DIY (Do-It-Yourself) Water Purification: Basic System Design

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Note:

This document provides general design specifications for the construction of a household- to community-scale drinking water purification system to remove chemical pesticides and can be constructed by the system's operators using simple, inexpensive and locally abundant materials. The system also incorporates ultraviolet disinfection to neutralize biological contaminants

Biological Decontamination

Contaminants that compromise the safety of drinking water are both biological and chemical and different strategies are required for their neutralization or removal. Strategies for removing biological contaminants include filtration with ceramic filters, chemical treatment (e.g. with chlorine or iodine), and exposure to ultraviolet (UV) radiation.

UV radiation is the surest method for biological decontamination, though until recent years it has been too delicate, expensive, complicated and resource intensive for use at the household or community scale in developing societies. Recently however, researchers and engineers have pioneered the development of simple, inexpensive and robust UV systems. AqueousSolutions has partnered with the US- and Vietnam-based MEDRIX, Inc. (Medical, Educational and Development of Resources through International eXchange), a non-profit company that has developed and deployed robust and inexpensive point-of-use germicidal UV units in a number of Southeast Asian communities to receive the materials and training for implementation of this aspect of the treatment system. We refer the reader to their website (www.medrix.org) for detailed information regarding the germicidal UV units.

Chemical Decontamination

Biological contamination of drinking water is only part of the problem, especially when considering pesticides and other agricultural runoff. Filtration with ceramics, chemical treatment and UV radiation will not remove pesticides from drinking water.

Charcoal (graphite carbon) is an inexpensive material that has been manufactured worldwide for millennia, and because of its electrochemical surface properties has great potential for effectively removing agrichemical contaminants from water. Charcoal water filtration is in fact an ancient technique, and today is employed at the municipal scale for water treatment. The charcoal that is used in water treatment plants, however, is a high-grade material produced using an industrial process to increase its reactivity and enhance its capacity as a filtration medium (often called "granular activated carbon," or GAC). The US EPA, the World Health Organization and numerous academic studies identify granular activated carbon (GAC) as the best available technology for the control of many agrichemicals and synthetic organic chemicals in drinking water. [i, ii, iii, iv]

The charcoal filtration system design presented here, under development by AqueousSolutions, utilizes basic, garden-variety charcoal that can be produced at home or purchased in local markets all over the developing world.

Our research suggests that this material performs nearly as good as industrial GAC as a filtration medium. For example, 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]

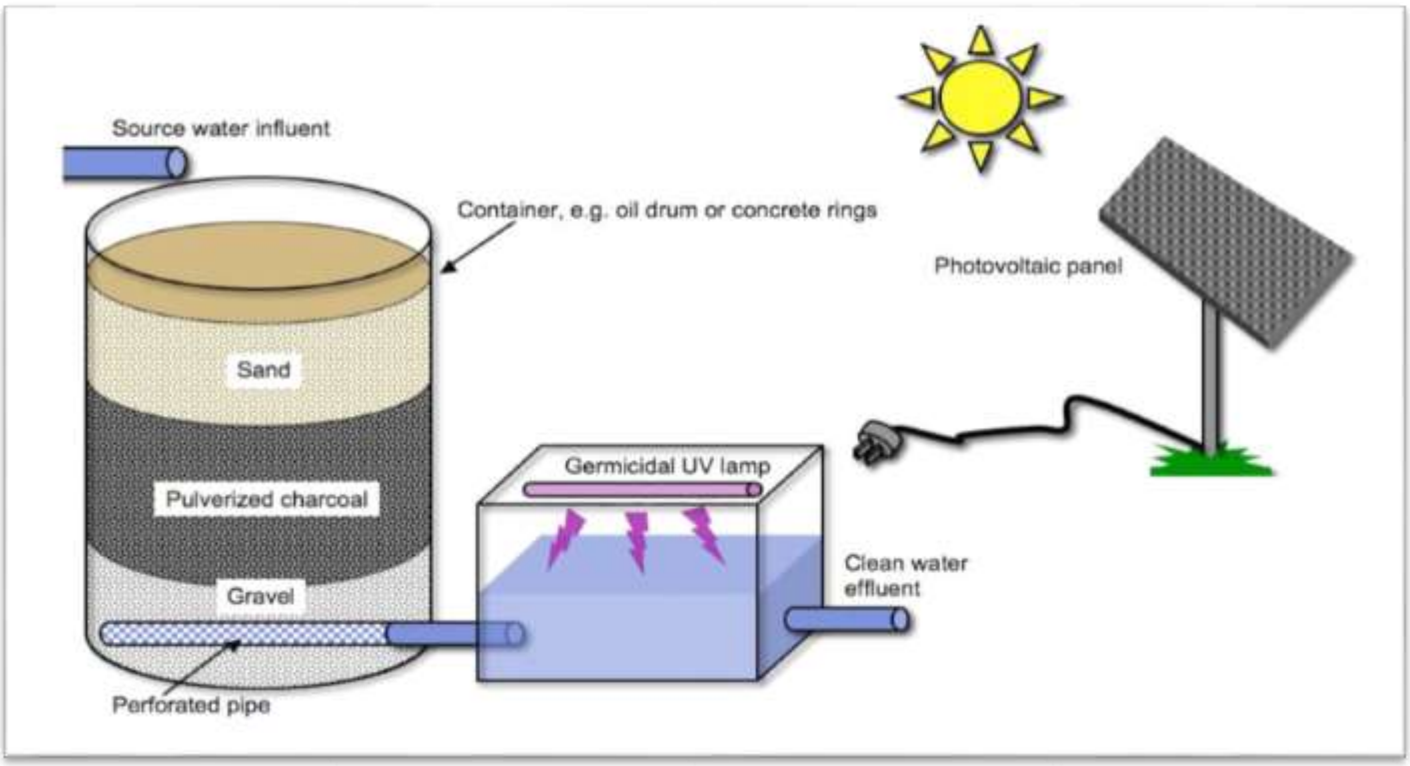
Since the wheat straw was exposed to air during the charring process, it is likely that proper charcoal manufactured in an earthen kiln or brick oven is of appreciably higher quality than wheat straw char and exhibits a significantly larger capacity for adsorption of water contaminants.

Treatment System Design

The amount charcoal necessary to treat a given volume of drinking water depends on the concentration of contaminants in the water as well as the chemical adsorption capacity of the pulverized charcoal.

The water filtration system described here is designed around a general set of parameters, making conservative estimates regarding its capacity for contaminant adsorption. In place of experimental data using specific agrichemical pesticides, we regard dissolved organic carbon (DOC) as our general contaminant and design the system around its removal. Several studies have shown that DOC adsorption by granular carbon can block or displace other adsorbed organics such as pesticides. [viii] Therefore, we estimate the capacity of charcoal to adsorb DOC in general, assuming a modest propensity for adsorption on the part of the charcoal and a generous concentration of DOC in the local water supply.

Conservatively assuming 10 mg DOC/g charcoal as the adsorption capacity of charcoal [ix] and 50 mg DOC/L as the DOC concentration in natural surface waters [x], we estimate that 5 grams of charcoal are needed to sufficiently purify 1 liter of water. With this ratio, and assuming the EPA recommended daily water intake of 2.5 liters per person per day, roughly 4.5 kilograms (about 10 lbs.) of charcoal are required to supply drinking water to one person for one year.



Cartoon illustration of the treatment system design

Design for a gravity-fed system will employ a sand pre-filter followed by pulverized charcoal filter medium supported on a bed of gravel. Exposure to UV radiation after filtration will neutralize biological contaminants. A photovoltaic panel provides electricity for the UV lamp.

Conservative estimates suggest that the sand layer should be about 50 centimeters thick. The sand acts both as a prefilter to remove particulates and to precipitate aqueous iron complexes, which can interfere with UV disinfection. [xi]

A diffuser plate is placed over the sand to reduce the turbulence of the influent and prevent channels forming through the sand. The thickness of the charcoal layer will depend upon how many people are using the system as well as its desired lifetime (i.e. the time until the charcoal has to be replaced). The purpose of the gravel layer is to prevent clogging of the perforated pipe by carbon granules – this layer need only be about 20 centimeters in thickness.

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] Effect of preadsorbed background organic matter on granular activated carbon adsorption of atrazine. Wang G-S and Albena KT. The Science of the Total Environment 224 1998 221 – 226. And, 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.

[ix] 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.

[x] Dissolved organic carbon concentration of a natural water body and its relationship to water color in Central Kalimantan, Indonesia. Ishikaw T, Trisliana, Yurenfrie, Ardianor and Gumiri S. Limnology,Vol. 7, No. 2, August 2006.

[xi] For more information on slow sand filters and UV decontamination see Rau,

Robert, *UV Water Purification Made Simple*, Home Power # 91, October/November 2002. Also, National Drinking Water Clearing House, *Slow Sand Filters*. Tech Brief Fourteen, June 2000.