. To determine the phenol concentration in the equilibrium solution several modified analytical methods were employed, depening on the concentration range.

It can be seen from figure 1 that in concentrations below 1 mg/dm^3 carbon B adsorbs phenol better than carbon A, which is better at higher concentrations. If we compare the data obtained for the absorptivity of a given carbon determined by such testing methods as DIN 19603 — for small concentrations and phenol number — for high concentrations then it follows that the adsorptivity of coal at a given concentration cannot be inferred from the value determined for another concentration. The results of our experiments conducted on twenty odd samples of activated carbons produced in the laboratory and available in the market are presented in figs. 2–4.

The plots well ilustrate the effect of concentration. The adsorptivity of the carbons is different depending on the concentration range.

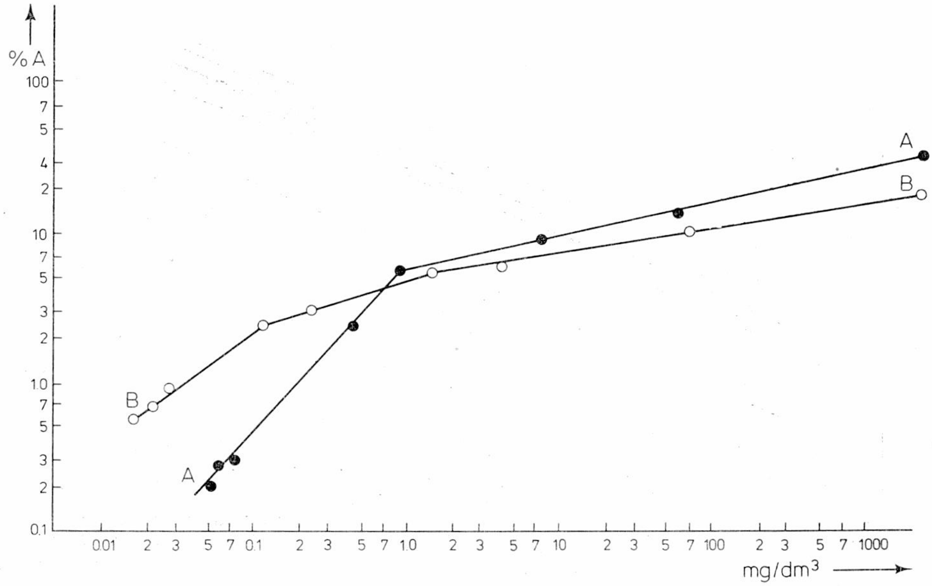

Fig. 1. Adsorption isotherms for phenol on activated carbons A and B

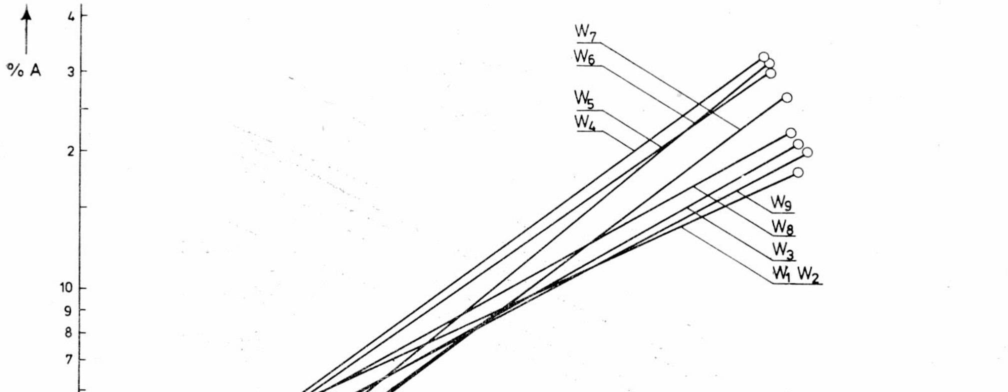

Fig. 2. Characteristics of activated carbons based on DIN 19603 and phenol number. Carbons W_1 to W_9 were produced in our laboratory and activated with steam (850°C) at different steam to carbon ratios

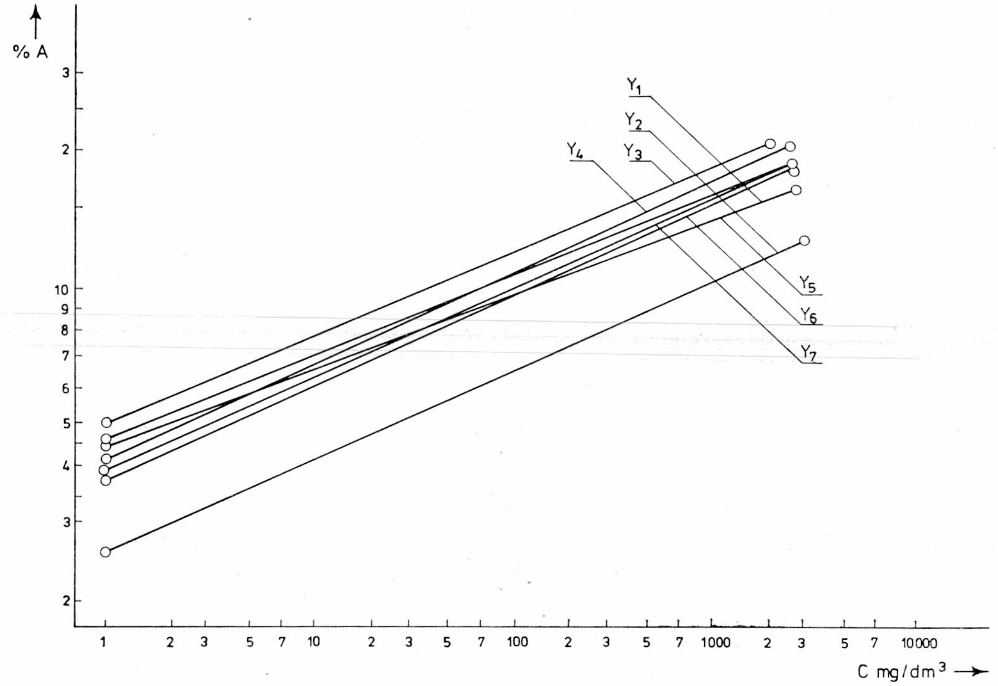

Fig. 3. Characteristics of activated carbons Y_1 to Y_9 based on DIN 19603 and phenol number, produced in our laboratory and activated with steam (850 °C) at different steam to carbon ratios

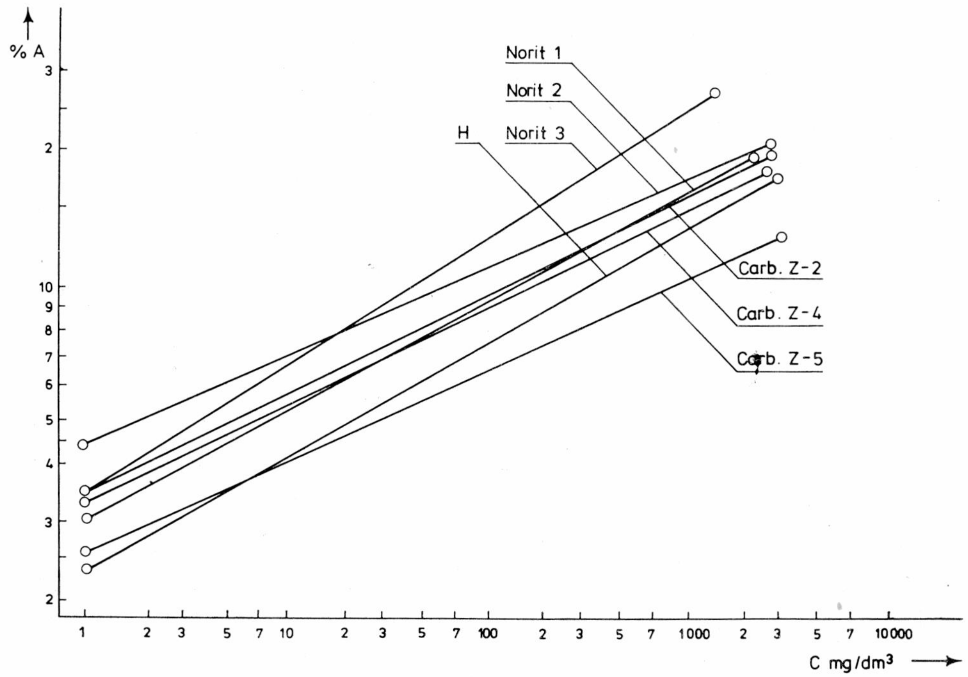

Fig. 4. Characteristics of activated carbons based on DIN 19063 and phenol number. Commercial samples: Carbopol Z-2, Z-4, Z-5, Norit 1, 2, 3, Hajnówka A

CONCLUSIONS

From the review of methods used for the estimation of activated coal as adsorbent from aqueous solutions it follows that so far its testing problem have not been solved in a uniform way. In some cases a higher numerical value indicates better adsorption properties, while in others it is vice versa. The lack of uniform testing methods creates a lot of difficulties in the choice of activated carbon produced by different manufactures. On the basis of the present studies it appears that the adsorption isotherm should be made for the given adsorbate/adsorbent pair within a wide concentration range. It seems that in order evalute the usefulness of a given kind of carbon for a particular application it suffices to make several measurements of the adsorption in the required range of concentrations.

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