



**American Water Works
Association**

The Authoritative Resource on Safe Water®

AWWA Standard

Powdered Activated Carbon



STANDARD

Since 1881



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Foreword

This foreword is for information only and is not a part of ANSI/AWWA B600.*

I. Introduction.

I.A. *Background.* Activated carbon is a crude form of graphite that is produced by a carefully controlled oxidation process to develop a porous carbon structure with an internal surface area greater than 500 m²/g. This surface area gives the activated carbon the capacity to adsorb dissolved organic chemicals, many of which are taste- and odor-causing substances in water.

The major raw materials used in the manufacture of powdered activated carbon (PAC) include, but are not limited to, peat, bituminous coal, coconut shells, wood, and lignite coal. During activation, the raw materials are either reacted at high temperatures in the presence of steam or at moderate temperatures in the presence of activation chemicals. The activation process first drives off volatile components from the raw material, creating a fine porous structure, and then enlarges the pores, which creates the extensive internal pore structure required to obtain appreciable adsorption of organic chemicals. Subsequent processing may include crushing, screening, grading, and packaging.

PAC is applied by mixing it with water to form a slurry that is metered into the water at a suitable point in the treatment process. The activated carbon, along with adsorbed contaminants, is removed by settling or filtration.

I.A.1 *Source of supply.* Activated carbon used for water treatment should be obtained from manufacturers that are regularly engaged in the production of activated carbon that is found to be satisfactory for service in the water treatment field.

I.B. *History.* The first edition of ANSI/AWWA B600, Powdered Activated Carbon, was approved as tentative by the AWWA Board of Directors on July 11, 1949, and later as a standard on May 15, 1953. Subsequent revisions to ANSI/AWWA B600 were approved on Jan. 23, 1966, Jan. 28, 1978, June 17, 1990, Feb. 4, 1996, and Jan. 16, 2005. This seventh edition of B600 was approved on June 20, 2010.

ANSI/AWWA B600 provides information on preparing purchase documents for the purchase of PAC to be used as an adsorption medium for the treatment of municipal and industrial water supplies. Granular activated carbon is covered in ANSI/AWWA B604, Granular Activated Carbon.

*American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.



This standard does not cover the design of activated carbon handling facilities or adsorption processes. Design information may be found in the *AWWA Journal* and in other publications, some of which are listed in the bibliography (appendix A) of this standard.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International (NSF*) to develop voluntary third-party consensus standards and a certification program for direct and indirect drinking water additives. Other members of the original consortium included the American Water Works Association Research Foundation (AwwaRF, now Water Research Foundation) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.[†] Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health effects of products and drinking water additives from such products, state and local agencies may use various references, including

1. An advisory program formerly administered by USEPA, Office of Drinking Water, discontinued on Apr. 7, 1990.
2. Specific policies of the state, provincial, or local agency.
3. Two standards developed under the direction of NSF, NSF/ANSI 60, Drinking Water Treatment Chemicals—Health Effects, and NSF/ANSI 61, Drinking Water System Components—Health Effects.
4. Other references, including AWWA standards, *Food Chemicals Codex*, *Water Chemicals Codex*,[‡] and other standards considered appropriate by the state, provincial, or local agency.

Various certification organizations may be involved in certifying products in accordance with NSF/ANSI 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdiction. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

* NSF International, 789 N. Dixboro Road, Ann Arbor, MI 48105.

† Persons outside the United States should contact the appropriate authority having jurisdiction.

‡ Both publications available from National Academy of Sciences, 500 Fifth Street, NW, Washington, DC 20001.



Annex A, “Toxicology Review and Evaluation Procedures,” to NSF/ANSI 61 does not stipulate a maximum allowable level (MAL) of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of “unregulated contaminants” are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Annex A procedures may not always be identical, depending on the certifier.

ANSI/AWWA B600 does not address additives requirements. Users of this standard should consult the appropriate state, provincial, or local agency having jurisdiction in order to

1. Determine additives requirements, including applicable standards.
2. Determine the status of certifications by parties offering to certify products for contact with, or treatment of, drinking water.

3. Determine current information on product certification.

II. Special Issues.

II.A. *Storage and Handling Precautions.* The following safety precautions should be exercised to minimize or eliminate hazards when handling and storing PAC. Wet activated carbon will readily adsorb oxygen from the air, creating an acute oxygen-depletion hazard in confined areas. Appropriate safety measures for oxygen-deficient atmospheres should be strictly adhered to when entering enclosed or partially enclosed areas containing activated carbon.

PAC should be stored in a building or compartment that is as fire-resistant as possible. Bags of PAC should be stacked in rows with aisles between them so that each bag may be easily removed in case of fire. Nothing else should be stored in the same building or compartment with activated carbon. Strict precautions must be taken to avoid PAC contacting strong oxidizing agents such as chlorine, hypochlorites, potassium permanganate, ozone, and peroxide. Mixing activated carbon with hydrocarbons (such as oils, gasoline, diesel fuel, grease, paint thinners, and so forth) may cause spontaneous combustion. Therefore, activated carbon must be kept separate from hydrocarbon storage or spills.

In case of an activated carbon fire, the safest procedure, if possible, is to place the smoldering material in a metal container and remove it from the building. An activated carbon fire may also be smothered by means of a very fine spray or mist of water from a hose or by a foam-type chemical extinguisher. A direct stream of water should not be used, as it will cause the smoldering particles to fly into the air and spread the fire.

II.B. *Activated Carbon Dust.* Respiratory protection shall be worn when bags of activated carbon or dry bulk material are unloaded, sampled, prepared for analysis,



or otherwise handled. Excessive dusting and inhalation of activated carbon dust should be avoided. Activated carbon dusts are classified as “nuisance particulates,” and the applicable threshold limit values (TLVs) should be followed.

Activated carbon is an electrical conductor and should not be allowed to accumulate as dust near or on open electrical circuits. Electrical outlets, lights, and motors in dry-activated-carbon feed and storage rooms should be watertight to preclude the entrance of activated carbon dust.

II.C. Adsorptive Performance Tests. Performance-based evaluation tests include the tannin value and 2-methylisoborneol (MIB)/geosmin test listed in appendix B. Tannin value is used as an index of a carbon’s ability to remove high-molecular-weight impurities such as organic compounds originating from decayed vegetation. The MIB/geosmin test should be completed to assist the user in choosing the most effective PAC for taste and odor removal and the lowest necessary dosage required to meet treatment objectives. These activated carbon tests should be completed using water from the particular plant in question. It is strongly recommended that users do this, as tests will reflect the actual conditions under which the activated carbon will be used. Additional information on the MIB/geosmin test can be found in the AwwaRF research report, *Optimization of Powdered Activated Carbon Application for Geosmin and MIB Removal*.*

Surrogate tests have been developed to give an indication of PAC’s general performance under specific conditions. Please note that the use of these surrogates may not model adsorption of actual water contaminants. Examples of these tests are the iodine number and threshold odor tests. These tests use a specific adsorbate at a high concentration to reduce the amount of test time required. These tests are of limited versatility and are not necessarily indicative of an activated carbon’s performance for a given application. Iodine number is used as an index of the acceptable surface area of a carbon and its ability to remove some types of chemical tastes and odors in addition to low-molecular-weight impurities. An iodine number of 500 mg/g is considered a minimum required value for any PAC. This value was determined by considering test performances for most of the manufactured activated carbons that are used successfully for water treatment.

The threshold odor test may be used to determine an activated carbon’s performance in removing tastes and odors from a particular water. The threshold odor test procedure is found in Sec. 5.2.7. This test is often used to determine the optimum

*Graham, M. et al. 2000. *Optimization of Powdered Activated Carbon Application for Geosmin and MIB Removal*. Denver, Colo.: AwwaRF.



dosage needed to remove taste- and odor-causing substances at a particular treatment facility. Because of the subjective nature of the test and the variability in water quality at a treatment facility, the threshold odor test may be difficult to use as a reproducible indicator of activated carbon quality and performance.

The purchaser may find it advisable to modify the figure specified for a minimum iodine number or to include the tannin value, MIB/geosmin, or threshold odor tests as dictated by the relationship of these parameters to the actual treatment performance.

III. Use of This Standard. It is the responsibility of the user of an AWWA standard to determine that the products described in that standard are suitable for use in the particular application being considered.

III.A. Purchaser Options and Alternatives. The following items should be provided by the purchaser.

1. Standard used—that is, ANSI/AWWA B600, Powdered Activated Carbon, of latest revision.
2. Whether compliance with NSF/ANSI 61, Drinking Water Treatment Chemicals—Health Effects is required.
3. Quantity of PAC to be purchased, in lb (kg).
4. When requested, a representative sample of the PAC shall be submitted to the purchaser for acceptance before shipment. The sample must be submitted in clean, vapor-proof containers, clearly marked with the address of the supplier, and identified with the lot number of the contents. A duplicate sample shall be tested by the supplier, and a certified test report shall be submitted to the purchaser with the purchaser's sample, showing compliance with the requirements of the purchase documents, along with a statement certifying that the material for shipment is equal in quality to the sample submitted.
5. Name of the manufacturer whose product will be provided by the supplier.
6. The purchaser may authorize shipment on the basis of the supplier's certification of quality or may test the reference sample submitted by the supplier to confirm compliance before shipment is authorized.
7. Details of other federal, state or provincial, and local requirements (Sec. 4.1).
8. Particle-size distribution, if other than that specified (Sec. 4.2.3).
9. Minimum iodine number, if other than that specified (Sec. 4.2.4).
10. Additional tests (Sec. 4.2.5).
11. Provisions for reaching agreement on sampling technique (Sec. 5.1).
12. The purchaser may elect to collect a representative sample of the material after delivery. The procedure used shall be in accordance with Sec. 5.1. One of the



three sample portions taken may be tested to determine compliance with the purchase documents.

13. Marking (Sec. 6.1).

14. Method of packaging and shipping (Sec. 6.2).

15. If shipment is to be in bulk: type of railcar or hopper truck (Sec. 6.2.4), and whether bulk shipments are to be accompanied by weight certificates of certified weighers (Sec. 6.2.5).

16. Whether an affidavit of compliance is required (Sec. 6.3).

17. The purchaser may elect to accept the PAC on the basis of (1) the supplier's certified test report and an accompanying affidavit of compliance (Sec. 6.3) indicating that the product proposed for use complies with this standard and with the purchase documents with no exceptions; (2) the supplier's certified test report completed by a qualified third-party testing laboratory approved by the purchaser and an accompanying affidavit of compliance; (3) the purchaser's own testing of the reference sample submitted by the supplier and the required affidavit of compliance; or (4) the purchaser's own testing of the representative sample, collected according to Sec. 5.1 after receipt of shipment, showing compliance with this standard and the purchase documents.

III.B. Modification to Standard. Any modification of the provisions, definitions, or terminology in this standard must be provided by the purchaser.

IV. Major Revisions. Major revisions made to the standard in this revision include the following:

1. Types of packaging and associated wastes were broadened.
2. The wet sieve method for the determination of the particle size was removed and replaced with the Alpine method (ASTM).

V. Comments. If you have any comments or questions about this standard, please call the AWWA Engineering and Technical Services Group at 303.794.7711, FAX at 303.795.7603, write to the group at 6666 West Quincy Avenue, Denver, CO 80235-3098, or e-mail the group at standards@awwa.org.



**American Water Works
Association**

AWWA Standard

Powdered Activated Carbon

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard describes powdered activated carbon (PAC) for use in adsorption of impurities for water supply service applications.

Sec. 1.2 Purpose

The purpose of this standard is to provide the minimum requirements for PAC, including physical, testing, packaging, and shipping requirements.

Sec. 1.3 Application

This standard can be referenced in documents for purchasing and receiving PAC and can be used as a guide for testing the physical properties of PAC samples. The stipulations of this standard apply when this document has been referenced and then only to virgin (not reactivated) PAC used in water supply service applications.

SECTION 2: REFERENCES

This standard references the following documents. In their latest editions, they form a part of this standard to the extent specified within the standard. In any case of conflict, the requirements of this standard shall prevail.



ANSI*/AWWA B604—Granular Activated Carbon.

ASTM† D4607—Standard Test Method for Determination of Iodine Number of Activated Carbon.

ASTM D5158—Standard Test Method for Determination of Particle Size of Powdered Activated Carbon by Air Jet Sieving.

ASTM E11—Standard Specification for Wire Cloth and Sieves for Testing Purposes.

Standard Methods for the Examination of Water and Wastewater. APHA,‡ AWWA, WEF.§ Washington, D.C.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Activated carbon:* A family of carbonaceous substances manufactured by processes that develop graphitic structure and internal porosity, thereby creating adsorptive properties.
2. *Adsorption:* A process in which fluid molecules are concentrated on a surface by chemical forces, physical forces, or both.
3. *Day:* A day is defined as a 24-hr period.
4. *Manufacturer:* The party that manufactures, fabricates, or produces materials or products.
5. *Purchaser:* The person, company, or organization that purchases any materials or work to be performed.
6. *Supplier:* The party that supplies materials or services. A supplier may or may not be the manufacturer.

SECTION 4: REQUIREMENTS

Sec. 4.1 Materials

Materials shall comply with the requirements of the Safe Drinking Water Act and other federal regulations for water and wastewater systems as applicable.

*American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

†ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

‡American Public Health Association, 800 I Street NW, Washington, DC 20001.

§Water Environment Federation, 601 Wythe Street, Alexandria, VA 22314.



Sec. 4.2 Characteristics

4.2.1 *Moisture.* The moisture content of PAC shall not exceed 8 percent, by weight, of the listed container contents as packaged or at the time of shipment by the supplier in the case of a bulk shipment. The moisture content shall be determined according to Sec. 5.2.3.

Note: Because ambient conditions may be beyond the control of the supplier, the moisture content of activated carbon may increase during bulk shipment. A moisture content exceeding 8 percent is permitted in the reference sample that is collected after receipt of the shipment (Sec. III.A(12) and Sec. 5.3.1).

4.2.2 *Apparent density.* The apparent density of the activated carbon shall not be less than 0.2 g/cc nor greater than 0.75 g/cc, as determined according to Sec. 5.2.4.

4.2.3 *Particle-size distribution.* The particle-size distribution shall be determined according to Sec. 5.2.5. Unless otherwise specified by the purchaser, not less than 99 percent of the activated carbon shall pass a No. 100 sieve, not less than 95 percent shall pass a No. 200 sieve, and not less than 90 percent shall pass a No. 325 sieve, unless the activated carbon is wood-based. For wood-based activated carbons, not less than 95 percent of the activated carbon shall pass a No. 100 sieve, not less than 85 percent shall pass a No. 200 sieve, and not less than 60 percent shall pass a No. 325 sieve.

Note: A purchaser who prefers to use a coarser-ground material to prevent filter penetration and has a feed system capable of handling the larger material should modify the particle-size distribution listed previously as required.

4.2.4 *Iodine number.* The iodine number of the PAC shall be determined according to Sec. 5.2.6. Unless otherwise specified by the purchaser, the iodine number of the PAC shall not be less than 500 mg/g.

4.2.5 *Additional tests.* If the purchaser desires to use additional tests to measure adsorptive capacity, the purchaser shall notify the supplier of which type of shipment sampling will be required (Sec. III.A). The purchase documents should allow adequate time to complete testing and confirm analysis.

Sec. 4.3 Chemical Requirements

This standard has no applicable information for this section.



Sec. 4.4 Impurities*

4.4.1 *General impurities.* The PAC supplied according to this standard shall contain no substances in quantities capable of producing deleterious or injurious effects on the health of those consuming water that has been properly treated with PAC.

SECTION 5: VERIFICATION

Sec. 5.1 Sampling

5.1.1 *Sampling location.* If the purchaser elects to accept the material on the basis of those requirements outlined in Sec. III.A(12), samples shall be taken at the point of destination. The technique of sample collection should be agreed on between the supplier and the purchaser before shipment.

5.1.2 *Mechanical sampling.* If the PAC is handled by conveyor or elevator or shipped in bulk, a mechanical sampling arrangement may be used.

5.1.3 *Package sampling.* If the material is packaged, 5 percent of the packages shall be sampled. No sample shall be taken from a broken package. If the packaged material is shipped in carload quantities, one package from each lot number should be selected for sampling, with a minimum of 20 bags sampled from each carload.

5.1.4 *Sampling tube.* When taking samples from packages, the sampling tube shall be extended the full length of the package to obtain a representative sample.

5.1.5 *Sample size.* The gross sample, weighing from 5 lb to 6 lb (2.3 kg to 2.7 kg),[†] shall be mixed thoroughly and divided to provide three 1-lb (0.45-kg) samples. These shall be sealed in airtight, moisture-proof containers. Each sample container shall be labeled for identification, and the label shall be signed by the sampler.

Sec. 5.2 Procedures

5.2.1 *Samples.* If the purchaser elects to accept the material on the basis specified in Sec. III.A(12), samples shall be taken from each shipment of PAC, according to Sec. 5.1. The sample delivered to the laboratory shall be divided to

* See Sec. I.C of the foreword.

[†] Metric conversions given in this standard are direct conversions of US customary units and are not those specified in International Organization for Standardization (ISO) standard.



provide approximately 1 lb (0.45 kg). After thorough mixing, the sample should be stored in an airtight, vapor-proof container and weighed immediately to avoid change in moisture content.

5.2.2 Testing period. The laboratory examination of a sample shall be completed in time to meet the requirements of Sec. 5.3.1 for notification of the supplier in the event that tests reveal the material does not comply with this standard or the purchase documents.

5.2.3 Moisture.

5.2.3.1 Procedure. In a tared weighing bottle, accurately weigh approximately 2 g of the sample. Dry in a drying oven at 140°C (284°F) for 2 hr or 100°C (230°F) for 3 hr; then cool in a desiccator to room temperature and weigh rapidly. If a moisture balance is used for the determination of moisture content, the endpoint should be less than 0.1 percent change in weight for 5 min.*

5.2.3.2 Calculation.

$$\frac{\text{loss of weight}}{\text{weight of sample}} \times 100 = \% \text{ moisture} \quad (\text{Eq 1})$$

5.2.4 Tapped apparent density.

5.2.4.1 General. The apparent density of an activated carbon is the weight in grams per cubic centimeter (g/cc) of the activated carbon in air. Activated carbons should have the density determined on an “as-received” basis with corrections made for moisture content.

5.2.4.2 Procedure.

1. Dry approximately 10 g of activated carbon, per Sec. 5.2.3, and cool to room temperature in a desiccator.
2. Accurately weigh (to the nearest 0.01 g) approximately 10 g of the activated carbon to be tested.
3. Carefully transfer one third of the weighed sample to a 50-mL or 100-mL graduated cylinder. While gently tapping the graduated cylinder on a rubber pad or stopper, continue adding more activated carbon until the entire sample is transferred.
4. Tap carbon for 5 min, and then continue to tap for 2-min periods until there is no further settling produced by a 2-min period of tapping. Note the volume of the settled activated carbon.

* This protocol may also be satisfied as part of a multistep procedure such as that performed by a thermogravimetric analysis (TGA) (which also determines ash content).



5.2.4.3 Calculation. Calculate the apparent density, g/cc, on the dry basis:

$$\text{apparent density} = \frac{(\text{weight of sample, in grams}) \times (100 - \% \text{ moisture})}{(\text{volume of sample, in cubic centimeters}) \times 100} \quad (\text{Eq 2})$$

5.2.5 *Particle-size distribution.* The procedure for determining the particle-size distribution of PAC is the Alpine method (ASTM D5158).

5.2.6 *Test method for iodine number.* The procedure for determining the iodine number of activated carbon is found in ASTM D4607.

5.2.7 *Threshold odor test.*

5.2.7.1 Description. The threshold odor test is useful in determining the cost-effectiveness of different types of activated carbon for removing taste- and odor-causing substances from a particular water and for determining optimum activated carbon dosage rates at a treatment facility. The threshold point is the dilution of the test water with odor-free water at the point at which the odor is just detectable. The results of the test should be reported as the threshold number, which is equal to 100 divided by the percentage of the sample in the diluted portion at the threshold point.

5.2.7.2 General requirements. The threshold odor number shall be determined by using the following procedure, which includes increment differences of 15 percent dilution (see Figure 1) and requires two operators to conduct. Selection of persons to conduct the odor tests should be made carefully. Extreme sensitivity is not required; however, individuals who are insensitive to odors should not be used for the test. A good observer should have a sincere interest in conducting the test. Smoking or eating before the test should be avoided. The room in which the tests are conducted should be relatively quiet and free from odors. Water and glassware should be checked for odor before the test. Glassware, including pipettes, cylinders, flasks, and sample bottles, must be freshly cleaned before use. Rubber stoppers and corks should not be used. Narrow-mouth vessels are not suitable. If odor-free glassware is to be stored before use, it is helpful to keep it filled with odor-free water.

5.2.7.3 Odor-free dilution water. Odor-free dilution water should be prepared by passing tap water through a glass column 6 ft (1.8 m) in length and 2 in. (51 mm) in diameter containing granular activated carbon (mesh size about 10 × 30). A 5-gal (20-L) glass jar filled with granular activated carbon and equipped with glass tubing for water inlet and outlet is an acceptable alternative. A flow rate of no greater than 75 mL/min should be used. The water can be collected

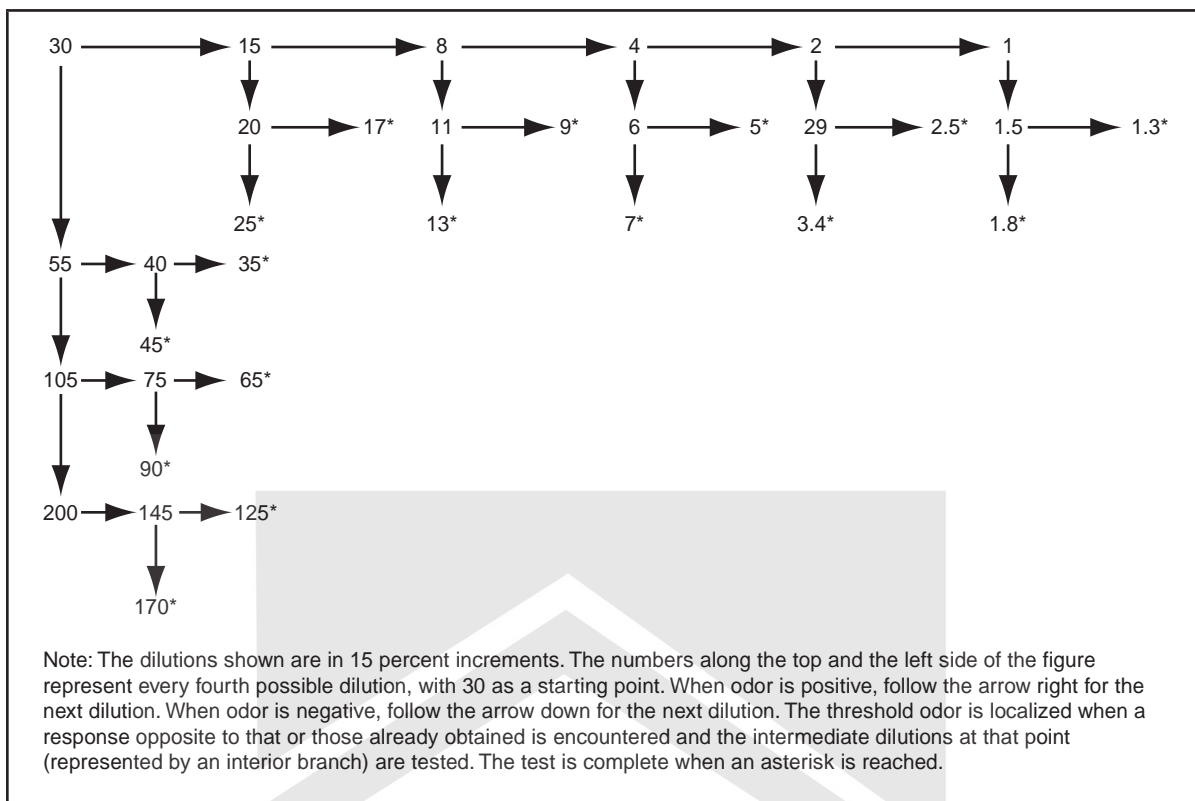


Figure 1 Parallel threshold dilution chart

and stored in clean 1-gal (4-L) jugs. Detection of odor in the water coming through the carbon indicates that a change of carbon is needed.

5.2.7.4 Apparatus.

1. Erlenmeyer flasks—six 500-mL flasks with ground-glass stoppers
2. Thermometers—two with ranges from -20°C to 100°C
3. Graduated cylinders—one each of 200-mL, 100-mL, 50-mL, and 25-mL cylinders
4. Measuring pipette—10 mL
5. Two-unit electric hot plate
6. Carbon filter-tube funnels—five 36-mm inside diameter Corning No. 9840, Kimball No. 46170, or equivalent
7. Glass wool
8. Stirring or mixing apparatus—equipped to mix at least four samples; a six-place mechanical stirrer is preferable. Stirrers should be of glass; a $\frac{3}{16}$ -in. (5-mm) glass rod of sufficient length with a $1\frac{1}{2}$ -in. (38-mm) bend at a 45° angle to the shaft is ideal. A stirring rate of $200 \text{ rpm} \pm 10 \text{ rpm}$ should be used. A 2,000-mL square jar or beaker is preferable to a 1,000-mL container because it permits pipet-



ting larger volumes of the activated carbon suspensions and improves the accuracy of the test.

5.2.7.5 Reagent. Use 1 g of activated carbon (weighed as received) and 1,000 mL of odor-free water to make an activated carbon stock suspension. One mL of this suspension contains 1 mg of activated carbon and is equivalent to a dosage of 1 mg/L when added to 1,000 mL of water to be treated.

5.2.7.6 Procedure.

1. Preliminary trials will be required to determine the range within which the activated carbon is to be applied. Generally speaking, a threshold odor of not more than 15 requires 2 mg/L to 8 mg/L of activated carbon, with a corresponding increase or decrease for higher and lower threshold values. The treatment applied must be such that an appreciable odor remains in some of the treated samples. The volume of each sample should be at least 1,000 mL. The stock activated carbon suspension should be stirred continuously at 200 rpm, \pm 10 rpm, while it is being measured into the jars.

2. The stirring time of the samples or the contact time of the activated carbon should be the same for samples evaluated. If known, the time of contact with the water in treatment plant practice is a good contact period to use. Otherwise, a 1-hr period is suggested. At the end of the contact period, the samples must be filtered quickly to obtain threshold values and conclusions as soon as possible. If it is beneficial or customary in treatment plant practice to add other chemicals to the water at the same time the activated carbon is applied, these chemicals, in amounts equivalent to those used in plant practice—with the possible exception of chlorine—should be added to the sample under examination in the same sequence as used in the plant.

3. Place about 4 g of glass wool in each filter funnel and press firmly into place. Place funnels over separate Erlenmeyer flasks. Wash the glass wool with odor-free water until the filtrate is odor free. Filter the sample through the funnels using a separate clean funnel for each sample. Discard the first 200 mL of the filtrate. Collect at least 600 mL of the filtered sample for the odor test.

4. This procedure includes the use of incremental differences of 15 percent dilution (see Figure 1) and requires two operators. Known as the “short parallel method,” it requires a diluter and an observer to achieve the greatest precision. Using this procedure, up to five different samples can be compared simultaneously. The five samples will provide for two dosages of two different activated carbons, plus a blank consisting of raw water or raw water plus any chemicals that may be



added during the test, in addition to the activated carbon. Before starting the test, prepare an adequate supply (about 4 L) of hot (60°C to 65°C [140°F to 150°F]), odor-free water. During the test, ensure that an adequate supply of hot, odor-free water is always available.

5. The diluter should label the water samples to be tested as A, B, C, and so forth. The diluter should prepare a dilution by adding 30 mL of sample A to 170 mL of odor-free water (200 mL total) in one flask. To another flask, add 200 mL of hot, odor-free water (control). Bring both flasks to 60°C (140°F) and give them, without identifying them, to the observer.

On receiving a pair of flasks from the diluter, the observer should agitate the flasks in turn, remove the stoppers, and sniff the vapors to detect any odor. If in doubt, the observer may sniff the vapors again for confirmation. The observer should report reactions to the diluter as “positive” if odor is detected and “negative” if no odor is detected. When irregular results occur, the diluter should prepare additional check dilutions to determine threshold odor level. After the observer’s reaction is noted, the flasks should be emptied, rinsed free of odor with odor-free water, and returned to the diluter. The diluter should then prepare a similar dilution for each sample. After noting the observer’s reaction to the first dilution of the samples tested, the diluter should refer to the parallel threshold dilution chart for further dilutions (Figure 1). In every case, sufficient hot, odor-free water must be added to give a total volume of 200 mL. Response to the first dilution indicates the direction—down if negative and right if positive—in which the next dilution will be found on the chart. The diluter should continue to give the observer a pair of flasks, one containing only odor-free water, until a response opposite to that of those already obtained is encountered with each sample.

After this, only two more dilutions—the second designated by an asterisk—will be necessary, unless an additional confirming dilution is needed. The results for each sample tested should include at least two positive and two negative responses. If there is only one positive response, run the next highest concentration not yet tested. If only one negative response is received, run the next lowest concentration not yet tested. The diluter should closely watch the results reported by the observer so that necessary confirming dilutions can be prepared without interrupting the continuity of the procedure. For each sample tested, the dilution containing the smallest volume of odor-bearing samples in which an odor was detected determines the threshold number. Refer to the parallel threshold chart (Table 1).

**Table 1 Parallel threshold dilution chart**

Sample Volume <i>mL</i>	Threshold Number	Sample Volume <i>mL</i>	Threshold Number	Sample Volume <i>mL</i>	Threshold Number
200	1.0	35	6	6.0	35
170	1.2	30	7	5.0	40
145	1.4	25	8	4.0	50
125	1.6	20	10	3.4	60
105	1.9	17	12	2.9	70
90	2.2	15	13	2.5	80
75	2.7	13	15	2.0	100
65	3.0	11	18	1.8	110
55	3.5	9	22	1.5	135
45	4.5	8	25	1.3	150
40	5.0	7	30	1.0	200

Sec. 5.3 Rejection

5.3.1 Notice of nonconformance. If the PAC delivered does not meet the requirements of this standard or the purchase documents, a notice of nonconformance must be provided by the purchaser to the supplier within 15 days after receipt of the shipment at the point of destination. The results of the purchaser's test shall prevail unless the supplier notifies the purchaser within five days of the notice of nonconformance that a retest is desired. On receipt of the request for a retest, the purchaser shall forward to the supplier one of the sealed samples taken according to Sec. 5.1. In the event that the results obtained by the supplier on retesting do not agree with the results obtained by the purchaser, the other sealed sample shall be forwarded, unopened, for analysis to a referee laboratory agreed on by both parties. The results of the referee's analysis shall be accepted as final.

5.3.2 Remedies. If the material does not meet the chemical, physical, safety, or security requirements of this standard, the supplier shall be notified promptly after observing the noncompliance. The supplier shall provide to the purchaser an adjustment that is agreed on between the supplier and the purchaser reflecting the diminished quality of the product.



SECTION 6: DELIVERY*

Sec. 6.1 Marking

Each shipment of material shall carry with it some means of identification.

6.1.1 *Packaged material.* Each container of PAC shall have marked legibly on it the net weight of the contents, the name of the manufacturer, country of origin, the lot number, a brand name, if any, and shall bear other markings as required by applicable regulations and laws.†

6.1.2 *Bulk material.* When shipped in paper bags, bulk bags, and bulk trailers, the information required in Sec. 6.1.1 for packaged material shall accompany the bill of lading.

6.1.3 *Conformance with standard (optional).* Containers may bear the statement: “This material meets the requirements of ANSI/AWWA B600, Powdered Activated Carbon,” provided that the requirements of this standard are met and the material is not of a different quality in a separate agreement between the supplier and the purchaser.

Sec. 6.2 Packaging and Shipping

6.2.1 *Containers.* PAC shall be shipped in paper bags, bulk bags, and bulk trailers in accordance with the applicable federal, state, local, and provincial regulations. Paper bags may contain from 35 lb to 150 lb (16 kg to 68 kg) in each package and semibulk containers may contain 500 lb (363 kg) to 2,000 lb (908 kg) or another quantity as agreed on between the purchaser and the supplier.

6.2.2 *Package shipments.* Paper bag and bulk bag packages used in shipments of activated carbon in less than carload lots shall be protected by an outer package of a resistant nature to avoid tearing the bags. Complete protection from weather shall be provided for the individual packages or by the conveyance.

6.2.3 *Tolerances.* The net dry weight of the packages shall not deviate from the recorded weight by more than ± 5 percent. Objections to the weight of the material received shall be based on a certified unit weight of not less than 10 percent of the packages shipped, which are selected at random from the entire shipment.

* Governmental marking, packaging, and shipping references reflect US requirements. Users of ANSI/AWWA B600 outside the United States should verify applicable local and national regulatory requirements.

† Because of frequent changes in these regulations, their specific provisions should not be included in the purchase documents.

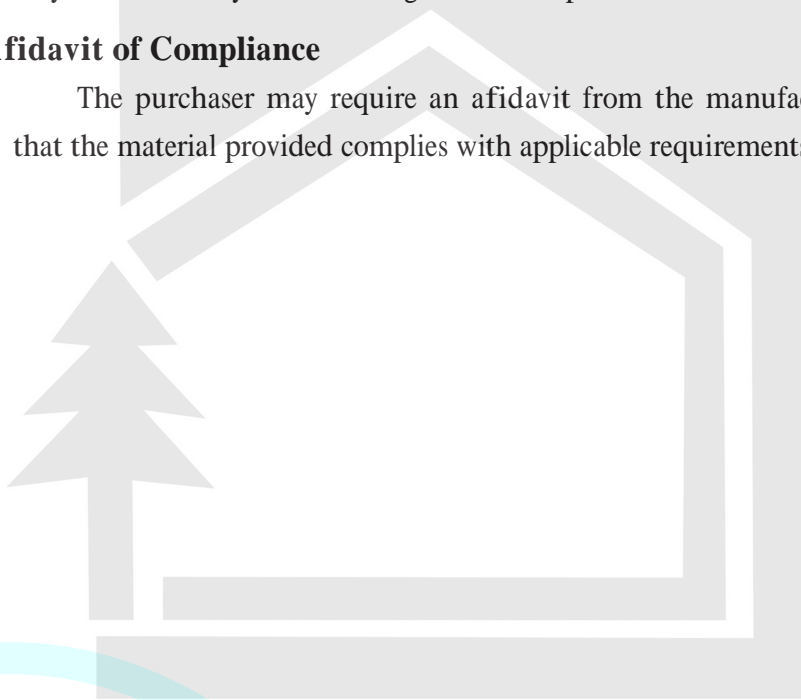


6.2.4 *Bulk shipments.* Bulk shipments of activated carbon shall be in cars or trucks with tight closures to avoid loss and contamination of the material in transit. The interior of the cars or trucks shall be clean and free from dirt, corrosion, scale, and other sources of contamination. Shipments in open-top, hopper-bottom cars are acceptable only with adequate provisions for covering the material and keeping it contained and protected during shipment. The type of freight car or hopper car shall be agreed on between the supplier and the purchaser before shipment. The criteria for choosing a car are the type of handling equipment and the unloading facilities at the point of destination.

6.2.5 *Weight certification (bulk).* Bulk shipments shall be accompanied by weight certificates of certified weighers, if specified by the purchaser, or the weights may be checked by certified weighers for the purchaser on delivery.

Sec. 6.3 Affidavit of Compliance

The purchaser may require an affidavit from the manufacturer or supplier that the material provided complies with applicable requirements of this standard.



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APPENDIX A

Bibliography

This appendix is for information only and is not a part of ANSI/AWWA B600.

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APPENDIX B

MIB/Geosmin and Tannin Values Tests

This appendix is for information only and is not a part of ANSI/AWWA B600.

SECTION B.1: MIB/GEOSMIN TEST

Sec. B.1.1 Performance-based Evaluation for 2-methylisoborneol (MIB) and Geosmin

The PAC evaluation test described here is designed to assist a utility in choosing the most cost-effective PAC for taste-and-odor removal. If this procedure is to be used to evaluate PAC bids, one of the compounds should be selected to represent the removal of both, so that conflicting results may be avoided.

This procedure is based on the principle that for water of a given quality, one dose of each type of PAC will produce a fixed removal percentage independent of initial concentration of the target geosmin or MIB. Therefore, choice of initial concentration of target compound should be based on ease of measurement and cost of the compound. An initial concentration of 50 ng/L works well for these studies.

Sec. B.1.2 Reagents and Equipment

B.1.2.1 Reagents

1. Raw water. Collect raw water in a 5-gal high-density polyethylene (HDPE) carboy. Transfer 18 L of the raw water to a second HDPE carboy (e.g., volumetrically using a 1-L graduated cylinder or use a second carboy calibrated to 18 L).
2. Test MIB/geosmin solution. To prepare a 50-ng/L MIB and geosmin solution matrix, add 9.0 μL of the reagent 100- $\mu\text{g/mL}$ MIB and geosmin solution to the 18 L of raw water. Magnetically mix for 30 min. Note: If it is known that MIB/geosmin concentrations are other than 50 ng/L, one can still follow this step because at these concentrations the initial concentration of MIB and/or geosmin will not affect percent removal. In addition, if it is known that MIB and/or geosmin are present in the raw water, determine concentration present via *Standard Methods for the Examination of Water and Wastewater*. In this case, there is no need to spike the raw water as previously described.
3. PAC slurry. Prepare a homogenous PAC slurry with a concentration of 10,000 mg of “as-received” PAC per liter of organic-free water. For example, weigh



out 1.0 g of “as-received” PAC. Transfer activated carbon to 100 mL of organic-free water in a 100-mL glass vial. Seal vial with screw-on PTFE or nonstick-coated top. Magnetically stir for 10 min. When not in use, PAC slurry should be stored in a dessicator. Prior to using PAC slurry for test, mix again for 10 min.

4. Test coagulant solution. Prepare a 10,000-mg/L concentrated coagulant solution by first weighing 5,000 mg of coagulant. Transfer weighed coagulant to 500 mL of organic-free water in an amber glass bottle and magnetically mix for 10 min. Store in a cool, dark place.

5. Other chemicals (e.g., polymers, oxidants, etc.). If other treatment chemicals are added during the full-scale purification of raw water, prepare concentrated solutions as per Sec. B.1.2.1(4).

B.1.2.2 *Equipment*

1. Jar testing apparatus
2. Timer
3. Vacuum filter apparatus and 0.45-mm filter paper

Sec. B.1.3 **Performance Test Procedure**

B.1.3.1 *Preparation*

1. Evaluate and record unit operations of a full-scale plant to determine the time scale for the addition of various treatment chemicals (i.e., at what point in the plant are the individual chemicals added). These times should mirror those times used during the jar testing experiment below.

2. Evaluate and record the known concentration of treatment chemicals (e.g., coagulant, polymer, oxidant, etc.) added during full-scale operation and prepare test solutions for these chemicals, as discussed in Sec. B.1.2.1(4). These concentrations should mirror those used during the jar testing experiment.

3. If, historically, PAC is used at the full-scale plant for taste-and-odor removal, PAC doses for the jar testing experiment should surround these historical concentrations. Otherwise, doses of 0, 10, 20, 30, and 40 mg/L should be adequate to establish a dose response curve that can be used to evaluate the performance of the activated carbons. The zero addition will serve as the control. The sixth jar should serve as a duplicate for quality control purposes. A tighter tolerance of PAC doses can be used once the initial curve has been established, if so desired.

4. Evaluate full-scale treatment objective for MIB and geosmin removal (i.e., what are the target plant effluent MIB and geosmin concentrations). The odor threshold concentrations for MIB and geosmin are between 9 and 13 ng/L, so the treatment objective should be less than this range. (Note: the exact treatment objective is dependent on the sensitivity of the customers.)



To best explain the performance test procedure, an example will be used with generic chemical doses and contact times. The following example pertains to a water utility that doses PAC at the raw water intake, allowing for a contact time of 5 min before reaching the rapid mix basin: 80 mg/L of alum is added at the rapid mix basin, which, when combined with flocculation, lasts 20 min; subsequently, the water settles for 2 hr. (Clearly, this portion of the procedure requires careful attention so that the jar-testing experiment accurately mimics full-scale operation.)

B.1.3.2 Procedure

1. Transfer 2 L of the test MIB/geosmin solution to each jar of the jar-testing apparatus.
2. Turn on mixer to 60 to 80 rpm (or G equivalent).
3. To each jar, simultaneously add 0, 2, 4, 6, 8, and 8 mL (these volumes correspond to PAC doses of 0, 10, 20, 30, 40, and 40 mg/L, respectively) of the PAC slurry. (The second 40-mg/L dose is for quality control purposes.) Start timer. Mix each jar at 60 to 80 rpm (or G equivalent) for 5 min.
4. At the end of the 5 min, to each jar simultaneously add 160 mL (equivalent to 80 mg/L) of the coagulant slurry. Reduce mixing speed to 30 rpm (or G equivalent) for 20 min.
5. At 25 min (5 min at 60 to 80 rpm and 20 min at 30 rpm), cease mixing and let jar contents settle for 2 hr.
6. After settling, collect, with as little disturbance as possible, approximately 1,200 mL of settled water and immediately vacuum filter.
7. Transfer filtrate to analysis containers (see *Standard Methods for the Examination of Water and Wastewater* for the analysis of MIB and geosmin in water).

B.1.3.3 Calculations

1. Once analysis of the samples from the jar test procedure has been completed, including a control (i.e., zero carbon jar), determine the percentage of MIB and geosmin removed for each carbon dose, using the following equation:

$$\% \text{ removed} = \frac{(\text{control concentration} - \text{final concentration})}{\text{control concentration}} \times 100$$

For example, if the control MIB concentration is determined to be 50 ng/L and the final MIB concentration from a particular PAC dose is 8 ng/L, the percent removal achieved by that carbon dose is 84 percent.

2. Plot the carbon doses on the x-axis and the percent removals on the y-axis for each PAC. The connection of points on the plot results in a dose removal or response curve.

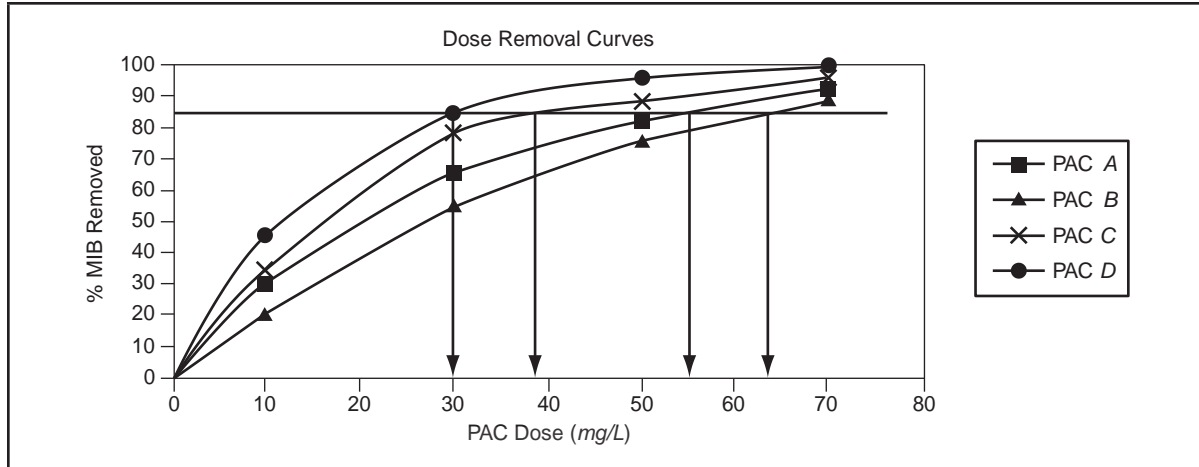


Figure B.1 Example of calculation of PAC dose-equivalent performance factors

3. The figure can then be used to develop performance factors that can be used subsequently to develop weighted PAC costs for the carbons of interest. Additionally, once it is determined which carbon is favored, its curve can be used for determining the proper PAC dose during taste and odor episodes. This is detailed in the following example (Figure B.1).

The following example outlines the method to determine performance factors for those carbons evaluated once the dose removal curves have been graphed.

1. The control for MIB (i.e., concentration in raw water or spiked concentration) = 50 ng/L.
2. The treatment target concentration = 8 ng/L, therefore, 84 percent removal is required.
3. Follow from the y-axis at 84 percent MIB removal to the right to the point at which it intercepts each PAC curve. Draw a line down to the x-axis to the corresponding dose. Repeat for each PAC curve and record corresponding dose. For example, the line from 84 percent MIB removal intercepts PAC D at a dose of 30 mg/L.

4. Divide the dose for each PAC that achieves the target removal (i.e., 84 percent) by the smallest dose of the PAC that achieves the target removal. This determines the relative performance factors. For example,

- PAC D = $30/30 = 1.00$
- PAC C = $38/30 = 1.27$
- PAC A = $55/30 = 1.83$
- PAC B = $63/30 = 2.10$

**Table B.1 Example weighted cost determined by performance factors**

PAC	Cost/Ton	Performance Factor	Weighted Cost
D	\$1,000	1.00	\$1,000
C	\$895	1.27	\$1,137
A	\$1,010	1.83	\$1,848
B	\$800	2.10	\$1,680

5. Determine the weighted cost (i.e., cost based on performance) by multiplying each PAC cost by its performance factor determined in step (d) above. Example costs are used in Table B.1.

6. Repeat calculations 1 through 5 for geosmin.

7. Final weighted cost determination can be made based on MIB factors, geosmin factors, or combination of the two. The utility should use historical data to determine which is appropriate. If no historical data is available, an average of the MIB factor and the geosmin factor is a reasonable approach to determining the final weighted cost.

SECTION B.2: TANNIN VALUE TEST

Sec. B.2.1 Tannin Value Test

The tannin value is defined as the concentration of activated carbon in milligrams per liter required to reduce the standard tannic acid concentration from 20 mg/L to 2 mg/L.

Sec. B.2.2 Procedure

B.2.2.1 Reagents.

1. Buffer solution. Dissolve exactly 133 g of Na_2HPO_4 in distilled water and make up to 12 L. Slowly add sufficient concentrated phosphoric acid to bring pH to 6.5 ± 0.1 (this should require approximately 17 mL of acid).

2. Tannic acid test solution (20 mg/L). Dissolve exactly 0.20 g of tannic acid (Merck National Formulary) into a 1-L portion of buffer solution. Blend the solution thoroughly with 9 L of buffer solution (giving 10 L total). The solution should be prepared fresh daily.

B.2.2.2 Activated carbon dosage.

1. Weigh out 80 mg, 160 mg, 240 mg, and 320 mg of “as received” activated carbon. Place in 1,000-mL beakers and add 800 mL of 20-mg/L tannic acid test solution.



2. Place the beakers on a paddle gang stirrer using an 800-mL portion of tannic acid test solution without activated carbon as a control. Stir samples at a uniform speed sufficient to keep activated carbon in suspension through the mixing period. Flat-type paddle mixers with an area of approximately 2 in.² (1,290 mm²) will require a speed of at least 100 rpm. Small propeller-type paddles require speeds of 100 rpm to 200 rpm, depending on the size of the paddle. Stir for 1 hr.

3. Remove beakers from stirrer. Immediately vacuum filter 200 mL of each sample through one sheet of 0.8-μm Millipore paper or equivalent for analyses. Filtration equipment that is used should be cleaned thoroughly and rinsed with distilled water prior to use.

B.2.2.3 Residual tannin determination. Determine the residual tannin concentration for each activated-carbon-treated filtrate by either the ultraviolet (UV) absorbance method or the colorimetric method according to the following procedures:

1. UV absorbance method. Tannic acid can be determined by UV absorbance at 275 μm. A 1-cm silica cell should be used for the control and for lower activated carbon dosages. A 5-cm cell length should be used for higher dosages or, if absorbance in a 1-cm cell is less than 0.1, a 5-cm cell should be used. Each reading should be made with buffer solution in the reference cell. The concentration of tannic acid in the activated-carbon-treated samples is determined by using a standard curve made by diluting 10 mL, 20 mL, 40 mL, and 70 mL of the original tannic acid test solution to 100 mL with buffer solution.

2. Colorimetric method. Tannin-lignin reagent. Dissolve 100 g of sodium tungstate dihydrate, Na₂WO₄·2H₂O; 20 g of molybdicphosphoric acid (also called phosphomolybdic acid), 20MoO₃·2H₃PO₄·48H₂O; and 50 mL of 85 percent phosphoric acid, H₃PO₄, in 750 mL distilled water. Boil the liquid under reflux for 2 hr; cool and make up to 1 L with distilled water.

Sodium carbonate solution. Dissolve 200 g of Na₂CO₃ in 500 mL of warm distilled water and dilute to 1 L to form a saturated solution. Store in a rubber-stoppered bottle. Add 2 mL of tannin-lignin reagent to 50 mL of clear sample and mix well. After 5 min, add 10 mL of sodium carbonate solution and mix thoroughly. Wait 10 min for color development. Determine tannic acid concentration using a standard curve made by diluting 10 mL, 20 mL, 40 mL, and 70 mL of the original tannic acid test solution to 100 mL with buffer solution. Use the following guide for the instrumental measurements at 600-μm wavelength:



Tannic acid in 62 mL final volume— μg	Light path—cm
50–600	1
10–150	5

If a suitable colorimeter is not available, the tannic acid concentration can be estimated visually using 100-mL matched, tall-form Nessler tubes. Determine the color intensity of the treated samples in the Nessler tubes with that of known concentrations of tannic acid prepared by dilution of the control with buffer solution. The tubes are viewed lengthwise from the top against a white background.

B.2.2.4 Calculations.

1. A data table is prepared giving the mg/L activated carbon, mg/L tannic acid remaining, and mg/L tannic acid removed. The mg/L removed per mg/L activated carbon (X/M) for each sample is calculated.

2. Plot the results on double logarithmic paper (2 by 2 cycles) to establish the relationship between the activated carbon dosage and the total amount of tannic acid remaining for each sample of the previous series (see Figure B.2). A

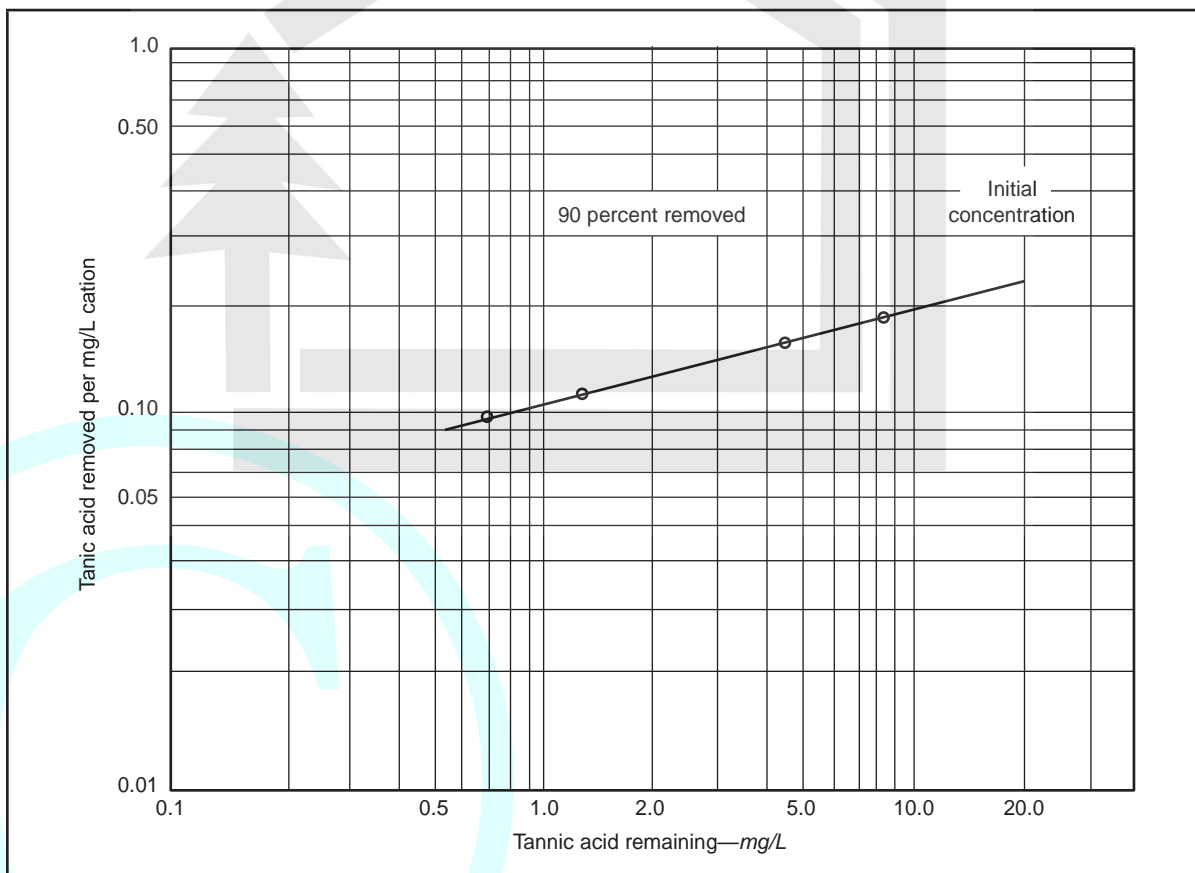
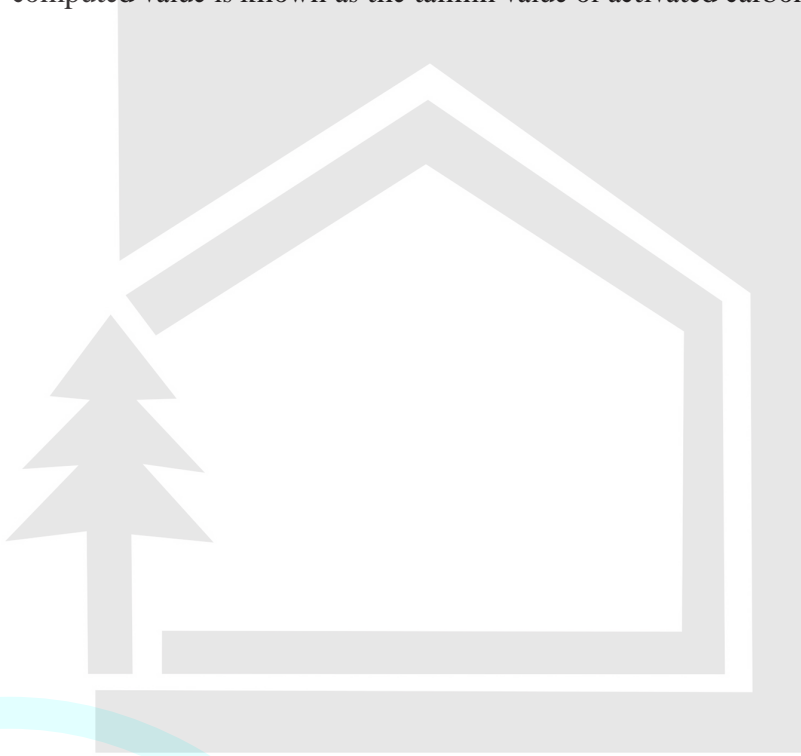


Figure B.2 Sample determination of tannin extract by carbon adsorption



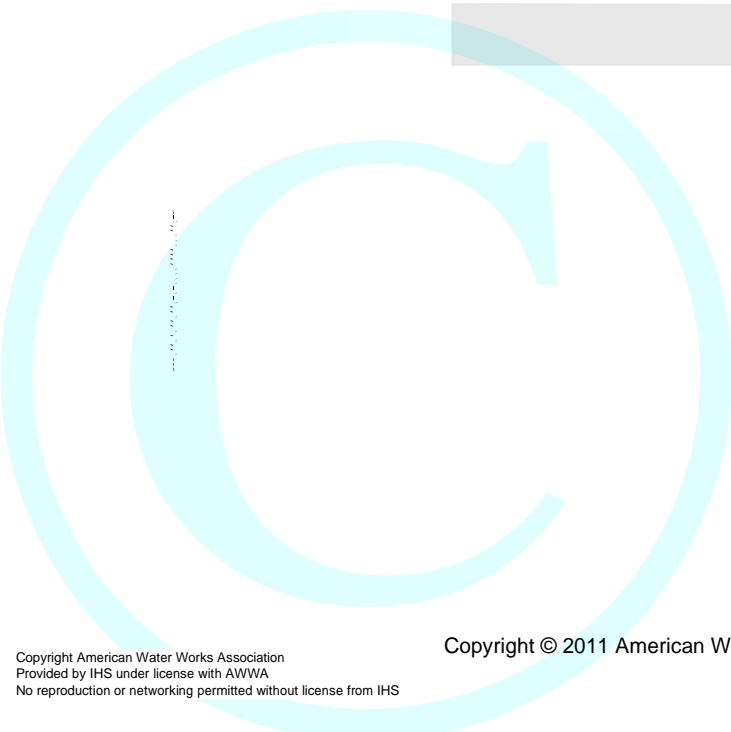
straight-line plot will be obtained by plotting the total amount of tannic acid removed in mg/L per mg/L of activated carbon at each activated carbon dosage as the ordinate and the corresponding mg/L of original tannic acid remaining as the abscissa. When plotting the line between points, the least squares method should be used to establish the correct position of the line.

3. The effectiveness of the activated carbon for tannic acid removal is obtained from the plot by determining the adsorption value of the activated carbon (the total amount of tannic acid removed per unit weight of activated carbon) corresponding to the 2-mg/L tannic acid residual (90 percent removal), and dividing it into the total amount of tannic acid removed (18 mg/L tannic acid). This computed value is known as the tannin value of activated carbon.





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