Tech Brief

A NATIONAL DRINKING WATER CLEARINGHOUSE FACT SHEET

Organic Removal

Summary

Some small drinking water systems face contamination of raw water by natural or synthetic organic chemicals (SOCs). Natural organic materials might be present in water supplies, especially from surface water sources. Dissolved organics may cause taste, odor, or color problems in a community's drinking water, resulting in consumer complaints. Sources of SOCs include leaking underground gasoline/storage tanks, agricultural runoff containing herbicides or pesticides, solid waste or hazardous waste landfills, and improperly disposed chemical waste.

The technologies most suitable for organic contaminant removal in drinking water systems are granular activated carbon (GAC) and aeration.

GAC has been designated by the U.S. Environmental Protection Agency (EPA) as the best available technology (BAT) for synthetic organic chemical removal. Various kinds of GAC are available for removing organics from drinking water. The most frequently used carbon in U.S. treatment plants is coal-based carbon because of its hardness, adsorption capacity, and availability. Some peat and lignite carbons have been used also.

Aeration systems that might be suitable for small drinking water systems include packed column aeration, diffused aeration, and multiple-tray aeration. Recent technologies that use aeration for organics removal include mechanical aeration, catenary grid, and Higee aeration.

Table 1 presents operational conditions for the organics treatment technologies most suitable for small systems.

Table 1. Organic Treatment Technologies Suitable for Small Systems

Technology	Level of Operational Skill Required	Level of Maintenance Required	Energy Requirements
Granular Activated Carbon (GAC)	Medium	Low	Low
Packed Column Aeration (PCA)	Low	Low	Varies
Diffused Aeration	Low	Low	Varies
Multiple-Tray Aeration	Low	Low	Low
Mechanical Aeration	Low	Low	Low
Catenary Grid	Low	Low	High
Higee Aeration	Low	Medium	High

Source: U. S. Environmental Protection Agency, 1989

Some technologies for organic removal in small systems:

A. Activated Carbon

DESCRIPTION

Activated carbon is carbon that has been exposed to very high temperatures, creating a vast network of internal pores.

Two types of activated carbon, granular and powdered, have been used widely in drinking water treatment. Powdered activated carbon (PAC), which is most often used for taste and odor control, is added directly to the raw water and removed by settling in sedimentation basins.

GAC removes many organic contaminants as well as taste and odor from water supplies.

PERFORMANCE/ADVANTAGES

Organics that are readily adsorbed by activated carbon include:

- aromatic solvents (benzene, toluene, nitrobenzenes);
- chlorinated aromatics (PCBs, chlorobenzenes, chloroaphthalene);
- phenol and chlorophenols;
- polynuclear aromatics (acenaphthene, benzopyrenes);
- pesticides and herbicides (DDT, aldrin, chlordane, heptachlor);
- chlorinated aliphatics (carbon tetrachloride, chloroalkyl ethers); and
- high molecular weight hydrocarbons (dyes, gasoline, amines, humics).

LIMITATIONS

Organics that are poorly adsorbed by activated carbon include:

- alcohols;
- low molecular weight ketones, acids, and aldehydes;
- sugars and starches;
- very high molecular weight or colloidal organics; and
- low molecular weight aliphatics.

GAC is not effective in removing vinyl chloride from water. In addition, because of the long empty bed contact time (EBCT) required, radon removal at the treatment plant scale is not feasible. However, at the residential scale, GAC systems are cost-effective for radon removal.

Several operational and maintenance factors affect the performance of GAC. Contaminants in the water can occupy GAC adsorption sites, whether they are targeted for removal or not. Also, adsorbed contaminants can be replaced by other contaminants with which GAC has a greater affinity. Therefore, the presence of other contaminants might interfere with the removal of the contaminants of concern.

A significant drop in the contaminant level in influent water will cause a GAC filter to desorb, or slough off, adsorbed contaminants because GAC is an equilibrium process. As a result, raw water with frequently changing contaminant levels can result in treated water of unpredictable quality.

Bacterial growth on the carbon is another potential problem. Excessive bacterial growth may cause clogging and higher bacterial counts in the treated water. Bacterial levels in the treated water must be closely monitored, and the final disinfection process must be carefully controlled.

PROCESS

Activated carbon removes contaminants through adsorption, primarily a physical process in which dissolved contaminants adhere to the porous surface of the carbon particles. The adsorption process can be reversed relatively easily. The ease of reversing adsorption is another key factor in activated carbon's usefulness because it facilitates the recycling or reuse of the carbon.

GAC can be used as a replacement for existing media (such as sand) in a conventional filter, or it can be used in a separate contactor (a vertical steel pressure vessel used to hold the activated carbon bed).

GAC contactors require monitoring to ensure that they work effectively. A GAC monitoring system should include:

- laboratory analysis of treated water to ensure that the system is removing organic contaminants,
- monitoring of headloss (the amount of energy used by water in moving from one point to another) through the contactors to ensure that backflushing (reversing the flow to remove trapped material) is performed at appropriate times,
- bacteria monitoring of the contactor's effluent (since bacteria can grow rapidly within the activated carbon bed),
- turbidity monitoring of the contactor's effluent (to determine if suspended material is passing through GAC bed).

After a period of months or years, depending on the concentration of contaminants, the surface of the pores in the GAC can no longer adsorb contaminants. The carbon must then be replaced. The GAC vendor will be able to provide guidance concerning when to replace the GAC. Disposing of carbon with contaminants that are classified as hazardous wastes will dramatically increase disposal costs.

EQUIPMENT/DESIGN

The typical GAC unit can be similar in design to either gravity or pressure filters. In some communities, the sand in existing filters has been either partially or completely replaced with GAC. Media depth of up to 10 feet is needed to ensure adequate removal of potentially harmful organic contaminants. Activated carbon filters can be designed to treat hydraulic loadings of 2 to 10 gallons per minute per square foot (gpm/ft^2). Sufficient detention time in the filter must be provided to achieve the desired level of the organic contaminant removal. The detention time is determined by the volume of the GAC filter divided by the flow rate. This is referred to as the EBCT since the volume of carbon in the bed is not considered. For adequate removal of most organic contaminants to occur, the EBCT should be about 10 minutes. EBCTs less than 7.5 minutes are generally ineffective.

GAC is available in different grades of effectiveness. Low-cost carbon requires a lower initial capital outlay but must be replaced more often, resulting in higher operating costs.

B. Aeration

DESCRIPTION

Aeration, also known as air stripping, mixes air with water to volatilize contaminants (turn them to vapor). The volatilized contaminants are either released directly to the atmosphere or treated and released. Aeration is used to remove volatile organic chemicals and can also remove radon.

EQUIPMENT

A small system might be able to use a simple aerator constructed from relatively common materials instead of a specially designed aerator system. Examples of simple aerators include:

- a system that cascades the water or passes it through a slotted container,
- a system that runs water over a corrugated surface, or
- an airlift pump that introduces oxygen as water is drawn from a well.

OTHER AERATION TYPES

Packed Column Aeration

Packed column aeration (PCA) or packed tower aeration (PTA) is a waterfall aeration process that drops water over a medium within a tower to mix the water with air. The medium is designed to break the water into tiny droplets and to maximize its contact with tiny air bubbles for removal of the contaminant. Air is also blown in from underneath the medium to enhance this process. (See figure 1 on page 4.)

Systems using PCA may need pretreatment to remove iron, solids, and biological growth to prevent clogging of the packing material. Post treatment such as the use of a corrosion inhibitor, may also be needed to reduce corrosive properties in water due to increased dissolved oxygen from the aeration process.

Packed columns usually operate automatically and need only daily visits to ensure that the equipment is running satisfactorily. Maintenance requirements include servicing pump and blower motors and replacing air filters on the blower, if necessary.

PCA exhaust gas may require treatment to meet air emissions regulations, which can significantly increase the costs of this technology.

Diffused Aeration

In a diffused aeration system, a diffuser bubbles air through a contact chamber for aeration. The diffuser is usually located near the bottom of the chamber. The air introduced through the diffuser, usually under pressure, produces fine bubbles that create water-air mixing turbulence as they rise through the chamber.

The main advantage of diffused aeration systems is that they can be created from existing structures, such as storage tanks. However, they are less effective than packed column aeration, and usually are employed only in systems with adaptable existing structures.

Multiple Tray Aeration

Multiple tray aeration directs water through a series of trays made of slats, perforations, or wire mesh. A blower introduces air from underneath the trays.

Multiple tray aeration units have less surface area than PCA units. This type of aeration is not as effective as PCA and can experience clogging from iron and manganese, biological growth, and corrosion problems.

Multiple tray aeration units are readily available from package plant manufacturers.

Mechanical Aeration

Mechanical aeration uses mechanical stirring mechanisms to mix air with the water. These systems can effectively remove volatile organic chemicals (VOCs).

Mechanical aeration units need large amounts of space because they demand long detention times for effective treatment. As a result, they often require open-air designs, which can freeze in cold climates. These units also can have high energy requirements. However, mechanical aeration systems are easy to operate and are less susceptible to clogging from biological growth than PCA systems.

Catenary Grid

Catenary grid systems are a variation of the packed column aeration process. The catenary grid directs water through a series of wire screens mounted within the column. The screens mix the air and water in the same way as packing materials in PCA systems.

These systems can effectively remove VOCs. They have higher energy requirements than PCA systems, but their more compact design lowers their capital cost relative to PCA.

Higee Aeration

Higee aeration is another variation of the PCA process. These systems pump water into the center of a spinning disc of packing material, where the water mixes with air.

Higee units require less packing material than PCA units to achieve the same removal efficiencies. Because of their compact size, they can be used in limited spaces and heights. Current Higee systems are best suited for a temporary application of less than 1 year with capacities up to 380 liters (100 gallons) per minute.

Where can I find more information? Information in this fact sheet was primarily obtained from three documents:

- *Technologies for Upgrading Existing or Designing New Drinking Water Treatment Facilities*, EPA/625/4-89/023;
- *Small Community Water and Wastewater Treatment*, EPA/625/R-92/010; and
- *Environmental Pollution Control Alternatives: Drinking Water Treatment for Small Communities*, EPA/625/5-90/025.

All publications can be ordered free from the U.S. Environmental Protection Agency Office of Research and Development at (513) 569-7562.

The NDWC offers these documents as well, but at a cost to help recover photocopying and other expenses. *Technologies for Upgrading Existing or Designing New Drinking Water Treatment Facilities*, item #DWBKDM04, a 209-page book, costs $30.05. *Small Community Water and Wastewater Treatment*, item #DWBKRE03, a 95-page book, costs $13.65. The third book, *Environmental Pollution Control Alternatives: Drinking Water Treatment for Small Communities*, item #DWBKGN09, an 82-page publication, costs $11.82. Shipping and handling charges apply.

Also, the NDWC's Registry of Equipment Suppliers of Treatment Technologies for Small Systems (RESULTS) is a public reference database that contains information about technologies in use at small water systems around the country. For further information on accessing or ordering RESULTS, call the NDWC at (800) 624-8301 or (304) 293-4191.

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- Tech Brief: Ion Exchange and Demineralization, *item #DWBLPE56;*
- Tech Brief: Corrosion Control, *item #DWBLPE52;*
- Tech Brief: Filtration, *item #DWBLPE5O;* or
- Tech Brief: Disinfection, *item #DWBLPE47.*

Figure 1: Packed Tower Aeration System