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# Water Treatment and Equipment Decontamination Techniques

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In responding to an intentional contamination of a drinking water system, water utility personnel (along with many other entities) will be faced with both providing clean and safe drinking water for their consumers and for cleaning up the contamination. How those two responsibilities are handled will be dictated by the type of contaminating event. For example, if a major ground water aquifer is contaminated, then decontamination of the aquifer may not be possible and treatment of the water from that aquifer would be required before the water could be used. If a storage tank is contaminated, the storage tank could possibly be taken off line. The contaminated water would then be treated prior to disposal and the storage tank decontaminated (cleaned) prior to bringing the storage tank back online.

This summary article will discuss the various water treatment and decontamination techniques that could be used during an intentional contamination event. For this article, water treatment will refer to techniques that would be used to treat the contaminated water and decontamination will refer to the techniques that would be used to clean hard surfaces such as the insides of a pipe or storage tank. Although this article will not discuss specific actions to take during specific events (or specific contaminants), the article provides summary information that will guide water personnel towards the proper treatment techniques.

The basic contaminants that could be used in an intentional attack against a water system could be broken down into chemical (inorganic or organic),

microbial (bacteria, protozoan, or viruses), and radiological classes. Various groups have made public lists available (States 2003; CDC 2003). This article will not discuss the merits of those lists, the specific contaminants on those lists, nor attempt to define where or how those contaminants could be introduced into a water system. The discussion contained in this article will start with the assumption that a contaminating event has occurred. Although this article focuses on the basis of an intentional contamination, the same process described here could be used during an unintentional contaminating event. This article will also address some of the knowledge gaps missing in the water treatment and decontamination area that could lead to research needs.

## Water Treatment

The various types of water treatment technologies available (or applicable) depend on the type of contaminant and the extent of the contamination. For example, if a storage tank was contaminated with a microbial contaminant that could be inactivated by disinfectant, then proper levels of the disinfectant could be added to the storage tank for the proper length of time and no additional treatment would be necessary. In the case where an inorganic chemical contaminant was introduced into an aquifer, a granular activated carbon water treatment plant might need to be constructed in order to treat the water for very long periods of time. The various typical water treatment practices are described

below along with a summary of their capabilities and where they could be used. A full description of the following techniques can be found in the literature (AWWA 1999).

Conventional coagulation/settling/filtration water treatment uses chemical pretreatment to cause particulate material in a water system to form floc that would then be settled out in a sedimentation basin and/or removed by filters. The typical pretreatment chemicals include aluminum or iron coagulants, lime or polymers and the type and amount of chemical depends on the water quality present. This type of treatment is very good at removing particulate matter (including microorganisms), small amounts of various chemical contaminants, and to some extent various radionuclide contaminants. Although this process is very good at removing many contaminants, the process would be difficult to install during an emergency situation. There are some mobile water treatment units that utilize this technology, but those mobile units could not treat large quantities of water. This technology would be (and is) very useful for treating the drinking water for communities that use surface waters for their source water. As an added advantage, this process provides a measure of protection in case their source water becomes contaminated.

One modification to the conventional process is known as direct filtration. In direct filtration, the sedimentation step is eliminated. Source waters that contain low levels of particulate material may be suitable for direct filtration. The types of contaminants removed by direct filtration and the limitations of direct filtration are similar to conventional treatment.

Granular activated carbon (GAC) is an absorption media that can be used to remove many organic contaminants from water. GAC is also effective in the removal of lesser amounts of inorganic contaminants and radionuclides. The GAC is typically placed into a contactor and the water passes over and through the carbon. The contaminants attach themselves to the carbon and are removed from the carbon during reactivation or remain on the carbon for disposal (depending on the contaminant). GAC contactors can be installed quickly and the carbon replaced when it is spent rather than trying to reactivate the carbon. GAC systems are also readily available for smaller applications such as apartment buildings; they are

even small enough for houses and single faucets. Thus, during an emergency situation, GAC units could be utilized to treat only the water that was to be used for consumption or to treat all of the water that was being distributed.

One modification to GAC is known as powdered activated carbon (PAC) where instead of the water flowing through a carbon contactor, the PAC is added to the water and then removed by other processes. The types of contaminants removed by PAC are similar to those listed under GAC. PAC is typically used in situations where seasonal (or occasional) contamination occurs and the activated carbon is only needed for relatively short times.

Aeration is a process in which high volumes of air are passed through the water in an effort to transfer the contaminant from the water to the air and thus remove the contaminant from the water. There are several types of aeration systems utilized in drinking water treatment and they range from pipes that bubble air into a pool of water, to pressurized, diffused bubble systems, to tower aeration processes. In all cases, the treatment process is to pass air through the water to strip out the contaminant. Aeration techniques are typically used to remove volatile organic contaminants but there are a few radionuclides that can be stripped from water by this process. Aeration systems can be installed in relatively short periods of time and they are adaptable to various sizes of systems. For example, aeration systems have been placed into open-air reservoirs, down single wells or to centrally treat water in a community. One draw back to aeration systems is that the water will have to be re-pumped after aeration to pressurize the system.

There are several treatment technologies that fall under the category of membrane treatment. Those technologies include reverse osmosis, nano-filtration, and micro-filtration. In all three cases, the idea is to pass water through a membrane by pressure while leaving the contaminants on the other side of the membrane and removed from the system in a concentrated waste stream. In drinking water treatment, these three technologies are differentiated by the size of the contaminant that will go through the membrane. Reverse osmosis systems are capable of removing chemicals (inorganic or organic), microorganisms, and radionuclides. Nano-filtration would typically be capable of removing inorganic chemicals, some large organic compounds,

and microorganisms. Micro-filtration would only be used to remove the microorganisms.

All of the membrane technologies are such that they can be installed easily and range in size from single faucet application (e.g., home reverse osmosis units) to large-scale applications for treating water for large communities. There are mobile water treatment systems utilized by the military and some of these use membrane technologies to be prepared to remove as many contaminants as possible.

Ion exchange technology is one where water passes over a bed of ion exchange media (typically resin beads). The resin beads have sacrificial chemical groups attached to them such as sulfate, sodium, potassium, hydrogen and others. The chemicals in the water exchange themselves for the chemical group on the resin. Currently, ion exchange systems are utilized for inorganic chemical, radionuclides, and some organic chemicals. Ion exchange systems can be installed easily and are readily available in cartridge systems for small applications, whole house systems (home water softener), commercial size for industrial uses, and full-scale water treatment systems.

Activated alumina treatment is not a common practice in drinking water treatment, but is being used to remove specific inorganic chemicals from some water supplies. The removal process is by both adsorption and ion exchange within the activated alumina. Activated alumina has not been used to remove organics or microorganisms from drinking water.

One of the most common forms of water treatment that would be used during and intentional attack of a water system is the use of a disinfectant. Currently, the most common drinking water disinfectants used are chlorine, chloramines, and ozone. Ultraviolet light is also used to disinfect drinking water. Typically, the drinking water disinfection processes are utilized to inactivate microorganisms, oxidize inorganic chemicals or destroy some organic compounds. The amount and type of disinfectant required is dependant on the water quality, type and number of organisms, and chemical to be oxidized. Disinfectant technologies are probably the easiest technology to implement in an emergency situation. Quantities of disinfectant could be added manually to a storage tank if necessary, the water utility could increase the disinfectant addition at the treatment plant or

disinfection equipment could be added in desired locations.

Heat inactivation is the final process to be discussed. During drinking water emergencies, boil water orders are often implemented. Notices are given for individuals to boil their water prior to consumption. This process is only given for microbial problems and should only be given when boiling is thought to be the desired treatment.

In all of the treatment technologies described above, one does need to be aware of the waste products that are generated. In the conventional (and direct filtration) technology, waste sludge is generated that could potentially be very hazardous. The waste sludge in this case would have to be disposed of (or treated) properly. All of the above technologies generate some sort of waste product.

## Decontamination Techniques

After an intentional contamination attack on a water system, there is a concern that some of the contaminant could remain on the interiors of the storage tanks, distribution system pipes, or in home fixtures. Decontamination of that infrastructure may be necessary to remove the contaminants from the interiors so that the residual contaminant does not pose a health or aesthetics problem. In most cases, simple flushing of the system with clean water will remove the bulk of the contaminants. Simple flushing may need to increase to high velocity flushing to allow for some physical scouring in addition to clean water rinsing. Processes for doing uni-directional flushing are described in the literature (AWWARF 2003) and care should be taken that the flushing program does not contaminate a clean area accidentally.

In some cases, other decontamination methods may need to be implemented to fully remove the specific contaminant. At this time, there are not definitive measures described for individual contaminants, thus generic decontamination techniques are described.

The disinfection chemicals described in the water treatment section may also play a major role in decontaminating a water system. High levels of disinfectant put into a storage tank (or pipe network) will inactivate many of the organisms that attached themselves to the interior structures. The high levels of disinfectants could also disrupt the normal biofilm

in the system that some of the contaminants could hide in and not come out during routine flushing. In many cases, the flushing technique described above will be done at the same time that high levels of disinfectant are added to the flush water.

At this time, little is known about the ability of various surfactants to remove specific contaminants from pipe walls. Other techniques used in drinking water distribution pipe network rehabilitation include pigging and relining. There is also little know about how these techniques could play a role in decontaminating a water system after an intentional attack. (See AwwaRF 2003b for a review of methods to clean the interior of pipes in order to improve bulk water quality.)

## Future Work

At the present, the U. S. Environmental Protection Agency's (U. S. EPA) National Homeland Security Research Center (NHSRC) is evaluating specific water treatment and decontamination technologies for various drinking water contaminants. The list of contaminants includes those not normally found in drinking water system and those that could be used in an intentional attack. The information gathered in those projects will be made available to water utilities and those that assist water utilities during an emergency. The data that are considered non sensitive will be published in peer journals or on EPA's web site. For data that are considered sensitive, secure publications and access will be available.

Future research will also be necessary on newly created chemicals and mutated or genetically altered microorganisms. Much of that work will be long term research projects as the specific contaminant is identified.

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