MAGR
GOVS
MN 2500
AGFO-5939

39

CLEAN WATER

You Can Make A Difference

UNIVERSITY OF MINNESOTA
DOCUMENTS

JUN 29 1992

ST. PAUL CAMPUS
LIBRARIES

Treatment Systems for Household Water Supplies: Activated Carbon Filtration

by Bruce Seelig, Fred Bergsrud, and Russell Derickson

MINNESOTA EXTENSION SERVICE

UNIVERSITY OF MINNESOTA

Treatment Systems for Household Water Supplies: Activated Carbon Filtration

What contaminants do activated carbon filters remove from water?

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. The 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 the 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 private water systems that are not regulated. AC filtration is a viable alternative to protect private drinking water systems from organic chemical contamination.

Radon gas can also be removed from water by AC filtration, but actual removal rates of radon for different types of AC filtration 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	
Inorganic Contaminants	
Contaminant	MCL, mg/L
Organic Aersenic 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-dichloroethane	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)	0.01
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

What water contaminants are 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 publications in the *Treatment Systems for Household Water Supplies* series for information on systems that do remove the contaminants listed above.

How to test your water

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. Testing should always be 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 regarding your 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 all depends on the type and amount of contaminants present in your water.

How the activated carbon filtration process works

Activated Carbon (AC) works by attracting and holding certain chemicals as water passes through it. Because AC is a highly porous material, 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.

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: 1) physical properties of the AC, such as pore size distribution and surface area; 2) the chemical nature of the carbon source, or the amount of oxygen and hydrogen associated with it; 3) chemical composition and concentration of the contaminant; 4) the temperature and pH of the water; and 5) the flow rate or time exposure of water to AC.

Physical properties

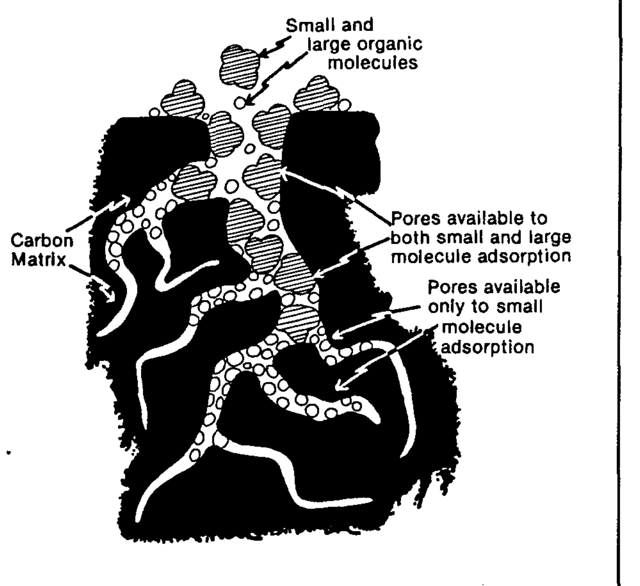
Forces of physical attraction or adsorption of contaminants to the pore walls is the most important AC filtration process. The amount and distribution of pores play key roles in determining how well contaminants are filtered. The best filtration occurs when pores are barely large enough to admit the 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 are most effective in removing contaminants that have relatively large molecules (most organic chemicals). The type of raw carbon material and its method of activation will affect types of contaminants that are adsorbed. This is largely due to the influence that raw material and activation have on pore size and distribution.

Chemical properties

Processes other than physical attraction also affect AC filtration. The filter surface may actually interact chemically with organic molecules. Also electrical forces between the AC surface and some contaminants may result in adsorption or ion exchange. Adsorption, then, is also affected by the chemical nature of the adsorbing surface.

The chemical properties of the adsorbing surface are determined to a large extent by the activation process. AC materials formed from different activation processes

Figure 1. Molecular screening in the micropores of an activated carbon filter. (after G. L. Culp and R. L. Culp)



will have chemical properties that make them more or less attractive to various contaminants. For example chloroform is adsorbed best by AC that has the least amount of oxygen associated with the pore surfaces. The consumer can't possibly determine the chemical nature of an AC filter. Different types of AC filters have varying levels of effectiveness in treating different chemicals. The manufacturer should be consulted to determine if their filter will adequately treat the consumer's specific water problem.

Contaminant properties

Large organic molecules are most effectively adsorbed by AC. A general rule of thumb is that similar materials tend to associate. Organic molecules and activated carbon are similar materials; therefore there is a stronger tendency for most organic chemicals 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. Often the smaller organic molecules are held most tightly because they fit into the smaller pores.

The concentration of organic contaminants can affect the adsorption process. One AC filter may be more effective than another type at low contaminant concentrations, but may be less effective than the other filter at high concentrations. This type of behavior has been observed with chloroform removal. The filter manufacturer should be consulted 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 are closely related 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 is also influenced by the length of time that the AC is in contact with the contaminant in the water. Increasing contact time allows greater amounts of contaminant to be removed from the water. Contact is improved by increasing the amount of AC in the filter and reducing the flow rate of water through the filter.

Figure 2. The three types of activated carbon filtration units are: A) pour-through; B) faucet-mounted; and C) high-volume.

Figure 2A: Pour-through

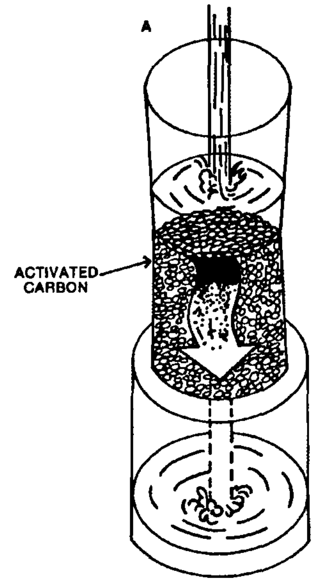
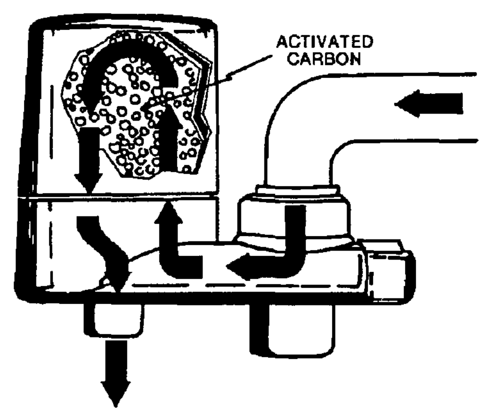


Figure 2B: Faucet-mounted

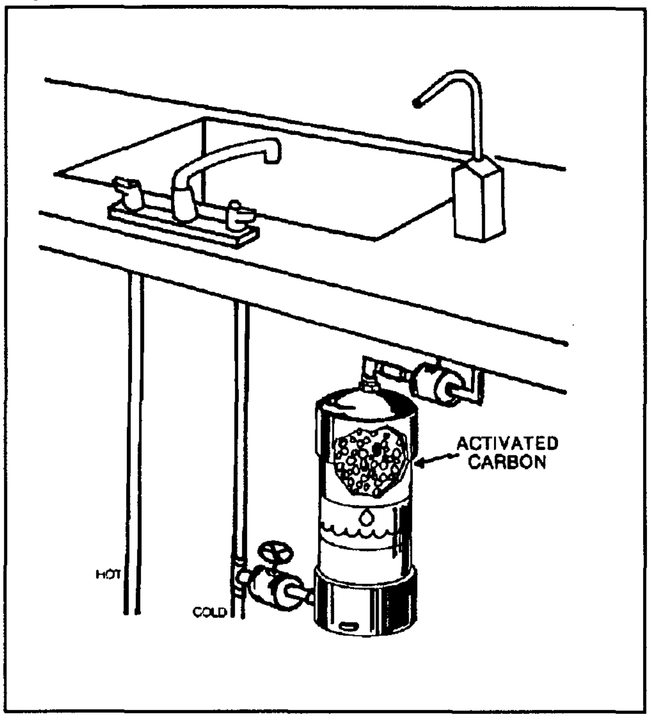


What types of AC filters are available?

AC filters can be placed in the three following categories: 1) pour-through; 2) faucet-mounted; and 3) high-volume (Figure 2).

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

Figure 2C: High volume



2. 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 units have bypass valves, to filter just the water needed for cooking and drinking.
3. High-volume AC filters contain much more AC 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. A high-volume unit may be installed at the point of entry to the house if all water needs to be treated.

How is the effectiveness of activated carbon filter tested?

In recent years, several independent laboratories have tested AC filtration equipment for effectiveness in contaminant removal. Organizations involved in AC testing include: 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. High-volume AC units should be used if removal of health-threatening contaminants is your concern. Pour-through and faucet-mounted units do not provide the contact time for significant removal of contaminants. If you are only concerned with taste, odor or color, pour-through and faucet-mounted units will probably do the job. However, they will still 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.

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

Table 2. A 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 Bacteriostatic 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 WP90X	22	5	30
Pour-through filters			
Brita	30	8	50
Innova	7	5	45
Glacier Pure	13	5	40

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 of knowing whether contaminant levels are acceptable or not is by having 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. A good sediment filter can be purchased for only a fraction of the price of most high volume AC filters.

Disadvantages of activated carbon filtration: Bacteria

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 types of bacteria. Disease-causing bacteria are those that cause human diseases such as typhoid, cholera and dysentery. Because public water systems must treat for disease-causing bacteria; the likelihood of disease-causing bacteria being introduced to an AC filter from public drinking water is remote. AC filtration should only be used on water that has been tested and found to be bacteria-free or effectively treated for disease-causing bacteria.

Other types of bacteria that do not cause diseases have been regularly found in AC filters, sometimes in high amounts. Research by R. L. Caldron and E. W. Mood (1987) shows little risk to healthy people who consume high amounts of non-pathogenic bacteria (bacteria that do not cause disease). We regularly take in millions of bacteria every day from other sources.

However, there is some concern for certain segments of the population, 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. Flushing out bacteria that have built up in the filter can be accomplished 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; thus avoiding ingestion of a high concentration of bacteria. The flushing procedure is most important in the morning or any other time of the day when the filter has not been used for several hours.

Some compounds of silver have been used as disinfectants. Silver has been added to 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. Any advantage to using an AC filter containing silver appeared only in the first month of operation.

The 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

For further information contact your local county Extension Office or state Health Department. Additional information can be found in other publications in this series: *Treatment Systems for Household Water Supplies.*

- Iron and Manganese Removal
- Chlorination
- Distillation
- Reverse Osmosis
- Softening

References

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

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

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

Caldron, R. L., and E. W. Mood. 1987. **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, OH. Reprinted by the Water Quality Association, Lisle, IL.

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

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

Rodale Press Product Testing Department Staff. 1985. **Water treatment handbook—A homeowner's guide to safer drinking water.** Rodale Press Inc., Emmaus, PA.

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

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

Printed on recycled paper with agribase ink.

Fred Bergsrud, Water Quality Coordinator, Minnesota Extension Service; Russell Derickson, Extension Associate in Water and Natural Resources, South Dakota Extension Service; Bruce Seelig, Water Quality Specialist, North Dakota Extension Service.

Funding for this publication was by the U.S. Department of Agriculture, Extension Service, under project number 90-EWQI-19252.

The University of Minnesota is committed to the policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, color, creed, religion, national origin, sex, age, marital status, disability, public assistance status, veteran status, or sexual orientation.