Interim Recommendations for Granular Activated Carbon (GAC) Installations - Design Review, Startup and Operations

This document is intended for use by local health departments (LHD) and New York State Department of Health (NYSDOH) engineering staff that review and approve granular activated carbon (GAC) treatment at public water systems (PWS). These recommendations are intended to be applicable to most GAC installations, but the LHD or NYSDOH should exercise best professional judgement during the review and approval process.

Contents

I. Definitions

Contactor: (a.k.a vessel, carbon contactor) A pressurized container in which granular activated carbon is held and through which water flows for the purpose of contacting the water with the granular activated carbon for contaminant removal.

Empty Bed Contact Time (EBCT): The amount of time water spends in contact with the GAC is quantified as the EBCT, which is calculated as the volume of the empty bed divided by the design flow rate.

Granular activated carbon (GAC): Activated carbon is commonly used to adsorb natural organic compounds, taste and odor compounds, and synthetic organic chemicals in drinking water treatment. Several raw materials can be used to make GAC, resulting in different final properties, including affinity for any specific contaminant. Final products can be manufactured to a variety of sizes. See American National Standards Institute (ANSI)/American Water Works Association (AWWA) Standard B604 for more information on GAC.

GAC10: Granular activated carbon filter beds with an empty-bed contact time of 10 minutes based on average daily flow and a carbon reactivation or replacement frequency of every 180 days, except that the reactivation frequency for GAC10 used as a best available technology for compliance with total trihalomethanes (TTHM) and haloacetic acids (five) (HAA5) maximum contaminant levels (MCLs) shall be 120 days (10 New York Codes, Rules and regulations (NYCRR) 5-1.1(aq)).

GAC20: Granular activated carbon filter beds with an empty-bed contact time of 20 minutes based on average daily flow and a carbon reactivation frequency of every 240 days (10 NYCRR 5-1.1(ar)).

GAC gravity filters: GAC may be used as a filtration media layer in conventional surface water treatment plant gravity filters. In this configuration, the GAC provides both particulate removal via filtration and chemical contaminant removal by adsorption. For simplicity, only contactors are referenced in this document, but most sections are equally applicable to gravity filters.

Lag contactor: When contactors are used in series as a lead-lag pair, the second contactor through which water flows is designated as the lag contactor. Lead and lag configuration in the treatment train can often be switched using valves.

Lead contactor: When contactors are used in series as a lead-lag pair, the first contactor through which water flows is designated as the lead contactor. Lead and lag configuration in the treatment train can often be switched using valves.

Treatment train: A GAC system may be comprised of one or more treatment trains, with each treatment train consisting of either a single contactor or multiple contactors in series. Each treatment train is designed to function as an individual unit within the GAC system capable of providing complete GAC treatment of the water which passes through that treatment train.

II. Design Plans and Specifications

A. General Design Considerations

Plans submitted to LHDs or NYSDOH should generally follow the requirements of Recommended Standards for Water Works Part 1 – Submission of plans. Reviewers should exercise best professional judgement in determining the applicability of any specific item based on the scope of the project. An engineer's report should accompany all submissions. Consideration should be given to downstream treatment processes and pump capacity.

The design parameters for the GAC system should be discussed in the engineer's report. The use of small scale or pilot testing to determine the design parameters is recommended. Where small scale or pilot testing is not completed, the design parameter values should be justified in the engineer's report. Such justifications will generally be based on design and performance of other GAC systems with similar water quality, contaminant concentrations and treatment requirements. The GAC design parameter discussion should, at a minimum, include:

- Number and size of GAC contactors and typical flow configuration;
- Depth of media when used as part of a surface water treatment plant gravity filter;
- GAC media selection;
- Empty bed contact time (EBCT);
- Potential competition for GAC adsorption sites by total organic carbon or other contaminants; and
- Anticipated lifespan of the GAC.

At least two contactors should be provided unless approved by the LHD or NYSDOH. These may be installed in series (lead-lag), parallel, or other approved configurations, which provide redundancy to allow for GAC system maintenance. Installing a single contactor may be considered only when the water system demonstrates it can meet the system maximum day demand with the source and GAC system out-of-service.

At a PWS where a single contactor may be placed into operation for any period of time (e.g. when a single contactor is being installed, when one contactor of a lead-lag pair is removed from service for maintenance, or when contactors may be operated in parallel rather than series) each contactor should be able to provide the required level of treatment, including EBCT, while remaining within the designed system operational parameters. When two or more treatment trains are provided, the GAC system should be capable of meeting the water treatment plant design capacity with one treatment train out-of-service and at a flow rate through the remaining contactors not to exceed that which has been approved for the GAC contactors.

GAC manufacturers generally recommend against regularly applying chlorinated water to the GAC because it will shorten the lifespan of the GAC media. Where pre-chlorination is required for normal operation, the chlorine concentration reaching the GAC should be minimized and any impacts on the GAC discussed as part of the engineer's report. Where changes to chlorine location or concentration are made, contact time (CT) calculations (as defined in 10 NYCRR 5-1.1(v)) demonstrating compliance shall be provided in the engineer's report.

The anticipated head loss across the GAC should be accounted for in the system design. The engineer's report should demonstrate that available head is sufficient to achieve the desired flow rate through the GAC at the anticipated maximum head loss or should include additional pumping as part of the design. Minimum system pressures following the GAC system must be maintained in conformance with 10 NYCRR 5-1.

A bypass around a GAC system may be provided, subject to the approval of the LHD or NYSDOH. Bypasses must be provided with protection to preclude cross-contamination of GAC treated water with non-GAC treated water by means of a removable spool piece, or other means approved by the LHD or NYSDOH. Depending on the target contaminant and local requirements, bypass using a single valve may be acceptable on a case-by-case basis.

Seasonal operation of a GAC system may lead to microbial growth in the GAC media. Systems proposing to operate the GAC system seasonally should include in the engineer's report a plan to prevent any negative impacts to water quality due to microbial growth in the contactors while not in use.

B. System Design Features

Recommended Standards for Water Works Part 2 – General Design Considerations is applicable for most designs. Reviewers should exercise best professional judgment in determining applicability of any specific item. Table 1 lists several technical design considerations that should be considered during the review of GAC plans and specifications.

Table 1: Technical Considerations for the Review of GAC Plans

Concept	Technical Considerations
GAC delivery	Sufficient space onsite for GAC delivery and removal trucks, noting that the trucks used to remove spent GAC from the site should be dewatered for several hours prior to departure.
	Accommodations in the building design for GAC transfer hoses, compressed air lines and water hoses from the GAC contactors to the GAC truck as needed to accomplish GAC transfer.
Treatment system location	Located within a building with appropriate environmental controls including lights, heat, and dehumidification.
	Adequate building size and layout for all operation, monitoring and maintenance tasks.
Equipment design	All water contact materials approved by the LHD or NYSDOH or certified for compliance with ANSI/National Science Foundation (NSF) Standard 61.
Contactor design	Even flow distribution across the inlet of the GAC bed.
	An underdrain system to collect the water after the GAC bed and to uniformly distribute backwash water.

Concept	Technical Considerations
Contactor design, cont.	An accessible manhole of adequate size to facilitate inspection and repairs for contactors 36” or more in diameter. Sufficient handholds for filters less than 36 inches in diameter. Manholes should be at least 24 inches in diameter where feasible.
	GAC fill pipe and fittings and GAC removal pipe and fittings.
	Compressed air fitting(s) where compressed air is to be used for GAC transfer. If compressed air is proposed as the motive force during the GAC transfer process, provisions for providing compressed air at the GAC truck unloading location(s) and at all GAC contactors should be provided. Use of an appropriately sized portable unit on an as needed basis may be appropriate.
	GAC treated water at each GAC truck unloading location for GAC wetting and at each GAC contactor for contactor washdown and necessary maintenance tasks. Appropriate backflow prevention shall be provided.
	GAC treated water at each contactor to facilitate backwash. Water should have sufficient quantity, flow and pressure for backwash per manufacturers recommendations. Appropriate backflow prevention and a means for controlling and measuring the rate of flow should be provided.
	Space above the GAC bed to allow the recommended bed expansion without GAC loss during backwash.
	A means of identifying the position of each contactor in the series where multiple contactors may be used in series. If the order of the contactors in the series can change, ability to change label positions accordingly.
	Chemicals introduced downstream of the GAC system where it will not compromise other treatment processes. Evaluation of potential impacts to the GAC for chemicals which must be introduced upstream of the GAC system.
	Introduction of phosphate downstream of the GAC system.

Plans and specifications should also be reviewed to ensure the system can be adequately operated and monitored once the system is installed. Table 2 outlines operational considerations that should be incorporated into GAC plans and specifications.

Table 2: Operation Considerations for the Review of GAC Plans

Concept	**Operation Considerations**
Pressure and flow control	Pressure relief fail-safes
	Pressure gauges before and after each contactor such that it is possible to determine the head loss across each contactor. Where contactors are operated in series, gauge(s) to measure the pressure before and after each contactor for all possible flow configurations through the series.
	A high point following the GAC contactor(s) with vacuum breaker or other means for preventing the GAC contactor(s) from being dewatered due to a downstream loss of pressure. Air releases at high points as necessary.
	A flow meter for each treatment train.
	Isolation valves between each contactor.
Operation to waste	Forward rinse to waste and backwash to waste capability with appropriate backflow prevention and sample tap(s).
Sample collection	Sampling taps before and after each GAC contactor. Where contactors are operated in series, samples tap(s) before and after each contactor for all possible flow configurations through the series. Where a single contactor is installed, sample ports within the contactor (e.g. at 25%, 50%, and 75%) are recommended.

III. Startup and Operations

A. Startup

Prior to system startup, pipes and their fittings should be hydrostatic tested in accordance with AWWA C605 for polyvinyl chloride (PVC); American Society for Testing and Materials (ASTM) F2164 for high density poly ethlylene (HDPE); or AWWA C600 for ductile iron. In addition, pipes, contactors, gravity filters and appurtenances shall be disinfected in accordance with AWWA C651 for pipes; AWWA C652 for contactors and AWWA C653 for gravity filters and other water treatment plant components. Modifications to standards are subject to the approval of the LHD or NYSDOH.

See the *Carbon Changeout Procedure* subsection under Section III. C. Carbon Changeout for additional details on the carbon placement and preparation process. During the initial GAC placement and startup process the design flow rate through the contactor should be tested during forward flushing, but a lesser flow rate may be used for most of the forward rinse to waste period if necessary.

Startup Monitoring

See the *Carbon Changeout Sampling Criteria* subsection under Section III. C. Carbon Changeout for sampling requirements for newly placed GAC. In addition to those requirements, the following sampling should be incorporated into the startup of new GAC installations.

A limited Part 5 analysis from a sample location representative of all new construction should be conducted as part of the startup sampling. All samples shall be analyzed at an Environmental Laboratory Approval Program (ELAP) certified lab following approved methods. At the discretion of the LHD, the system may be placed into service prior to receipt of all results. The limited Part 5 analysis should include at a minimum the analytes listed in Subpart 5-1 Tables 8B, 8D, 9C, and 9D of the State Sanitary Code (SSC), except, at the discretion of the LHD, the following parameters may be excluded unless it is a target compound for the GAC system:

- Fluoride
- Bromate (unless ozone is used prior to GAC)
- Chlorite (unless chlorine dioxide is used prior to GAC)
- Color
- Odor
- Diquat
- Endothall
- Glyphosate
- Dioxin

PWS should be returned to standard (6 month) monitoring for lead and copper following the installation of a new GAC treatment system.

B. Routine Monitoring

GAC systems should be monitored routinely to ensure that they are operating as designed.

Routine Target Contaminant Monitoring

It is recommended that all systems that have GAC treatment installed remain on quarterly monitoring to ensure the requirements of 10 NYCRR 5-1 are being met for the target contaminant(s), and to ensure GAC is replaced at the appropriate frequency. Monitoring may be reduced at the discretion of the LHD once changeout frequency is established. Additional monitoring may be requested by the LHD to ensure that the system continues to meet regulatory requirements. To ensure monitoring is conducted at the appropriate location(s), sample taps should be clearly identified, and a naming convention should be adopted.

If only a single contactor is installed, monitoring is recommended at intermediate ports (i.e. 25%, 50% and 75% of the contactor). Where multiple contactors are used in series, routine monitoring between contactors is recommended. Monitoring the progression of the contaminant(s) through the GAC is useful for estimating the remaining time until GAC change out will be necessary. Modifications to established monitoring schedules are at the discretion of the LHD.

Routine Nitrate Monitoring

Systems with detectable amounts of nitrate in the source water should develop a routine nitrate monitoring plan. Nitrate can weakly adsorb to the GAC, increasing the risk of a nitrate MCL violation once the nitrate breaks through the GAC. Breakthrough may occur at a higher concentration than is present in the source water as nitrate is displaced from the GAC by more strongly adsorbing contaminants.

Routine Supplemental Microbial Monitoring

Routine testing of GAC effluent to monitor for excessive microbial growth in the GAC contactors may be required at the discretion of the LHD. Monitoring can consist of total coliform (TC) and E. coli (EC) or heterotrophic plate counts (HPC) samples.

Water exiting each GAC contactor should be of similar bacteriological quality as the water entering. Source waters without a history of TC-positive samples should not produce TC-positive post-GAC samples. Source waters known to be TC-positive can be expected to produce occasional TC-positive post-GAC samples. Enumerated TC/EC samples can be a useful tool for differentiating between positive results due to source water and those which may indicate contamination of the GAC. Where HPC tests are used, determinations would be based on counts.

C. Carbon Changeout

GAC replacement should occur prior to exceeding the MCL for the target contaminant. The rate of replacement will be impacted by the contaminant concentration, flow rate, type of carbon used and presence of co-contaminants.

Reactivation of GAC may be acceptable, subject to approval by the LHD. Where reactivated GAC is to be used, sufficient documentation should be available to demonstrate that the same GAC sent out for reactivation was returned to the water system. Consideration should be given to performance loss, if any, of the reactivated GAC. Sufficient time will need to be built into the schedule to accommodate the reactivation process. See ANSI/AWWA B605 for additional information on reactivation of GAC.

Carbon Changeout Criteria

Sufficient time should be incorporated into the changeout plan to accommodate initial sample analysis and reporting time, scheduling delivery, completing changeout and post-changeout sample analysis and reporting. Initiation of changeout when a sample result indicates the GAC effluent concentration of the target contaminant is greater than or equal to one-half of the MCL may be a useful initial changeout trigger. Refinement of changeout triggers should be based on sample results in consultation with the LHD.

Carbon Changeout Procedure

Following placement of GAC in the contactors, a wetting period is needed to allow the GAC pores to fill with water prior to backwashing. In accordance with AWWA B-604, if the GAC is placed as a slurry, backwash may begin as soon as four hours after placement. If placed dry, the GAC should be completely submerged for approximately 24 hours before backwash.

After the wetting period, GAC backwashing is necessary to remove fines and level the GAC bed. It should start at a moderate flow rate and be stepped up to the recommended backwash flow rate, and then stepped back down. Flow rates and the duration for each flow rate should be specified. The backwash waste should be observed periodically during the process to monitor fines removal and to check for excessive GAC loss.

Forward flushing to waste may begin immediately following backwash completion when sufficient waste handling capacity is available. Forward flushing is used to remove any remaining fines and to send to waste any contaminants which may initially leach from the GAC. It is recommended that all water from the GAC be sent to waste until test results indicate acceptable water quality. Should results not be acceptable, additional forward flushing followed by additional sampling should be required.

Carbon Changeout Sampling Criteria

It is recommended that sampling of the GAC system be completed and the results reviewed and approved by the LHD prior to placing the system into service. Typically, these will be collected immediately following the forward rinse to waste process. All samples shall be analyzed at an ELAP certified lab following approved methods. Recommended samples and criteria for determining the acceptability of results are as follows:

- Turbidity ≤ 0.3 nephelometer turbidity units (NTU) in the effluent of each contactor.
- Target compound concentration(s) shall be below applicable MCLs or other agreed upon startup target concentration(s).

Arsenic

Arsenic is a naturally occurring inorganic often removed from the GAC during the initial forward rinse to waste. At least three samples should be collected during forward rinse to waste at no less than 30-minute intervals. Results for three consecutive results should be provided which show decreasing arsenic concentrations as the forward rinse to waste progresses and for which the last sample concentration is below the arsenic MCL.

At the discretion of the LHD, arsenic sampling may be waived, if information is provided which indicates detectable amount of arsenic in the water produced during the forward rinse to waste is not expected due to the GAC source material or treatment of the GAC by the manufacturer.

Microbiological

A minimum of two samples for total coliform and E. coli (TC/EC) should be collected at least 30 minutes apart during the forward rinse to waste. When a forward rinse to waste is not provided, samples should be collected downstream of the GAC but prior to disinfection once the GAC system is online. Water exiting each GAC contactor should be of similar bacteriological quality as the water entering. Source waters without a history of TC-positive samples should not produce TC-positive post-GAC samples. Source waters known to be TC-positive can be expected to produce occasional TC-positive post-GAC samples. Enumerated TC/EC samples can be a useful tool for differentiating between positive results due to source water and those which may indicate contamination of newly placed GAC.

<u>pH</u>

New and reactivated GAC may cause a temporary pH change once placed into service. The pH change, typically an increase, can be significant and can potentially impact downstream processes including disinfection and optimal corrosion control. The pH change will decrease as more water is treated and the effluent pH will return to the influent value. This potential increase should be anticipated in the startup schedule. Changes in pH of the water sent to distribution should be minimized. Additional forward rinse to waste, blending, and pH adjustment are potential solutions. Some GAC manufacturers also offer treatment of the GAC during the manufacturing process to minimize impacts to pH. Such treatments should not impact the ANSI/NSF 61 certification of the GAC.

IV. Operation, Monitoring and Maintenance Plans

A complete operation, monitoring and maintenance (OM&M) plan, including all components listed below, should be provided to the operator, designated operator in responsible charge (DO), and the system owner. Such plans are intended to be reference documents for those who operate, maintain, and monitor these systems.

This section provides suggested items to be covered in the OM&M plan but should not be considered exhaustive.

Table 3: Components of a GAC OM&M Plan

Key Component	Considerations
Preface	• Table of contents. • Tracking of versions and changes.
Site Safety	Site safety should be addressed, including, but not be limited to: • Identification of confined spaces. • GAC storage and handling. • Entrapment hazards in GAC gravity filter beds. • Nuisance dust. • Oxygen adsorption and depletion by GAC. Important safety information can be found in the AWWA/ANSI B604 and B600 guidance documents, and relevant codes from Occupational Safety Health Administration (OSHA) and the National Fire Protection Association (NFPA).
Record Keeping	Recommendations on record retention for routine operation, maintenance, repairs, and GAC changeout should be included. The plan should include any forms, checklists, and other documents needed to ensure tasks occur as required.
Roles and Responsibilities	Where a potentially responsible party or other 3rd party is involved with the GAC system, the responsibilities of the 3rd party and the PWS should be clearly identified. Items to be addressed should include, but are not limited to, responsibility for:

Key Component	Considerations
Roles and Responsibilities, cont.	• Daily operation of the GAC facility. • Backwashing contactor(s) as required. • Arranging for and facilitating GAC changeout. • Performing routine maintenance. • Responding to emergencies. • Performing repairs. • Routine sample collection and analysis. • Site security. • Grounds maintenance (mowing, snow plowing, etc.) at the GAC site.
System Description	The plan should include a description of: • Basic design parameters. • System size. • System capacity. • Major components.
System Operation	The plan should include: • Manufacturer operation manuals for all installed equipment. • Normal operating parameter values or ranges, including, but not limited to system pressure(s); pressure differentials across GAC contactors; flow rate through the system and treatment trains; head loss across a contactor at which a backwash is recommended. • Schedules of routine operation tasks and required frequency, such as checking pressures and flow meters. • A troubleshooting guide for common problems with the GAC system. • Directions for backwashing a contactor including, flow rates, duration and valve configurations. • Where valve trees are present for changing flow configurations, diagrams indicating valve open/close status for each desired flow configuration. • If system is operated only seasonally, directions for taking the system offline and for bringing it back online. Any steps necessary to prevent negative impacts to water quality due to microbial growth while offline should be included. The certified operator and DO should be provided associated training on system operation before a certificate of completed works is issued.
Maintenance	All maintenance manuals and routine maintenance schedules for all installed equipment should be included.

Key Component	Considerations
Routine Monitoring	Plans for target contaminant monitoring, nitrate monitoring and supplemental microbial monitoring developed in accordance with Section III. B. Routine Monitoring of this document. To ensure monitoring is conducted at the appropriate location(s), sample taps should be clearly identified, and a naming convention should be adopted. Diagrams or labeled photos are strongly recommended to be included.
GAC Changeout Procedure	The GAC changeout procedure which details changeout criteria, preparation for changeout, changeout procedure and post changeout monitoring developed in accordance with Section III. C. Carbon Changeout of this document. Step by step instructions on the GAC changeout process should be included for the following tasks: • Disinfecting equipment. • Removing spent GAC from contactors. • Inspecting and cleaning empty contactors. • Refilling contactors that includes instructions on wetting GAC; backwash; forward rinse to waste; and return to service. Instructions should include a list of parts, tools or other equipment needed, valves to be opened/closed, hose connections to be made and all other detailed steps to be taken during the process.