With groundwater, carbon is often in the mix

You'll need multiple techniques, with carbon playing a key role.

By William H. Brumfield

William H. Brumfield is president of Carbon Link Corp., based in Mount Vernon, OH, and has been in the activated carbon and filtration business for over 20 years. He has a bachelor of science degree in marketing and business and a technical degree in engineering. The company focuses on the sale, development and processing of unique, high-grade activated carbons, filtration media and equipment used for filtration in liquid and vapor phase applications. He can be reached at (800) 858-6889 or by e-mail at: info@carbonlink.com.

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Groundwater treatment for point-of-use (POU) and point-of-entry (POE) systems has always been a concern. The increased sophistication of groundwater contaminant analysis has fueled the development of higher efficiency and multiple levels of filtration equipment necessary to meet new technical demands.

Media reports recently indicated that there may be more widespread distribution of pharmaceutical substances in our drinking water than previously believed. The findings have not yet addressed the safety factor, but the possibilities are increasing the public's and water professionals' desire to learn how to effectively treat these potential problems to the highest levels possible.

Groundwater can become contaminated from a variety of sources, including manufacturing, farming (herbicides, pesticides and animal waste), petroleum products, solvents, disposable products and even naturally occurring substances such as arsenic and radium.

Municipalities tapping groundwater wells do the best they can by adding disinfectants and chemical products to kill germs, condition the water and adjust pH with soda ash (sodium carbonate) and lime (calcium carbonate), incorporate flocculation and sedimentation and/or use additional filtration.

EPA contaminant lists

While all of this has a positive effect on making water safe for drinking, disinfecting products can also react with naturally occurring background organics in the water, forming disinfecting byproducts such as trihalomethanes (THMs), haloacedic acid (HAA) and chlorite. These compounds have been shown to increase a person's risk of getting cancer.

To protect the public, the US Environmental Protection Agency (EPA) has established lists of various types of contaminants, which need to be regulated. These contaminants have been tested to define what the safest maximum allowable concentration level in our drinking water should be.

Sections A and B of the accompanying chart show examples of several common primary organic and inorganic contaminants which the EPA regulates. Section C shows some typical disinfectants used by municipalities, while section C shows several of the main disinfectant byproducts that can be formed.

More than the MCL

However, EPA has more than a maximum contaminant limit (MCL). In fact, for many contaminants, it has an even lower limit criterion, called the maximum contaminant limit goal (MCGL). This is the real limit the agency is trying to achieve. (See definitions of these terms in sidebar.)

In any case, every day we're learning more about the effects of these compounds at lower levels, and the EPA is implementing even smaller numbers for the MCLs, when justified. As more information becomes available, higher standards can be expected.

For the water professional, it can be a daunting task to determine and recommend the most cost-effective method of treatment. The customer wants a simple, one-piece, fix-all solution. But because of the complexities of each individual situation, the implementations of multiple techniques are often required.

When treating municipal groundwater at the consumer level, most treatment professionals first address the issue of softening hard water that has a high mineral content. Hard water is not defined as "harmful," but it is likely the most common concern of consumers. Most consumers and even some water professionals think it ends there, but it is really only the beginning.

Multiple filtration

Softening water has aesthetic and financial benefits, but the very process of municipal disinfection can have an adverse affect on the POE softening process. Over time disinfectants such as chlorine and chlorine dioxide can break down cation softening resins, eventually rendering them useless.

This is where multiple filtration techniques are introduced, in which a carbon filter should now be added to the equipment mix as a first line of defense to protect and increase the effectiveness of the cation resin.

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EPA contaminant definitions

Maximum Contaminant Level (MCL): The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.

Maximum Contaminant Level Goal (MCLG): The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.

Maximum Residual Disinfectant Level (MRDL): The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.

Maximum Residual Disinfectant Level Goal (MRDLG): The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.

Examples of EPA-regulated contaminants

Contaminant	MCLG (mg/L)	MCL (mg/L)	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
A — Organic Chemicals *(examples:)*				
Atrazine	0.003	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops
Trichloroethylene	Zero	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories
B — Inorganic Chemicals *(examples:)*				
Arsenic	Zero	0.010	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronics production wastes
Nitrate (measured as nitrogen)	10	10	Infants below the age of six months who drink water-containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
C — Disinfectants				
Chloramines (as Cl_2)	MRDLG= 4.0	MRDL= 4.0	Eye/nose irritation; stomach discomfort, anemia	Water additive used to control microbes
Chlorine (as Cl_2)	MRDLG= 4.0	MRDL= 4.0	Eye/nose irritation; stomach discomfort	Water additive used to control microbes
Chlorine dioxide (as ClO_2)	MRDLG= 0.8	MRDL= 0.8	Anemia; infants & young children: nervous system effects	Water additive used to control microbes
D — Disinfectant Byproducts				
Bromate	Zero	0.010	Increased risk of cancer	Byproduct of drinking water disinfection
Chlorite	0.8	1.0	Anemia; infants & young children: nervous system effects	Byproduct of drinking water disinfection
Haloacetic acids (HAA5)	n/a	0.060	Increased risk of cancer	Byproduct of drinking water disinfection
Total Trihalomethanes (TTHMs)	n/a	0.080	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection

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Different types of activated carbons possess different characteristics beneficial to specific applications. However, all activated carbons have the ability to perform the same thing on a basic level, which is adsorb contaminants and catalytically decompose chlorine and chlorine dioxide disinfectants.

In theory, the process of catalytic decomposition is not adsorption and therefore the carbon will never become exhausted. By removing chlorine from the water at the whole-house level, the cation resin in a softener is protected, there is no chlorine in the water to affect clothes during washing or the taste of drinking water, and disinfectants will not be absorbed into the skin during showers or baths.

Chlorine removal capability

To quantify a carbon's dechlorination capability, reference to its "Pick's Half Value" is most useful. This value is based on the bed depth of activated carbon required to reduce free chlorine concentration by one-half (for a given flow rate). The accompanying table (sidebar) illustrates the process of dechlorination based on Pick's half-life.

As the table shows, the bed depth of an activated carbon filter is a very important factor in its effectiveness at removing chlorine. When you size a whole-house residential carbon filtration tank, the minimum size should be no less than 8" diameter by 44" tall. This equates to a volume of about 1 cubic foot, with headspace.

Considering chloramines

In addition to chlorine reduction, a carbon filter also takes on another important function. The same chlorine that is used to make our water safe can also combine with background organic compounds still present in the water after treatment at the municipal level, forming carcinogenic compounds such as THMs and HAAs (section D of contaminant chart).

Because of this possibility, additional disinfectants — chloramines — are now being added to municipal water to reduce the possibility of THM and HAA formation.

Although useful for this purpose, chloramines do have some negative side effects. They can adversely affect the seals in water treatment equipment and there have been reports of chloramine-related objectionable tastes and odors, and mild indigestion.

A carbon filter will adsorb chloramines. It might be asked why chloramines should be removed if they fight the formation of THMs and HAAs. The answer is that carbon covers all the bases by removing these other substances as well, whichever is present.

VOCs in groundwater

Carbon has also always been an excellent, cost-effective way to remove volatile organic carbon (VOC) compounds. In quite a large number of groundwater sources, several types of VOC contaminants such as the solvent and industrial ingredient trichloroethylene (TCE, also called trichloroethene) and the former gasoline additive methyl tertiary butyl ether (MTBE) are present at former manufacturing facilities or from leaking gasoline station tanks. Concentrations may be as low as in the parts per billion (ppb), but cleanup is still required.

For larger-scale VOC removal operations, large carbon filtration tanks, aeration or other types of technology can be used at the municipal level. But if concentrations still exist at the consumer level even below the EPA maximums, consumers should still consider carbon filtration as a viable solution.

While activated carbon works well on a host of VOCs, it does not necessarily per-

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Carbon dechlorination* ("Pick's half-life")

Bed depth (cm)	Chlorine (ppm)
0	10
2	5
4	2.5
6	1.25
8	0.625
10	0.32
12	0.156
14	0.07

*Flow rate = approx. 10 gallons/square foot/minute

Examples of VOCs treatable with carbon adsorption

Acrylonitrile
Aniline
Aldrin
Benzene
Benzoic acid
Carbon tetrachloride
Chlorobenzene
Chlordane
Chloroethane
Chlororform
DDE
DDT
1, 2-Dichlorobenzene
1, 1-Dichloroethane
Dieldrin
2.4 Dinitrotoluene
Ethylbenzene
Ethylenediaminetetraacetic acid (EDTA)
Fluorene
Heptachlor
Hexachlorobenzene
Hexachloroethane
Methylene chloride
Naphthalene

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form the same for all contaminants. For some compounds the adsorption capacity is great, while for others it may be substantially lower.

Overall carbon is extremely versatile for a number of contaminants, and the accompanying list shows some of the compounds it will adsorb.

Versatile, but not a cure-all

If the water treatment professional has a specific question about performance and/or removal capacity, they are advised to contact the "activated carbon professional." These individuals should be able to provide supporting documentation on performance criteria to support their recommendations. Understanding what carbon cannot do is just as important as knowing what it can do.

While activated carbon is versatile and cost-effective solution, it is not a cure-all. To finish the process, a final step of filtration should be used. Reverse osmosis (RO) may be essential for the highest degree of water purification.

With RO feedwater that consists of municipal groundwater treated with disinfectants, it is again necessary to use activated carbon for pre-filtration. Most residential RO units have a carbon pre-filter to remove chlorine or chlorine dioxide, to prevent degradation of the RO membrane.

RO removes dissolved solids, including ions of salts, and this is where RO becomes a last line of defense. A tiny residual of salt may be left in softened water, which will be removed by the RO unit.

Most ROs also also remove barium, chromium (hexavalent and trivalent), copper, cysts, lead, radium 226 and 228, selenium and nitrates. As with any piece of equipment, review the RO's performance criteria for actual removal certification. WT