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FS 877A

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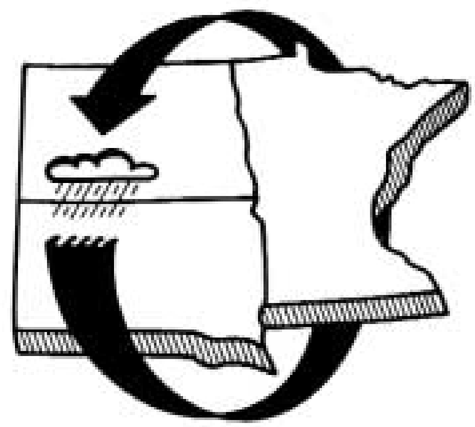

A Three-State Water Quality Effort

Cooperative Extension Service
South Dakota State University
U.S. Department of Agriculture

FS 877A

Treatment Systems for Household Water Supplies

Activated Carbon Filtration

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Water Contaminants Removed by Activated Carbon Filters

Activated carbon (AC) filtration is most effective in removing organic contaminants from water. Organic substances are composed of two basic elements, carbon and hydrogen. Because organic chemicals are often responsible for taste, odor, and color problems, AC filtration can generally be used to improve aesthetically objectional water. AC filtration will also remove chlorine. AC filtration is recognized by the Water Quality Association as an acceptable method to maintain certain drinking water contaminants within the limits of the EPA National Drinking Water Standards (Table 1).

AC filtration does remove some organic chemicals that can be harmful if present in quantities above the EPA Health Advisory Level (HAL). Included in this category are trihalomethanes (THM), pesticides, industrial solvents (halogenated hydrocarbons), polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs).

THMs are a byproduct of the chlorination process that most public drinking water systems use for disinfection. Chloroform is the primary THM of concern. EPA does not allow public systems to have more than 100 parts per billion (ppb) of THMs in their treated water. Some municipal systems have had difficulty in meeting this standard.

The Safe Drinking Water Act mandates EPA to strictly regulate contaminants in community drinking water systems. As a result, organic chemical contamination of municipal drinking water is not likely to be a health problem. Contamination is more likely to go undetected and untreated in unregulated private water systems. AC filtration is a viable alternative to protect private drinking water systems from organic chemical contamination.

Radon gas also can be removed from water by AC filtration, but actual removal rates of radon for different AC filtering equipment have not been established.

Table 1. Water contaminants that can be reduced to acceptable standards by activated carbon filtration.
(Water Quality Association, 1989.)

PRIMARY DRINKING WATER STANDARDS

Contaminant	* MCL, mg / L
Inorganic Contaminants	
Organic arsenic complexes	0.05
Organic chromium complexes	0.05
Mercury (Hg+2) inorganic	0.05
Organic mercury complexes	0.002
Organic Contaminants	
Benzene	0.005
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
1, 2-dichlorothene	0.005
1, 1-dichloroethylene	0.007
1, 1, 1-trichloroethane	0.200
Total trihalomethanes (TTHMs)	0.10
Toxaphene	0.005
Trichloroethylene	0.005
2, 4-D	0.1
2, 4, 5-TP (Silvex)	0.1
Para-dichlorobenzene	0.075

SECONDARY DRINKING WATER STANDARDS

Contaminant	**SMCL
Color	15 color units
Foaming agents (MBAS)	0.5 mg/L
Odor	3 threshold odor number

*Maximum contaminant level
**Secondary maximum contaminant level

Water Contaminants Not Removed by AC Filtration

Similar to other types of water treatment, AC filtration is effective for some contaminants and not effective for others. AC filtration does not remove microbes, sodium, nitrates, fluoride, and hardness. Lead and other heavy metals are removed only by a very specific type of AC filter. Unless the manufacturer states that its product will remove heavy metals, the consumer should assume that the AC filter is not effective in removing them. Refer to the other fact sheets in this series for information on systems that do remove the contaminants listed above.

Water Testing

Regular water testing is recommended to reduce the risk of consuming contaminated water. Many contaminants are not detected by the senses. Even if contamination can be detected by color, smell, or taste, only a laboratory test can tell you the quantity of contaminant actually present.

Always have water testing done by a reputable or certified laboratory. Prior to sending in your water sample, determine what you want your water tested for. Contact the laboratory to find out how to take a proper water sample. Remember, there are thousands of substances that can contaminate your water, and they all have slightly different chemical behavior. Proper sampling and handling for one type of contaminant may cause erroneous results for other types of contaminants.

Once you have the laboratory results in hand, make sure you understand the numbers. If you don't fully understand the results, don't assume anything. The testing laboratory will be able to answer any questions you may have about the test results. Understanding the laboratory results will help you select the best and most economical water treatment system. Sometimes just a single piece of equipment, such as an AC filter, is all that is necessary to treat the problem. Other times you may need completely different equipment or possibly a combination of equipment. It depends on the type and amount of contaminants present in your water supply.

The Activated Carbon Filtration Process

AC works by attracting and holding certain chemicals as water passes through it. AC is a highly porous material; therefore, it has an extremely high surface area for contaminant adsorption. The equivalent surface area of 1 pound of AC ranges from 60 to 150 acres.

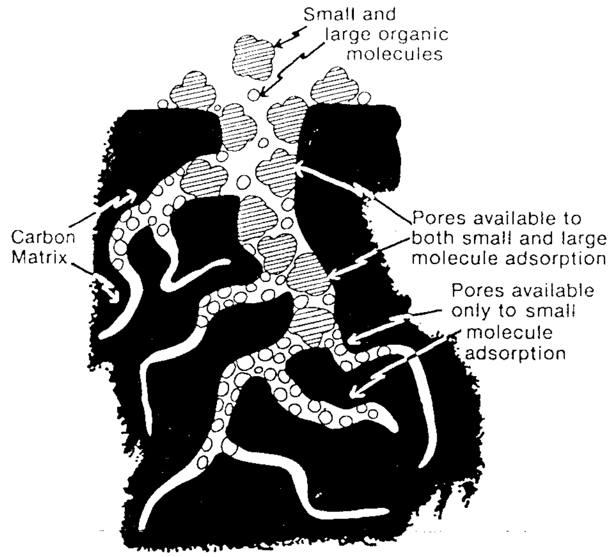


Figure 1. Molecular screening in the micropores of an activated carbon filter.

AC is made of tiny clusters of carbon atoms stacked upon one another. The carbon source is a variety of materials, such as peanut shells or coal. The raw carbon source is slowly heated in the absence of air to produce a high-carbon material. The carbon is activated by passing oxidizing gases through the material at extremely high temperatures. The activation process produces the pores that result in such high adsorptive properties.

The adsorption process depends on the following factors:

- Physical properties of the AC, such as pore size distribution and surface area.
- Chemical nature of the carbon source or the amount of oxygen and hydrogen associated with it.
- Chemical composition and concentration of the contaminant.
- Temperature and pH of the water.
- Flow rate or time exposure of water to AC.

Physical Properties

Forces of physical attraction or adsorption of contaminants to the pore walls is the most important AC filtration process. The amount and distribution of pores play key roles in determining how well contaminants are filtered. The best filtration occurs when pores are barely large enough to admit the contaminant molecule (Figure 1).

Because contaminants come in all different sizes, they are attracted differently depending on pore size of the filter. In general, AC filters with relatively large molecules (most organic chemicals) are most effective in removing contaminants. Type of raw carbon material and its method of activation will affect types of contaminants adsorbed. This is due largely to the influence of raw material and activation on pore size and distribution.

Chemical Properties

Processes other than physical attraction also affect AC filtration. The filter surface actually may interact chemically with organic molecules. Electrical forces between the AC surface and some contaminants also may result in adsorption or ion exchange. Adsorption, then, also is affected by the chemical properties of the adsorbing surface which are determined to a large extent by the activation process. AC materials formed from different activation processes will have chemical properties that make them more or less attractive to various contaminants. For example, chloroform is adsorbed best by an AC that has the least amount of oxygen associated with the pore surfaces.

The consumer can not determine the chemical nature of an AC filter. Different types of AC filters will have varying levels of effectiveness in treating different chemicals. Consult the manufacturer to determine if its filter will adequately treat your specific water problem.

Contaminant Properties

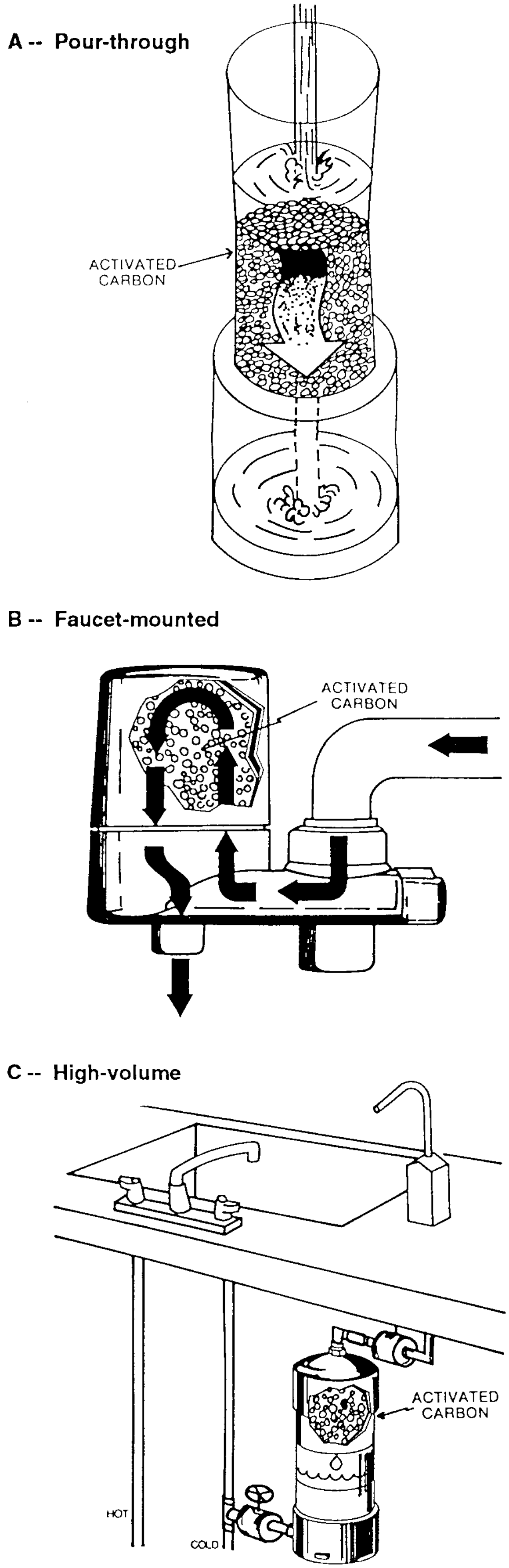
Large organic molecules are adsorbed most effectively by AC. A general rule of thumb is that similar materials tend to associate. Organic molecules and activated carbon are similar materials; therefore, most organic chemicals have a strong tendency to associate with the activated carbon in the filter rather than staying dissolved in a dissimilar material like water. Generally, the least soluble organic molecules are most strongly adsorbed. The smaller organic molecules often are held the tightest, because they fit into the smaller pores.

Concentration of organic contaminants can affect the adsorption process. A given AC filter may be more effective than another type of AC filter at low contaminant concentrations, but may be less effective than the other filter at high concentrations. This behavior has been observed with chloroform removal. Consult the filter manufacturer to determine how the filter will perform for specific chemicals at different levels of contamination.

Water Temperature and pH

Adsorption usually increases as pH and temperature decrease. Chemical reactions and forms of chemicals

Figure 2. Three types of activated carbon filtration units.



are related closely to pH and temperature. When pH and temperature are lowered, many organic chemicals are in a more adsorbable form.

Exposure Time

The process of adsorption also is influenced by the length of time the AC is in contact with the contaminant in the water. Increasing contact time allows greater amounts of contaminant to be removed. Contact is improved by increasing the amount of AC in the filter and reducing the flow rate of water through the filter.

Activated Carbon Filtration Equipment

There are three categories of AC filters: pour-through, faucet-mounted, and high-volume (Figure 2).

Pour-through AC filters are the simplest. They work like a drip coffee maker. Water is poured in the top and, by gravity, filters through to the bottom. They are quite slow and handle only small volumes of water.

Results of Activated Carbon Filter Testing

Several independent laboratories have tested AC filtration equipment for effectiveness in contaminant removal. Organizations involved in AC testing Gulf South Research Institute; National Sanitation Foundation; Canadian Bureau of Health; Consumer Reports; and Rodale Press Product Testing Department.

Based on the testing results of these organizations, general recommendations can be made regarding AC filtration. Use high-volume AC units if removal of health-threatening contaminants is your concern. Pour-through and faucet-mounted units do not provide the contact time required for significant removal of contaminants. If you are concerned only with taste, odor, or color, pour-through and faucet-mounted units will probably do the job. However, they still will require changing much more often than high-volume AC filters.

Efficiency of contaminant removal and equipment operation vary even among the high volume AC units (Table 2). The most efficient unit is not always the most expensive one.

Faucet-mounted AC filters are small units attached on the end of a standard kitchen faucet. They are convenient to use but, because of their size, require frequent change. Some unitshave bypass valves, so that just water for cooking and drinking is filtered.

High-volume AC filters contain much more activated carbon than either the pour-through or faucet-mounted models. High-volume units are designed to be installed in-line, generally under the sink. They are installed on the cold water line, and some units are installed with a bypass to separate cooking and drinking water from other uses.

Under exceptional circumstances all water may need to be treated by AC filtration. In that case, a high-volume unit may be installed at the point of entry to the house.

Table 2. Comparison of activated carbon filtration units.
(Consumer Reports, 1990.)

Brand & Model	Price $	Cartridge Cost $	Chloroform Removal %
High-volume filters			
Ametek CCF-201	158	20 (2)	100
Ecowater Water Master	250	33 (2)	100
Amway E-9230	276	69	100
Hurley II	375	--	100
Filtrate CF 10	85	8	90
Cuno AquaPure AP-CRF	155	15	90
Kinetico MAC	275	32	90
Culligan SuperGard THM	349	37	90
Teledyne Instapure IF-10	50	12	80
Omni UC-2	99	20 (2)	80
NSA Bacyteriostatic 50C	179	--	80
(The following two models were downrated because they clogged after filtering only 300 gallons.)			
Bionaire H20 BT850	199	100	100
Everpure H200	298	90	100
Faucet-mount filters			
Cuno Purity PP01105	30	6	60
Teledyne Instapure F-2C	24	5	45
Pollenex WP90K	22	5	30
Pour-through filters			
Brita	30	8	50
Innova	7	5	45
Glacier Pure	13	5	40

Eventually, the AC filter loses its ability to remove contaminants, because it becomes clogged with material. In the case of taste and odor, the time to change the filter is easy to detect. However, in the case of other contaminants, it is more difficult to determine when the filter is no longer performing at an adequate level. Most manufacturers recommend a filter change after a certain volume of water has passed through the filter. Some AC units actually meter the water and automatically shut down after a specific quantity of water has passed through the filter. A general rule of thumb for high-volume AC filters is to change the filter after six months of use or 1000 gallons of filtered water.

Tests done by Rodale Press Product Testing Department indicated that filtering performance was reduced dramatically after 75 percent of the manufacturer's recommended life time. These results suggest that filters should be changed more often than suggested by the manufacturer. Some AC filters are claimed to last for five years, because they are rechargeable with hot water (145 degrees F). The heat is supposed to release adsorbed organic chemicals. Little information is available on the prolonged effectiveness of rechargeable AC units.

General recommendations are somewhat useful guidelines, but there is no guarantee that they apply to any specific situation. Remember, the only certain way to know whether contaminant levels are acceptable or not is to have your water tested.

A sediment filter installed ahead of any AC filter will prolong the life of the AC unit. Sediment can easily clog the pores of an AC filter within a short period of time.

The Bacteria Issue

AC filters can be a breeding ground for microorganisms. The organic chemicals that are adsorbed to the AC are a source of food for various bacteria. Pathogenic bacteria are those that cause human diseases such as typhoid, cholera, and dysentery. Public water systems must treat for disease-causing bacteria; therefore, the likelihood of disease-causing bacteria being introduced to an AC filter from public drinking water is remote. Only use AC filtration on water that has been tested and found to be bacteria free or effectively treated for pathogenic bacteria.

Other types of non-pathogenic bacteria that do not cause diseases have been found regularly in AC filters. There are times when high amounts of bacteria (non-pathogenic) are found in water filtered through an AC unit. Research by R. L. Caldron and E. W. Mood (1987) shows little risk to healthy people who consume high amounts of non-pathogenic bacteria. Humans regularly take in millions of bacteria every day from other sources. There is some concern for certain segments of the population, however, such as the very young or old and people weakened by illness. Some types of non-pathogenic bacteria can cause illness in those whose natural defenses are weak.

Bacteria that have built up in the filter can be flushed out by running water through an AC filter for about 30 seconds prior to use. Water filtered after the initial flushing will have much lower levels of bacteria, and ingestion of a high concentration of bacteria will have been avoided. The flushing procedure is most important in the morning or any other time of day when the filter has not been used for several hours.

Some compounds of silver have been used as disinfectants in certain AC filters as a solution to the bacteria problem. Unfortunately, product testing has not shown silver impregnated AC to be much more effective in controlling bacteria than normal AC filters. Only in the first month of operation did there appear to be any advantage to using an AC filter that contained silver.

EPA requires registration of all types of water treatment equipment that contain an active ingredient for the purpose of inhibiting the growth of microorganisms. Registration does not guarantee that the product is effective. It only guarantees that the active ingredient will not leach from the filter at levels that would be a health hazard.

Further Information

Contact your county Extension Office or the State Health Department. Ask for other publications in the *Treatment Systems for Household Water Supplies* fact sheet series:

FS 877C Chlorination
FS 877D Distillation
FS 887IM Iron and Manganese Removal
FS 88RO Reverse Osmosis
FS 887S Softening
FS 877P Identifying and Correcting Water Problems

References

Recognized treatment techniques for meeting the National Primary Drinking Water Regulations with the application of point-of-use systems. Water Quality Association, Lisle, Il. 1989.

Recognized treatment techniques for meeting the National Secondary Drinking Water Regulations with the application of point-of-use systems. Water Quality Association, Lisle, Il. 1989.

Fit to drink? Consumer Reports. January 1990. pp. 27-43.

Caldron, R. L., and E. W. Mood. Bacteria colonizing point-of-use, granular activated carbon filters and their relationship to human health. Research Project CR-811904-01-0, Health Effects Research Lab., U.S. EPA, Cincinnati, Ohio. 1987. Reprinted by the Water Quality Association, Lisle, Ill.

Culp, G. L. and R. L. Culp. New concepts in water purification. Van Nostrand Reinhold Co. New York. 1974.

Ishizake, C., I. Marti, and M. Ruiz. Effect of surface characteristics of activated carbon on the adsorption of chloroform from aqueous solution. In M. J. McGuire and I. H. Suffet (ed.). Treatment of water by granular activated carbon. Advances in Chemistry Series. American Chemical Society, Washington, D.C. 1983. pp. 95-106.

Rodale Press Product Testing Department Staff. Water treatment handbook -- A homeowners guide to safer drinking water. Rodale Press Inc., Emmaus, Pa. 1985.

Taraba, J. L., L. M. Heaton, and T. W. Ilvento. Using activated carbon filters to treat home drinking water, IP-6. University of Kentucky Cooperative Extension Service, Lexington, Ky. 1990.

Temple, Barker, and Sloan Inc. Staff. Point-of-use treatment for compliance with drinking water standards. Reprinted by the Water Quality Association, Lisle, Ill. 1983.

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