Charcoal Filtration Basics

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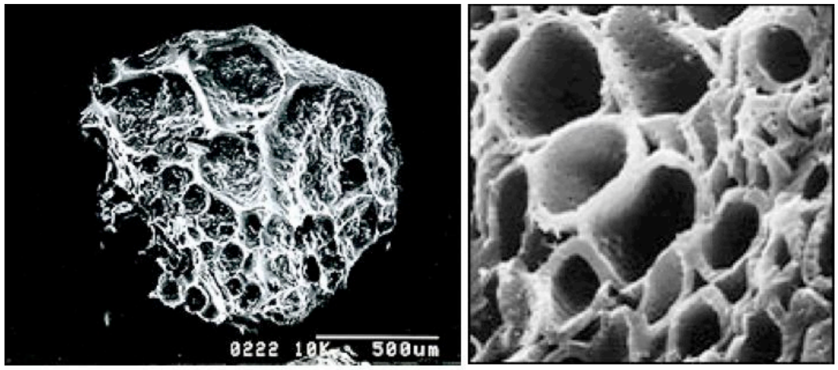
Abstract

The US EPA, the World Health Organization and several academic studies identify granular activated carbon (GAC) as the best available technology for the control of many agrochemicals and synthetic organic chemicals in drinking water.[i, ii, iii, iv] Although it is not possible to produce high-grade GAC without an industrial process, lower-grade charcoal-derived GAC is readily made in earthen kilns and may exhibit appreciable capacity for aqueous contaminant adsorption. Studies have shown low-grade char from the burning of crop residues to be about one-third as efficient for adsorbing dissolved pesticides when compared with industrial-grade GAC.[v, vi, vii] Taking conservative estimates for the capacity of homemade charcoal-based GAC to adsorb dissolved organic carbon (DOC), our research and calculations suggest that a maximum of 9 kg (20 lbs) of pulverized charcoal is needed to purify drinking water for one person for one year. In-depth molecular-scale characterization of various homemade charcoal materials to refine this estimate may permit a reduction in quantity by as much as ten times.

Charcoal Filtering

Charcoal consists of elemental carbon in its graphite configuration. Carbon has been used for water purification for centuries, possibly dating back as far as ancient Egypt and India.[viii] Carbon, in the form of graphite, exhibits an exceptionally high surface area per volume: one gram of industrially produced activated carbon may have a surface area of 400 – 1500 m^2 (a football field is about 5000 m^2). Non-polar organic molecules dissolved in water are strongly attracted to this surface and bind due to van der Waals (induced dipole) interactions. Carbon filters are employed in commercial home water treatment systems (to improve water taste, for example) as well as in large-scale municipal treatment facilities.

Scanning electron microscope images of GAC. The grain on the left is about 1 mm across. The right image shows a close-up of the pore space.



Carbon filters are effective for removing chlorine, mercury, iodine, and some inorganic compounds as well as many problematic organic contaminants such as hydrogen sulphide (H_2S), formaldehyde (HCOH), and volatile orgnanic compounds (VOCs). Activated carbon does not bind well to certain chemicals including lithium, alcohols, glycols, ammonia, strong acids and bases, metals, and most inorganic substances such as sodium, lead, iron, arsenic, nitrates and fluoride.

As a general rule, carbon will bind non-polar materials while polar materials will tend to remain in aqueous solution. Most pesticides are organic and strongly non-polar and thus should display an affinity for adsorption onto the carbon surface.

Water contaminants that can be reduced to acceptable standards – according to EPA National Drinking Water Standards – by activated carbon filtration include: organic arsenic, chromium and mercury complexes as well as inorganic mercury, benzene, endrin, lindane, methoxychlor, 1,2-dichloroethane, 1,1-dichloroethylene, 1,1,1-trichloroethane, trihalomethanes, toxaphene, 2,4-D, 2,4,5-TP (Silvex), and p-dichlorobenzene. [ix]

Carbon filters have limited capacity for removing microbial contaminants and should not be considered a sufficient method for eliminating this risk. The World Health Organization recommends coupling charcoal treatment with chemical (e.g. iodine, chlorine) or UV disinfection to ensure removal of microbial pathogens.[ii]

Charcoal Making

Charcoal is made by pyrolizing wood or other organic matter such as coconut or rice husks, nut hulls, peat, etc. in earthen kilns, brick ovens, or underground pits. The process involves heating the base material to temperatures of 600 – 900 ^{o}C in the absence of oxygen. “Activation” of charcoal typically refers to physical or chemical processes designed to increase the reactive surface area of the carbon. Industrial activation processes may use chemicals and/or steam to enhance surface area, although simply heating the material to sufficient temperatures can produce a significantly activated charcoal. In conjunction with researchers in the United States, we are currently planning experiments to determine the degree of activation of locally produced charcoals as compared with high-grade industrial materials.[x]

Earthen kilns near Mae Taeng, Chiang Mai Province, Thailand. Charcoal can be purchased in bulk for 2 - 10 Baht per kilogram ($0.03 – $0.08 per pound).

An underground pit kiln for clandestine charcoal making (using illegally logged wood) located in the national forest in Chiang Mai province, Thailand.

Once a sufficient quantity (mass) of charcoal is obtained, it must be pulverized into grains fine enough to pass through a 3 mm sieve. The grinding process is necessary to increase the material's surface area and enhance contaminant adsorption. The plastic mesh bags that produce (e.g. potatoes) is sold in are widely available, are free or inexpensive, and make a good sieve for the pulverized carbon.

Plastic mesh bag sieve.

Other uses for charcoal and its by-products

Charcoal has many uses in addition to water treatment. It is the preferred cooking fuel for the majority of rural people who cook indoors over an open fire as it burns longer and hotter than the common alternatives (cornhusks, bamboo) and produces less smoke. Charcoal is pulverized and used as an additive to bar soap as a scrubbing aid and skin exfoliant. Very finely ground charcoal has medicinal qualities and is used to treat stomach and enteric infections, as well as poisonings and overdoses following oral ingestion (it prevents absorption of the poison by the gastrointestinal tract).

Wood vinegar (pyroligneous acid) is a by-product of the charcoal making process. It is distilled by passing the smoke through a long chimney or heat exchanger to encourage condensation of water and a mixture of volatile organic compounds driven off from the pyrolizing wood. Its principal components are acetic acid, methanol and acetone. It is reputed to be a natural aid for various uses including mild pain relief such as tooth aches and to sterilize and promote the healing of minor wounds. Wood vinegar is also a mild natural pest deterrent and can be applied to crops or to wood surfaces to protect from termites.[xi]

Wood vinegar collection from kiln chimney.

For more information on pesticides and drinking water filtration using charcoal, see our website: ***aqsolutions.org***

References

[i] US EPA. National primary drinking water regulations; final rule. Federal Register, 30 January 1991. 1991; 56 20: 3526 3597.

[ii] World Health Organization website: (http://www.who.int/water_sanitation_health/dwq/wsh0207/en/index6.html) section 2.3 Charcoal and activated carbon adsorption

[iii] Pontius F. An update of the federal drinking water regs. J AWWA 1995; 87: 48-58.

[iv] Pesticide Adsorption by Granular Activated Carbon Adsorbers. 1. Effect of Natural Organic Matter Preloading on Removal Rates and Model Simplification. Matsui Y, Knappe DRU, Takagi R. Environ. Sci. Technol. 2002, 36, 3426-3431.

[v] pH-Dependence of Pesticide Adsorption by Wheat-Residue-Derived Black Carbon. Yang Y, Chun Y, Sheng G, and Huang M. Langmuir 2004, 20, 6736-6741.

[vi] Pesticide Adsorptivity of Aged Particulate Matter Arising from Crop Residue Burns. Yang Y, Sheng G. J. Agric. Food Chem. 2003, 51, 5047- - 5051.

[vii] Enhanced pesticide sorption by soils containing particulate matter from crop residue burns. Yang Y, Sheng G. J. Environ. Sci. Technol. 2003, 37, 3635-3639

[viii] Wikipedia: http://en.wikipedia.org/wiki/Carbon_filtering

[ix] Water Quality Association, 1989. Recognized treatment techniques for meeting the National Primary Drinking Water Regulations with the application of point-of-use systems.; and, Water Quality Association, 1989. Recognized treatment techniques for meeting the National Secondary Drinking Water Regulations with the application of point-of-use systems. See also Seelig B, Bergsrud F, and Derickson R. Treatment Systems for Household Water Supplies: Activated Carbon Filtration. February 1992. (http://www.ag.ndsu.edu/pubs/h2oqual/watsys/ae1029w.htm)

[x] Professor Detlef Knappe of the Department of Civil, Construction, and Environmental Engineering at North Carolina State University (Campus Box 7908 Raleigh, NC 27695-7908 USA) has offered his laboratory for characterization of our charcoal samples.

[xi] Retrieved from "http://en.wikipedia.org/wiki/Pyroligneous_acid" ; also, Jon Jandai, personal communication.