Spring 2004
Vol. 15, No. 2

Pipeline

Small Community Wastewater Issues Explained to the Public

NESC NESC

The Disinfection Question – Answers for Onsite Systems

The purpose of any wastewater treatment is the removal of pathogens agents—among other harmful com-ponents. For the final purification step in most onsite wastewater sys-tem designs, the mostly-treated efflu-ent flows through a layer of soil before reaching the groundwater. But with water reuse becoming more and more important, is there a way to produce an effluent clean enough to safely use for toilet flushing or watering vegetation? Is there tech-nology that will produce a more fin-ished product? This issue of *Pipeline* will investigate the option of disin-fection—what it means, how it works, and what method might be right for your situation.

Disinfection is generally required with onsite treatment systems where the effluent is to be surface dis- charged or prior to some other imme-diate reuse of effluent (such as toilet flushing or watering of vegetation). State reg-ulations regarding the disin-fection requirements varies from state to state. Check with your local health officials or onsite permitting authorities to learn about the laws applying to your area.

Disinfection can be defined as the destruction of disease-causing or-gan-isms. The organisms of greatest con-cern, due to their disease produc-ing capabilities, are bacteria, viruses, and protozoans. Disinfection is the best way to prevent the spread of water-borne diseases such as typhoid fever, dysentery, and cholera into the envi-
ronment. A table listing common infectious agents potentially present in untreated domestic wastewater is shown below.

Disinfection processes for onsite dis-posal must be simple, and safe to operate, reliable, and economical. They normally are the last pro-cess in the treatment flow scheme. Waste-water must be adequately treated prior to the disinfection stage. There is no perfect disinfectant for all situations. Cost of operation and maintenance, ease and safety of use,

effectiveness, and amount of residue that is left in the wastewater after treatment are parame-ters that must be weighed before determining the most appropriate solution for each situation.

The three most common methods of disinfection in the U.S, use chlorine, ozone, or ultraviolet (UV) light. This newsletter will focus on chlorination and UV systems, because ozone disinfection is very expen-sive for both equipment and power use for individual onsite systems.

Sufficient contact time between the wastewater and the disinfectant is impor-tant. Chemical disinfectants must be mixed thoroughly with the wastewater at the appropri-ate concentration and for a specific amount of time. UV radiation also requires a specific time of exposure as well as a prescribed strength of light wave.

The effectiveness of disinfection is measured by the reduction of indi-ca-tor bacteria (total or fecal coli-form) or disinfectant residual in the case of chlorine. The general design of disin-fection processes requires the deter-mination of the wastewater character-istics, wastewater tempera-ture, pathogen(s) to be destroyed, and dis-infectant to be employed. From this information, the required residual concentration relationship may be developed and the disinfectant dose can be calculated.

Table 1

in untreated domestic wastewater

Organism	*Disease caused*
Bacteria	
Escherichia coli	Gastroenteritis
Leptospira	Leptospirosis
Salmonella typhi	Typhoid fever
Salmonella (=2,100 serotypes)	Bacilliary dysentery
Vibrio cholerae	Cholera
Protozoa	
Cryptosporidium parvum	Cryptosporidiosis
Entamoeba hystolytica	Amoebic dysentery
Giardia lamblia	Giardiasis
Viruses	
Various Enteroviruses	Gastroenteritis, meningitis
Hepatitis A virus	Infectious hepatitis

(Source: EPA Wastewater Technology Fact Sheet: Ultraviolet Disinfection)

Chlorination

Chlorine, the most widely used water disinfectant, has a long history of being a reliable disinfecting agent. It is unclear precisely how it does such a good job; most theories point to the breakdown of the pathogen's cell wall by oxidation. Chlorine is fairly cheap to purchase and is effective against a wide range of pathogens. In some cases, chlorine can eliminate bad odors associated with waste-water.

Available as a gas, liquid, or solid, chlorine is corrosive and toxic in all forms. Storing, shipping, and han-dling it all pose a risk. Chlorine gas is highly reactive and poisonous; therefore its use is limited to treatment plants where the operators have proper training in handling tech-niques. The economic benefits of handling the potentially dangerous gas offset the safety concerns.

Forms of chlorine called hypoch-lo-rites are the most widely used chlo-rine compounds for small and onsite systems. Hypochlorites are available in liquid, tablet, or powder form. (See Figure 1.) The chlorine compounds, such as calcium and sodium hypoch-lo-rites, are highly toxic to microorganisms, highly soluble in water, and relatively inexpensive.

Figure 1 Chlorine tablets (calcium hypochlorite) for use in tablet feeders. [Please note that operator should wear gloves when handling chlorine tablets.] Photo by Chris Metzgar, NESC.

Chlorine has an inter-esting benefit for water purification in that the residual chlo-rine that remains in the water prolongs disinfection even after initial treatment. Unfortunately, resid-ual chlorine is toxic to aquatic life, even at low concentra-tions, and so this is not a huge benefit for wastewater disinfection when the wastewater is discharged directly into a body of

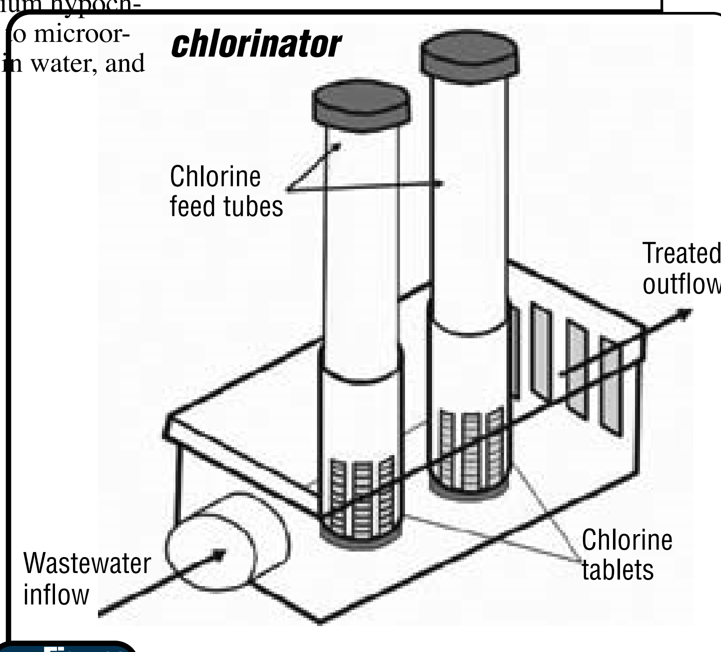

Figure Stack feed chlorinator
Drawing courtesy of Don Jones, Purdue University

National Environmental Services Center
NESC Assistance. Solutions. Knowledge.
Pipeline

Pipeline is published quarterly by the National Environmental Services Center at West Virginia University, P.O. Box 6064, Morgantown, WV 26506-6064

Pipeline is funded through a grant from the U.S. Environmental Protection Agency Washington, D.C.

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ISSN 1060-0043

Figure 3 *At this package treatment plant, the wastewater is sent to the chlorinator then to the dechlorinator before final dispersal. [Please note that operator should wear gloves when handling chlorine tablets.] Photo by Chris Metzgar, NESC.*

water. Wastewater may require a special process called dechlorination to remove these residuals. This is a fairly expensive process and is mini-mized by using only the least amount of the chemical compound necessary to do the job. (See sidebar at right for a complete description of the dechlo-rination process.)

Wastewater requires at least 30 minutes of contact time for effective dis-infection using chlorine. Chlorination can also be varied in strength as the effluent quality changes. The required degree of disinfection can be achieved by varying the dose and contact time. It is important to control the exact amount of chlorine used to prevent inadequate disinfection, but also to prevent the discharge of excessive concentrations of residual chlorine to the receiving environ-ment. To calculate the minimum size of the contact tank, use this formula:

$$\frac{\text{design flow(gpd) x contact time(minutes)}}{\text{1440(minutes per day)}}$$

Solid calcium hypochlorite is the most favored form for onsite applica-tions. It is usually introduced into the effluent flow using a tablet feeder device. (See Figure 2.) Tablet feed devices designed for in-line installation are economical and simple. Having no moving or metal parts, they do not need electricity as the wastewater flows through the feeder, dissolv-ing the tablet in proportion to flow rate, and then flows to a contact tank. The contact tank is baffled so that the effluent is forced to remain in the tank for the required contact time. Then the effluent passes to the disper-sal area.

The rate at which chlorine tablets dissolve depends on the amount of wastewater passing it and the length of time it is in contact with the wastewater. If too much contact time is allowed, the wastewater will be over-chlorinated and the tablet will be used up too rapidly. If there is too little contact time allowed, the wastewater will not be chlorinated thoroughly enough for

Dechlorination

Dechlorination is the process of removing free and combined chlorine ions to reduce toxicity before dis-charge into the environment. Typically, dechlorination is done by adding sul-fur dioxide or sulfite salts (i.e., sodium sulfite, sodium bisulfite, or sodium metabisulfite.) Efficient decholorina-tion protects aquatic life from the toxic effects of any residual chlorine and prevents the formation of harmful chlorinated compounds that may be created when the residual chlorine interacts with waterborne organic materials. Problems can occur with dechlorination processes if near zero levels of residual chorine are required or the use of too much sulfites cause sulfates to form.

Table 2

Chlorine disinfection dose in mg/L design guidelines for onsite applications

Calcium hypochlorite	Septic tank effluent	Biological treatment effluent	Sand filter effluent
pH 6	35-50	15-30	2-10
pH 7	40-55	20-35	10-20
pH 8	50-65	30-45	20-35

Note: Contact time = 1 hour at average flow and temperature 20º C. Increase contact time to 2 hours at 10º C and 8 hours at 5º C for comparable efficiency. Dose = mg/L as Cl. Doses assume typical chlorine demand and are conservative estimates based on fecal coliform data.

Source: USEPA Onsite Wastewater Treatment Systems Manual, February,

discharge to the environment. (See Table 2.)

Problems with these tablet feeders can occur when the tablets swell and cake together, preventing them from dropping freely. Operation is also hindered if solids build up in the contact chamber. Routine maintenance includes restocking the tablets as necessary, cleaning the chamber of solids, monitoring and adjusting for the correct amount of residual in the effluent. It is important to pull the feeder out and check it for clogged tablets. A visual inspection from the top side only will not reveal this problem. Note that in addition to being toxic to many animals and plants, under the right circumstances, the small amounts of chlorine that remain in the wastewater can react with the organic matter and can form suspect-ed carcinogens or compounds toxic to the environment, such as tri-halo-methanes and chloramines. Because chlorine residuals can persist in the effluent for many hours, many states will not allow the use of chlorination alone for pristine receiving waters because of its effects on aquatic species. To minimize these effects, chlorinated waste-water must often be dechlori-nated or treated to reduce the chlorine residuals to a level not toxic to aquatic life. Chlorin-ation/dechlorination systems are more complex to operate and maintain than chlorination alone. See sidebar on page 3 for details on this process.

UV

Using UV light for disinfection is becoming an increasingly popular method for small wastewater streams. UV light kills microorgan-isms by penetrating the surface of the micro-organism and causing biochem-ical changes. UV light damages the RNA and DNA of the organism, making it unable to reproduce.

UV is proving to be a reliable, simple alternative to chlorination— requiring only simple maintenance from the homeowner. Unlike chlo-ri-nation, there is little danger of over-dosing with UV light, and it has the advantage of leaving no residue in the water. Maintenance consists of replacing the lamp periodically and keeping the lamp bulb clean.

All commercially produced UV units operate basically the same: a thin film of water or wastewater is exposed to short-wave UV light. Because the distance over which UV light is effective is very limited, the most effective disinfection occurs when a thin film of the water to be treated is exposed to the radiation.

The effectiveness of a UV disin-fec-tion system depends on the charac-teristics of the treated effluent, the intensity of UV radiation, the time the microorganisms are exposed to the radiant, and the configuration of

Table 3

Wastewater characteristics affecting UV disinfection performance

(BOD) Minor effect but if a large portion is humic compounds, then UV transmit-tance may be diminished

Iron High absorbency of UV radiation

pH Affects the solubility of metals that can absorb UV light

TSS Absorbs UV radiation and shields embedded bacteria

(Source: EPA Wastewater Technology Fact Sheet: Ultraviolet Disinfection

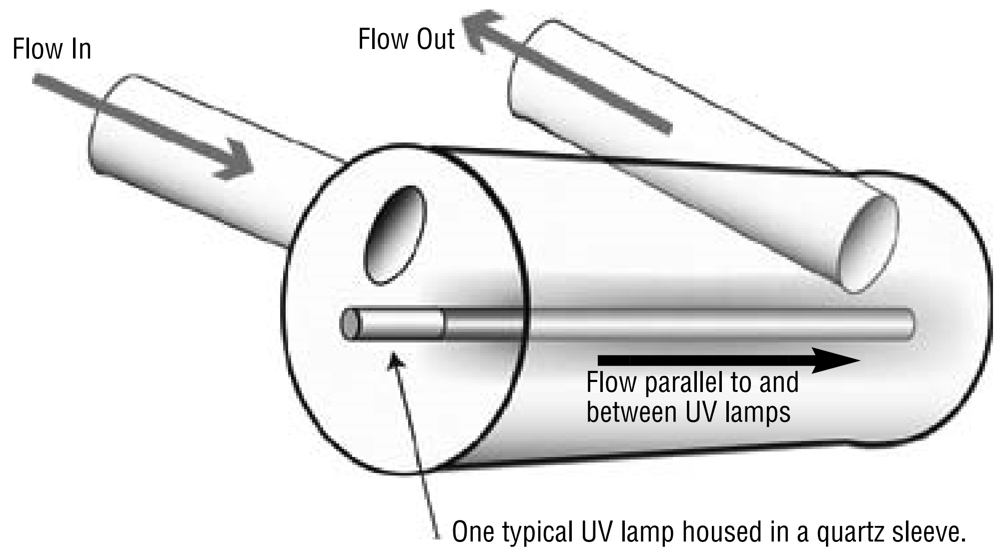

Figure 4 *Wastewater flow in a quartz UV unit.*

the device. High levels of suspended solids block the light from doing its job. The bacteria tend to cling to these particles and are shielded from the light. This is also why it is important that the lamp is kept clean. The light must pass evenly through the film of water to do its job. (See Table 3.)

The optimum wavelength to ef-fec-tively inactivate microorganisms is in the range of 250 to 270 nanome-ters (nm). The intensity of the radia-tion emitted by the lamp dissipates as the distance from the lamp increases. Lamps recommended for onsite sys-tems are considered low-pressure and emit light at a wave-length of 253.7 nm. Standard lengths of the low-pressure lamps are 0.75 and 1.5 meters with diame-ters of 1.5 to 2.0 centimeters. The ideal lamp wall temperature is between 95 and 122º F. (See Table 4.)

Advantages of using UV disinfection

as compared to other technologies in-clude its effectiveness at inactivat-ing most viruses, spores and cysts, and its shorter reaction time, and rel-atively small space requirements. The use of UV is considered user-friendly for operators since no dan-gerous chem-icals have to be handled, and there is no harm-ful residual effect in the wastewater.

Drawbacks to using UV include the fact that organisms can sometimes repair and reverse the damage done to them if they are allowed to rest in a dark place. This process is known as “dark repair.” Also, the light tubes must be kept clean to work properly which requires some routine mainte-nance even if an automatic cleaning system is used. The initial startup costs are higher for U.S. sys-tems than for the standard chlorina-tion systems.

How UV works

A UV disinfection system creates radiation energy by sending an elec-tri-cal discharge through mercury vapor. This radiation penetrates the genetic material of microorganisms and retards their ability to reproduce. Microorgan-isms vary in their resist-ance to UV light. The portion killed depends on the UV light intensity and the exposure time. These two variables combined are known as the dosage, and it is the single most important parameter for rating UV disinfection equipment.

The other important variable is the clarity of the water. Water is an excel-lent transmitter of UV light, but

Table 4

Typical ultraviolet system design parameters

Design Parameter	Typcial design value
UV dosage	20-140 mW-s/cm2*
Contact time	6-40 seconds
UV intensity	2-12 mW-s/cm2
Wastewater UV transmittance	50-70%
Wastewater velocity	2-15 inches per second

*microWatt-seconds per square centimeter

Source: USEPA Onsite Wastewater Treatment Systems Manual, February, 2002.

Figure 5 *Side view of a residential UV unit*
Photo courtesy of Ashco – A Corp., Morgantown, WV

the dissolved and suspended substances are strong absorbers. The source of the suspended particles deter-mines what effect they will have on the disinfec-tion process. Clay or silt particles have little effect while biological debris limits disinfection. Microorganisms buried within the biological debris particles are shielded from the damaging UV light. Technically speaking, turbidity and total suspended solids (TSS) can render the UV disin-fection ineffective. TSS levels must be below 30 mg/L for the secondary effluent. (Table 3 describes the wastewater char-ac-teristics affecting UV disin-fection performance.)

The main components of a UV system are the mercury arc lamps, a reactor and ballasts. For gravity flow wastewater disinfection, several sleeved lamps are placed on a remov-able vertical rack and suspend-ed in an open flow channel. The system should be installed below grade with easily remov-able components. The home-owner must clean the sleeve and replace the bulb on an annual basis.

Comparing the advantages and disadvantages of using chlorine vs. ultraviolet light for disinfection

Advantages

Chlorine

- A well-known technology
- More cost-effective
- Reliable against a wide spectrum of pathogenic organisms
- Effective in oxidizing certain organic and inorganic compounds
- Has a flexible dosing control
- Eliminates certain noxious odors

UV

- Effective at killing most viruses, spores, and cysts
- Eliminates the need to handle toxic chemicals
- No residual effect
- User-friendly for operators
- A shorter contact time is required
- The equipment requires less space

Disadvantages

Chlorine

- The residual compounds are toxic to aquatic life and may require dechlorination
- All forms of chlorine are toxic and corrosive
- Feeders are sometimes unreliable (tablets can cake and clump)
- Oxidizes certain types of organic matter into even more hazardous compounds
- Dissolved solids are increased
- Some parasites are resistant to low doses
- Long-term effects of dechlorinated compounds in the environment are unknown
- Safety concerns for operators and maintenance providers

UV

- Low doses not effective against some viruses, spores, and cysts
- Organisms can repair and reverse the effects of UV
- Maintenance is required to control fouling of the light tubes
- High total suspended solids and turbidity can render UV light useless
- No measurable residual to indicate the efficacy

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