

Pipeline



Small Community Wastewater Issues Explained to the Public

The Disinfection Question – Answers for Onsite Systems

The purpose of any wastewater treatment is the removal of pathogens—disease-causing agents—among other harmful components. For the final purification step in most onsite wastewater system designs, the mostly-treated effluent 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 technology that will produce a more finished product? This issue of *Pipeline* will investigate the option of disinfection—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 discharged or prior to some other immediate reuse of effluent (such as toilet flushing or watering of vegetation). State regulations regarding the disinfection 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 organisms. The organisms of greatest concern, due to their disease producing capabilities, are bacteria, viruses, and protozoans. Disinfection is the best way to prevent the spread of waterborne 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 disposal must be simple, and safe to operate, reliable, and economical. They normally are the last process in the treatment flow scheme. Wastewater 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 parameters 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 expensive for both equipment and power use for individual onsite systems.

Sufficient contact time between the wastewater and the disinfectant is important. Chemical disinfectants must be mixed thoroughly with the wastewater at the appropriate 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 indicator bacteria (total or fecal coliform) or disinfectant residual in the case of chlorine. The general design of disinfection processes requires the determination of the wastewater characteristics, wastewater temperature, pathogen(s) to be destroyed, and disinfectant to be employed. From this information, the required residual concentration relationship may be developed and the disinfectant dose can be calculated.

Table 1

Infectious agents potentially present in untreated domestic wastewater

<i>Organism</i>	<i>Disease caused</i>
Bacteria	
<i>Escherichia coli</i>	Gastroenteritis
<i>Leptospira</i>	Leptospirosis
<i>Salmonella typhi</i>	Typhoid fever
<i>Salmonella</i> (=2,100 serotypes)	Bacillary dysentery
<i>Vibrio cholerae</i>	Cholera
Protozoa	
<i>Cryptosporidium parvum</i>	Cryptosporidiosis
<i>Entamoeba histolytica</i>	Amoebic dysentery
<i>Giardia lamblia</i>	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 wastewater.

Available as a gas, liquid, or solid, chlorine is corrosive and toxic in all forms. Storing, shipping, and handling 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 techniques. The economic benefits of handling the potentially dangerous gas offset the safety concerns.

Forms of chlorine called hypochlorites are the most widely used chlo-



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, NESCS.

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 hypochlorites, are highly toxic to microorganisms, highly soluble in water, and relatively inexpensive.

Chlorine has an interesting benefit for water purification in that the residual chlorine that remains in the water prolongs disinfection even after initial treatment. Unfortunately, residual chlorine is toxic to aquatic life, even at low concentrations, and so this is

not a huge benefit for wastewater disinfection when the wastewater is discharged directly into a body of



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Stack feed chlorinator

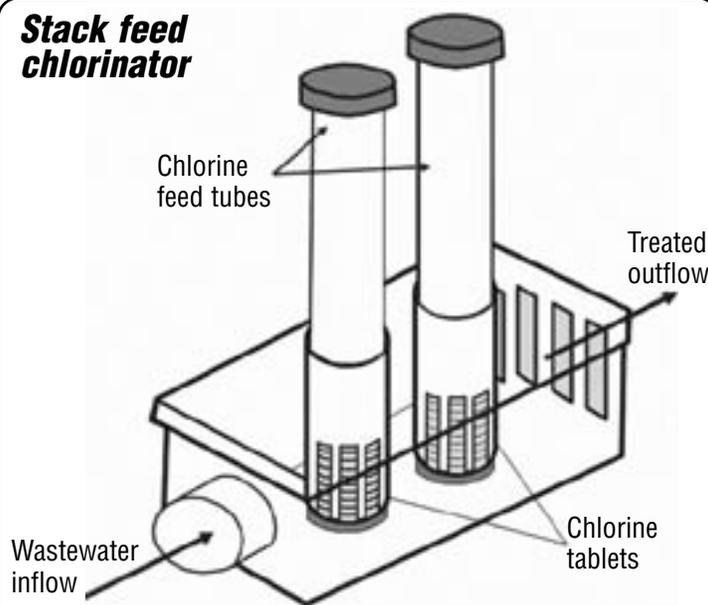


Figure 2 Stack feed chlorinator
Drawing courtesy of Don Jones, Purdue University



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, NESCA.

water. Wastewater may require a special process called dechlorination to remove these residuals. This is a fairly expensive process and is minimized 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 dechlorination process.)

Wastewater requires at least 30 minutes of contact time for effective disinfection 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 environment. To calculate the minimum size of the contact tank, use this formula:

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

Solid calcium hypochlorite is the most favored form for onsite applications. 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, dissolving 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 dispersal 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 discharge into the environment. Typically, dechlorination is done by adding sulfur dioxide or sulfite salts (i.e., sodium sulfite, sodium bisulfite, or sodium metabisulfite.) Efficient dechlorination 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 chlorine 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

<i>Calcium hypochlorite</i>	<i>Septic tank effluent</i>	<i>Biological treatment effluent</i>	<i>Sand filter effluent</i>
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 20° C. Increase contact time to 2 hours at 10° C and 8 hours at 5° 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, 2002.

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 suspected carcinogens or compounds toxic to the environment, such as trihalo-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 wastewater must often be dechlorinated or treated to reduce the chlorine residuals to a level not toxic to aquatic life. Chlorination/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 microorganisms by penetrating the surface of the microorganism and causing biochemical 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 chlorination, there is little danger of overdosing 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 disinfection system depends on the characteristics of the treated effluent, the intensity of UV radiation, the time the microorganisms are exposed to the radiant, and the configuration of

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Table 3

Wastewater characteristics affecting UV disinfection performance

- (BOD)** Minor effect but if a large portion is humic compounds, then UV transmittance 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)

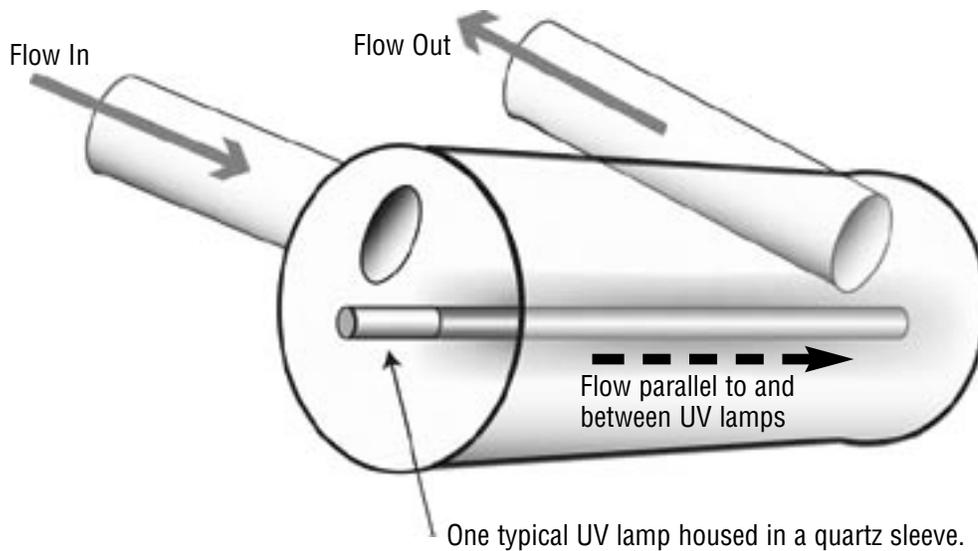


Figure 4

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 effectively inactivate microorganisms is in the range of 250 to 270 nanometers (nm). The intensity of the radiation emitted by the lamp dissipates as the distance from the lamp increases. Lamps recommended for onsite systems are considered low-pressure and emit light at a wavelength of 253.7 nm. Standard

lengths of the low-pressure lamps are 0.75 and 1.5 meters with diameters of 1.5 to 2.0 centimeters. The ideal lamp wall temperature is between 95 and 122° F. (See Table 4.)

Advantages of using UV disinfection as compared to other technologies include its effectiveness at inactivating most viruses, spores and cysts, and its shorter reaction time, and relatively small space requirements. The use of UV is considered user-friendly for operators since no dangerous chemicals have to be handled, and there is no harmful 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 maintenance even if an automatic cleaning system is used. The initial startup costs are higher for U.S. systems than for the standard chlorination systems.

How UV works

A UV disinfection system creates radiation energy by sending an electrical discharge through mercury vapor. This radiation penetrates the genetic material of microorganisms and retards their ability to reproduce. Microorganisms vary in their resistance 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 excellent transmitter of UV light, but



Figure 5

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

Table 4

Typical ultraviolet system design parameters

<i>Design Parameter</i>	<i>Typical design value</i>
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.

the dissolved and suspended substances are strong absorbers. The source of the suspended particles determines what effect they will have on the disinfection 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 disinfection ineffective. TSS levels must be below 30 mg/L for the secondary effluent. (Table 3 describes the wastewater characteristics affecting UV disinfection 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 removable vertical rack and suspended in an open flow channel. The system should be installed below grade with easily removable components. The homeowner must clean the sleeve and replace the bulb on an annual basis.

References

EPA Wastewater Technology Fact Sheet: Dechlorination. Office of Water, Washington, DC. September, 2000. EPA 832-F00-022. (WWFSGN188) \$1.40

EPA Wastewater Technology Fact Sheet: Ultraviolet Disinfection. Office of Water, Washington, DC. September, 1999. EPA832-F-99-064. (WWFSGN199) \$1.40

Benedict, A. and R. Skrinde. "Disinfection Applied to On-Site Wastewater Treatment, College of Engineering University of Washington Proceedings," 7th NW On-site Wastewater Treatment Short Course and Equipment Exhibition, 1992. (#L003089) \$3.60

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

Cruver, James E. "Improved Disinfection of Small Wastewater Treatment Effluents," 9th NW On-site Wastewater Treatment Short Course and Equipment Exhibition, 1997. (#L005361) \$2.55

Mitchell, D. and M.E. Iverson. "Ultraviolet Disinfection of Septic Tank-Sandfilter Effluent," American Society of Agricultural Engineers, 1987. (#L002234) \$0.75

—The materials listed above are available from the NESC, either by calling (800) 624-8301 or via e-mail at nsfc_orders@mail.nesc.wvu.edu. Actual shipping charges apply to all orders. Please refer to the materials by the numbers in parentheses.

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Our Readers Reply...

The response to the 2004 *Pipeline* Reader Survey was outstanding. It is so rewarding to have such interested readers who are eager to voice their comments. We thought it would be worthwhile to share some of the more pertinent findings after compiling all of the returned surveys.

While most of you also subscribe to our other publications (*Small Flows Quarterly*, *On Tap* and *E-Train*), less than half have visited our Website. Let us take a minute to encourage you to explore www.nesc.wvu.edu! Consider it your source for all current information for small communities on wastewater, drinking water, and training and projects related to these

issues. We are constantly improving it so if you haven't visited it in a while, please stop by and see what is new.

It is nice to learn that 94 percent of our readers use their issues of *Pipeline* to educate others, while over 50 percent of our readers save their back issues for reference and 28 percent route them to other people.

Your surveys indicated that the majority of our readership is made up of local health and government officials and consultants in the wastewater field. If you know of other professionals or homeowners who might benefit from a free subscription to *Pipeline* or any of our other publications, contact us and we

will be pleased to add them to our mailing list.

We received many suggestions for future topics, and these are always appreciated. The purpose of *Pipeline* is to provide our readers with practical information presented in a non-technical style on topics related to small, onsite wastewater treatment systems, introducing new technologies and helpful developments for homeowners and local officials. Please feel free to share your comments at any time.

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Other Resources Available from the National Environmental Services Center

Ultraviolet Disinfection: A Technical Overview
WWFS0M20 \$0.40

Ultraviolet Disinfection: A General Overview
WWFSGN98 \$0.20

Chlorine Disinfection: A Technical Overview
WWFS0M21 \$0.40

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WWFSGN99 \$0.10

Ozone Disinfection: A Technical Overview
WWFS0M22 \$0.40

Ozone Disinfection: A General Overview
WWFSGN100 \$0.20

Ozone Disinfection Technology Assessment
WWBKRE41 \$26.50

**Wastewater Technology Fact Sheet:
Chlorine Disinfection**
WWFSGN189 \$1.40

**Wastewater Technology Fact Sheet:
Ozone Disinfection**
WWFSGN180 \$1.40

**Wastewater Technology Fact Sheet:
Ultraviolet Disinfection**
WWFSGN199 \$1.40

**On-site Wastewater Treatment Systems:
Tablet Chlorination**
WWFSGN206 \$1.00

**On-site Wastewater Treatment Systems:
Tablet Chlorination (Spanish Version)**
WWFSGN206 \$1.00

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