CHAPTER 4

GRANULAR ACTIVATED CARBON

4-1 Purpose

The use of granular activated carbon for the adsorption of organic materials from wastewater has become firmly established as a practical, reliable, and economical unit process for water pollution control. It is a valuable new tool for which sanitary engineers will have many uses and will make wide application in preserving water quality, meeting discharge requirements, and producing reclaimed water free of color, odor, froth, and other evidences of the presence of organic pollutants. Historically, in wastewater treatment, some organic materials have been removed by biological oxidation methods, including activated sludge treatment and trickling filtration. These conventional processess may remove nearly all of those organic measured by the biochemical oxygen demand (BOD) test, but are ineffective in removing the so-called refractory organic materials as measured by the chemical oxygen demand (COD) test. Even well-treated secondary effluents contain 50-120 mg/l. of organics. These materials include tannins, lignins ethers, proteinaceous substances, and other color and odor producing organics, as well as MBAS (methylene blue active substances), herbicides and pesticides such as DDT. Certain refractory organic substances added to the water in a stream may contribute to algal growth, contribute to fish kills and tainting fish flesh, produce tests and odor in water supplies withdrawn from the stream, and may have cumulative harmful physiological effects if present in drinking water. (Culp, 1971).

There are a rather limited number of unit processes which are capable or removing these refractory organic materials from wastewater, including reverse osmosis, freezing, chemical oxidation, distillation, adsorption on powdered carbon, and adsorption on granular carbon. Powered activated carbon could be used on a once through basis but these are severe dust problems in handling the rather large quantities needed in wastewater treatment. There is also a problem of disposal of the spent carbon unless it is incinerated along with the sewage sludge. Powdered carbon used in sugar refineries was reactivated with reasonable success for many years but its use was discontinued in favor of the use of granular carbon. This change came about as the result of problems in regeneration of powdered carbon with dust and dirt, the production of carbon fines so small that they were not filterable, and poor recoveries ranging from 60-90 percent. It is possible that some of the current research which is under way in regenerating powdered carbon will find ways to correct these deficiencies but the solutions do not appear to be at hand now. Reverse osmosis, freezing, and distillation are not yet developed to the point of being either practical or economical processess for removing organics from water. Adsorption on granular activated carbon is at this time the best method for this purpose.

The commercial availability of a high-activity, hard, dense granular activated carbon made from coal, plus the development of multiple hearth furnaces for on-site regeneration of this type of carbon have drastically reduced the cost of granular activated as a unit process for wastewater treatment. Beds of granular carbon have the adsorptive capacity of handle shock hydraulic or organic loads with no loss in efficiency. (Culp, 1971).

Presently, the major manufacturers of granular activated carbon include Calgon Corp. (formerly Pittsburg Activated Carbon Co.), West Virginia Pulp and Paper Co., Atlas Chemical Industries., Inc., National Carbon Co., American Norit Co., Inc., and Witco Chemical Co., Inc. (Culp, 1971).

4-2 How Carbon Adsorbed Organics

Upon contact with a water containing soluble organic materials, granular activated carbon selectively removes these materials by adsorption. Adsorption is the phenomenon whereby molecules adhere to a surface with which they come into contact, due to forces of attraction at the surface. The use of surface energy to attract and hold molecules is physical adsorption. The fact that activated carbon has an extremely large surface area per unit weight (on the order of 1,000 m^2/g) makes it an extremely efficient adsorption material. The activation of carbon in its manufactures produces many pores within the particles, and it is the vast areas of the walls within these pores that accounts for most of the total surface area of the carbon. In water, activated carbon has a preference for large organic molecules and for substances which are nonpolar in nature. The forces of attraction between the carbon and the adsorbed molecules are greater the closer the molecules are in size to the pores. The best adsorption takes place when the pores are just large enough to admit the molecules. (Culp, 1971).

Crushing of carbon particles to produce smaller particles enhances the rate of adsorption by exposing more entrances to the carbon pores. Because the carbon particle size primarily affects the rate of adsorption and not the total adsorptive capacity of the carbon, the difference in performance of columns containing different size carbon decreases as the contact time increases. (Culp, 1971).

The rate of adsorption of MBAS and other organics found in wastewater increases with decreasing p^H of the water. Adsorption is very poor at p^H · value above 9.0. (Culp, 1971).

The effect of turbidity or suspended solids in water applied to granular carbon on the efficiency and life of the carbon has not been determined precisely. However, it is evident that any restriction of pore openings or buildup of ash or other materials within the pore openings due to the presence of suspended or colloidal materials and their accumulation on or in the carbon particles might have an adverse effect upon the adsorptive capacity or service life of the carbon. These hazards can be minimized by applying water which has been pretreated to the highest practical clarity to carbon. (Culp, 1971).

4-3 Carbon Specifications

Presently the best carbons for treatment of wastewater appear to be those made from select grades of coal. These carbons are hard and dense and can be conveyed in water slurry with no appreciable deterioration. The physical strength of the carbon must be great enough to withstand the repeated handling required during regeneration. (Culp, 1971).

The two most popular sizes of granular carbon for wastewater treatment are nominally 8 x 30 mesh and 12 x 40 mesh. The finer material has a higher rate of adsorption, but also has a higher head loss per unit depth of bed, and since the beds lower porosity, they have a greater tendency to plug with materials filtered out of the wastewater. The 8 x 30 mesh carbon is the better choice. It reduces losses during regeneration and greatly simplifies carbon column operation, at only slight loss in efficiency. Recommended carbon specifications are given in Table 2. (Culp, 1971).

TABLE 2 SUGGESTED SPECIFICATIONS FOR GRANULAR ACTIVATED FOR USE IN WASTEWATER TREATMENT.

Total surface area (m^2/g)	950-1500
Bulk density (lb/ft^3)	26
Particle density, wetted in water (g/cc)	1.3-1.4
Effective size (mm)	0.8-0.9
Uniformity coefficient	1.9 or less
U.S. Standard Series, sieve size	
Larger than No. 8	max. 8 %
Smaller than No. 30	max. 5 %
Mean particle diameter (mm)	1.5-1.7
Iodine number	min. 900
Abrasion number	min. 70
Ash	max 8 %
Moisture	max 2 %

In the upflow countercurrent carbon columns at Tahoe, the capacity of 8 x 30 mesh carbon for COD is 0.5 lb of COD per pound of carbon. (Culp, 1971).

4-4 Selecting Activated Carbon for Wastewater Treatment

The selection of the carbon specified above appears on the basis of present knowledge to be the best can be made for treatment of wastewater from those granular carbon now available. It must be pointed out however, that information and methods now available for selection are not fully developed and some of the decisions involved are necessarily somewhat arbitrary. For liquid adsorption systems there is not precise method for predicting the performance of carbon founded on their basic properties or those of the adsorbing molecules. In wastewater, the substances to be removed such as color, COD, MBAS, and other refractory organics are always a composite of ingredients of unknown identity. (Culp, 1971).

Further, the use of granular carbon is fairly new for treatment of wastewater, the potential market is great, and the competition among carbon manufacturers is likely to be keen. Therefore, it is not unreasonable to expect not only a future reduction in prices for granular carbon, but also a possible improvement in the kind and quality of carbon commercially available. (Culp, 1971).

Sanitary engineers chemists, and others responsible for selecting or purchasing these materials should be aware of the best methods for evaluating and characteristics, describing the physical properties, and conducting and interpreting pilot carbon column studies. With the use of these techniques. advantage can be taken of new developments and improvements in the field as they occur. (Culp, 1971).

The adsorptive capacity of a carbon can be measured to a fair degree by determining the adsorption isotherm experimentally in the system under consideration. Simple capacity tests such as the iodine Number of the Molasses Number also may be an appropriate measure of adsorptive capacity.

The adsorption isotherm is the relationship, at a given temperature, between the amount of substance adsorbed and its concentration in the surrounding solution. If a color adsorption isotherm is taken as an example the adsorption isotherm would consist of a curve plotted with residual color in the water as the abscissa, and the color adsorbed per gram of carbon as the ordinate. A reading taken at any point on the isotherm gives the amount of color adsorbed per unit weight of carbon, which is the carbon adsorptive capacity at a particular color concentration and water temperature. In very dilute solutions, such as wastewater, a logarithmic isotherm plotting usually gives a straight line. In this connection, a useful formular is the Freundlich equation, which relates the amount of impurity in the solution to that adsorbed as follows:

$$X/m = KC^{1}/n$$

where x = amount of color adsorbed

m = weight of carbon

X/m = amount of color adsorbed per unit weight of carbon

k and n are constants

C = unadsorbed concentration of color left in solution

In logarithmic form:

$$\log X/m = \log k + 1/n \log C$$

in which $1/n$ represents the slope of the straight line isotherm.

Detailed procedures for establishing the experimental conditions and conducting isotherm adsorption tests are presented later appendix. Test results for X/m against C are usually plotted on log-log paper to obtain the adsorption isotherm.

From an isotherm test it can determined whether or not a particular purification can be effected. It will also show the approximately capacity of the carbon for the application, and provide a rough estimate of the carbon dosage required. Isotherm tests also afford a convenient means of studying the effects of p^H and temperature on adsorption. Isotherm put a large amount of data into concise form for ready evaluation and interpretation. Isotherm obtained under identical conditions using the same test solutions for two test carbons can be quickly and conveniently compared to reveal the relative merits of the carbons. (Culp, 1971).

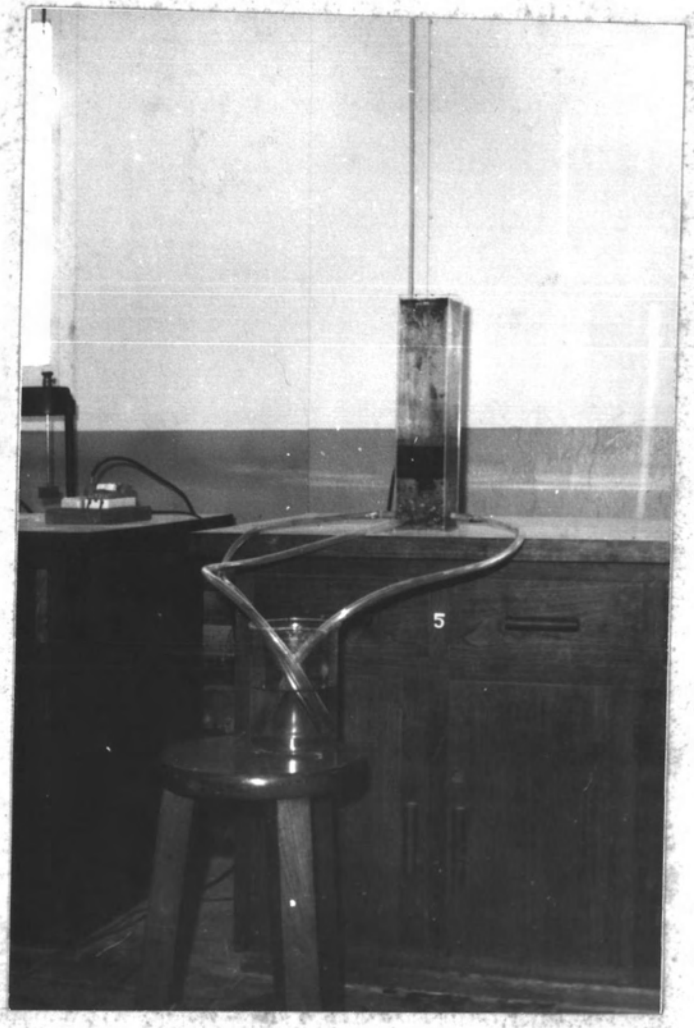

FIGURE 5 ACTIVATED CARBON COLUMN TEST.

Surface area 10 x 10 cm^2

Activated carbon, depth 3 cm.

Fine sand, passing sieve No. 18

depth 4 cm.

Gravel, passing sieve 3/8"

retained on sieve No. 18

depth 6 cm.