Options for Rule Revisions to Allow Seasonally Discharging Systems in Areas with Soil Limited by Slow Permeability and/or Seasonal High Water Table

12-19-2005

The Technical Advisory Committee (TAC), and a subcommittee of the TAC, has discussed several options related to revising the rules in a way that would allow for development on sites that currently cannot be permitted. In many cases these sites are severely limited because of a high seasonal water table, which may be at less than 6” from the surface of the naturally occurring ground and which may reach the ground surface for a brief period during the wet times of the year.

The range of changes includes:

A. making no changes whatever,

B. using large property line setbacks as a presumptive approach,

C. creating a prescriptive design for use that does not require a determination of whether the system will discharge or not,

D. trying to refine site evaluation techniques,

E. allowing direct discharge to a roadside ditch,

F. discharge to a wetland, or

G. direct discharge to surface waters.

The members of TAC believe that any option must include an analysis of the hydraulic capacity of the site and that the potential for, and the safety of, any discharge must be discussed. Items B and C do not meet this standard. Item D is discussed as option #1 below. TAC does not support a direct discharge from a treatment system directly to the ground surface and so modified E as discussed in option #2. Items F and G are related and discussed as option #3.

Option #1 (Item D)

Revise the 6” design standard for the performance based approach in §1-502(d) of the Wastewater System and Potable Water Supply Rules

The rules currently require that a sewage treatment and disposal design, prepared using the performance based approach, be designed to maintain at least 6” of naturally occurring soil above the calculated level of the effluent plume during all portions of the year. This standard was developed based on an expectation that systems using this approach have a good chance of not becoming failed systems, i.e. will not discharge to the surface of the ground. A site developed using this approach on fine grained soils can be expected to have free water at 6” below the surface of the naturally occurring ground in an open hole, with the soil above the free water level being saturated to or near to the ground surface, and to feel soft underfoot during the wet time of year.

The question is whether the 6” design standard could be revised to a lesser amount while maintaining a position that such systems will reliably function without surfacing. The TAC has considered this question in the past and the consensus has been that any reduction in the design standard would result in more systems that surface at least periodically during the wet times of the year. Assuming that a reduction in the 6” design standard could lead to more regular surfacing of effluent in the wet time of the year, this approach should be considered in conjunction with option #2.

Option #2 (Item E)

Approve systems that may discharge to the surface of the ground but which do not discharge to surface waters.

The TAC reviewed the question of whether the use of systems, that by their design may result in periodic discharges to the surface of the ground, are appropriate for use in Vermont. TAC considered three questions:

1. What level of treatment is required to ensure that any increase in risk to the public health is both the minimum necessary and acceptable in relation to the benefit that would result?

   The TAC decided that advanced treatment of the wastewater would be required followed by a disinfection process. The level of treatment required would be that needed to make the disinfection process effective.

2. Are there currently available treatment and disinfection systems that can provide the required level of treatment and disinfection?

   The TAC determined that there are several currently approved advanced treatment systems that can be designed to provide the level of treatment needed to ensure proper disinfection. The TAC also believes that commonly available U.V. (ultra-violet light) and chlorination systems can achieve the required level of disinfection.

The TAC also decided that some passive treatment should be incorporated to provide additional protection. This passive treatment would be by flow through soil, either naturally occurring or placed as part of the system construction.

3. What is required in the way of maintenance, operation, and oversight to ensure the systems maintain the designed level of performance?

The TAC determined that each system would need to be subject to an operating permit, a maintenance contract, remote monitoring, and some form of organized regulatory oversight. The operating permit would periodically expire, requiring a review of each system to ensure that it was operating successfully. The operating permit concept would also provide a source of funds to pay for the continuing regulatory oversight that is essential to minimize any public health risk. The remote monitoring makes it practical for at least daily checks of basic parameters of each system. The regulatory oversight could be done at the state level or delegated to the local or fire district level. The TAC estimates that each system constructed based on this option would require about 8 hours per year of regulatory oversight. One FTE of regulatory oversight could oversee about 250 systems. To be effective, one or more people would need to be hired and have this assigned as their principal function. An action plan would be required that would be implemented in the event the system fails to operate properly.

Note: The TAC believes that a discharging system should only be used on sites that cannot comply with the current rules.

Option #3 (Items F + G)

Approve systems that discharge to surface waters

The TAC has not discussed this concept extensively. Any direct discharge to surface waters is subject to both federal and state regulation. Portions of the federal Clean Water Act are delegated to Vermont for administration. Under Vermont implementation of the National Pollution Discharge Elimination System (NPDES) any direct discharge must first establish a waste management zone, with current procedures based on a zone at least one mile long. Any decision to allow the establishment of such a zone must consider existing uses of the proposed zone including activities such as fishing, swimming, and boating. Many of the issues that make establishing a waste management zone difficult are related to Vermont’s statutory language and could theoretically be changed. This would likely be difficult, but would ensure that there is legislative support for allowing the discharges from this type of on-site systems to eventually reach surface waters.

Any approval for a new discharge to surface waters would also depend on nutrient effects on the surface water. Some watersheds are already limited by elevated levels of one or more nutrients such as phosphorus and nitrogen under the TMDL's. Any widespread use of direct discharging systems would likely require additional levels of advanced treatment to remove specific nutrients.

Sheet flow to surface water is currently considered a discharge under Vermont rules but not under federal NPDES standards. The federal rules may change and include such discharges. The federal rules are already extensive and include any swale, ditch, or other surface feature carrying waste to surface waters.

Related Issues

Surfacing and the definition of failure

One key issue is whether a system has failed by virtue of effluent being exposed to the open air or by pooling on the ground surface. Once the effluent has been discharged from the leachfield there are limited pathways for it to follow. Some amount is dispersed through evapo-transpiration by plant uptake, though this occurs only during the growing season, and in Vermont is very limited. Some of the effluent travels downward until it reaches the groundwater table. And some of it flows through naturally occurring soil for a distance and then emerges on the ground surface to flow overland to surface waters.

This surfacing effect can occur because the rules only require that complying soil conditions exist under and for 25' downslope of the system. The rules also require 25' setbacks to road ditches and to slopes greater than 30%. If the site conditions do not extend beyond the specified distances it is possible that surfacing will occur. These soil conditions and isolation distances were not established based on a decision that after flowing through this amount of soil the effluent would be sufficiently renovated as to be safe for human contact, nor with an expectation that effluent would surface. These isolation distances were likely established based on existing practices from other states. In practice, evidence of surfacing at one of these points would be considered to be a failure when it is clear that the surfacing is primarily caused by effluent from a wastewater system. However, in most cases, surfacing only occurs during SHWT periods when the SHWT intersects the ground surface, such as at a road ditch or slope break. Because these wet areas seldom have the appearance of wastewater effluent, having no color or odor, they are generally ignored. Determining that the surfacing is at least in part caused by wastewater would require some laboratory analysis, something that is rarely done. However, if testing is done and the results indicate the presence of effluent at the point of surfacing, this would constitute a failed system.

The one portion of the rules where it is likely that a conscious decision was made that surfacing is acceptable is the requirements related to subsurface drains installed downslope of leachfields. This isolation distance was first established at 100’ in the 1979 rules and revised to 75’ in the 1982 revision. In this case, the expectation is that surfacing would only occur during the portion of the year when the SHWT intersected the drain and any effluent would be mixed with the naturally occurring ground water. There is no apparent decision on what the response would be if effluent was discharging through a subsurface drain when SHWT was not present.

The Agency should address this issue and decide if there is a point at which an outbreak of effluent on the ground surface is considered to not be a failed system. The follow-on decision would then be whether this distance must be naturally occurring soil or whether it could be part of the system construction. It seems clear from discussions related to NPDES, that a 50’ wick of sand, crushed stone, or other media leading to a surface water, would be considered to be a direct discharge conduit that is not different in effect from a pipe. It might, however, be possible to determine that a discharge from the end of a 50’ layer of sand does not constitute a failed system, and if the subsequent flow from the system only reached the surface waters in the form of sheet flow, that it would not be a discharge under federal regulations. Vermont regulations would still need revision.

One additional reason to address this issue is that with more sophisticated water quality testing becoming available over the years, there will be the increasing chance that effluent will be determined to be present in water samples collected from surface runoff. A determination that certain discharges are in fact acceptable under Vermont and federal statutes would address the issues head-on as opposed to just ignoring them. With a determination that a particular discharge is acceptable, the permitting program would be on a sound basis, which would benefit landowners, designers, and regulators.

Public notice

Any decision as to the use of systems, where by design there will be surfacing of treated effluent to the ground surface, needs to include a consideration as to whether some form of notice to the neighboring landowners and/or the general public should be required. The Agency has opposed requiring a public notice process for routine issuance of subdivision permits or permits for wastewater disposal systems of less than 6500 GPD. The vast majority of small wastewater systems involve routine application of rules that have been developed in a public process. With 3000+ permits per year, a public notice and comment period for each permit is not a cost effective approach. In the rare situation where important information was not considered, there is a permit revocation process that can be used to correct the situation.

However, use of systems that include one or more treatment and/or disposal components that require active management, and which depend on disinfection processes that will in at least some cases breakdown, may include an obligation to notify neighboring property owners of the proposed use of a such a system. This notice would ensure that neighbors would know that a permitted system was not expected to operate in the conventional fashion and the neighbors might serve as an additional party of interest that would ensure proper operation and maintenance of the system.

Notice of system failure

Any system approved for use that includes a surfacing concept as part of the design should be required to have an approved operations manual. The manual should include specific instructions of the actions that are required if there is any failure of the system. If there is any possibility that effluent that has not been fully disinfected can reach the surface of the ground, specific actions related to preventing contact between the effluent and humans and their pets should be required. If the effluent will, or may, pass onto neighboring property, the neighboring property owner should be notified. If ANR pursues these systems, it should consider what the permittee should be required to do relative to work on the neighboring property in the event of a failure. This could include fencing, posting written notice, disinfecting with lime, etc.

List of components for a seasonally discharging system and their estimated costs

Note: The site must have at least a 3% slope and at least 9” of naturally occurring soil with a percolation rate of 120 minutes per inch or less and at least 18” of naturally occurring soil above bedrock.

Cost

The subcommittee prepared the following list of components that should be considered to be part of a low and moderate strength wastewater treatment and disposal system with a surfacing component:

	Component	Estimated cost installed
1.	Septic tank	$1,000
2.	Intermittent sand filter Low application rate (1 gallon/sqft.day) with 36” of sand below the application level	$12,000 - $15,000
3.	Disinfection unit (ultraviolet light process)	$5,000
4.	Sand blanket and surface preparation extends 50’ downslope of leachfield	$10,000- $12,000
5.	Remote monitoring equipment capable of testing UV effectiveness	$5,000
6.	Disposal system installed on sand blanket (drip disposal or shallow mound)	$5,000
	Total cost	$38,000 - $41,000

There would also be design costs and operational costs. Design costs might be in the range of $3,000 - $7,500, because in most cases, these systems will require more effort to conduct site evaluations, design, and provide construction inspections than systems currently permitted, for which consulting fees are in the $2,000 - $5,000 range. Operational costs are likely to be approximately $1,000 per year. There would be additional costs for regulatory oversight.

Note: The system outlined above is for low and moderate strength wastewater, such as for average domestic sources. High strength wastewater requires modifications to the design, including an advanced treatment system installed in series prior to the low rate intermittent sand filter.

Note: An acceptable alternative design would include an advanced treatment system followed by the low rate intermittent sand filter with a minimum of 18" of sand below the application level.

Note: The committee discussed whether other treatment systems could be substituted for the low rate intermittent sand filter. It was decided that no other currently permitted system provides an equivalent level of treatment and stability with as few possible modes of failure. This is likely to be a point of contention with various manufacturers and vendors of treatment systems.

Expected levels of treatment and possible modes of failure

The proposed system includes 2 treatment components with estimated levels of treatment. Each component also has the potential to fail. TAC has considered the potential modes of failure and has estimated their effect on the potential that there will be a significant health risk associated with that failure.

The Onsite Wastewater Treatment Systems Manual, February, 2002, published by EPA (**OWTSM, 2002)** contains estimates of fecal coliform and viral concentrations and removals. A copy of Table 3-19 is attached. Initial concentrations of fecal coliform are estimated at 10^6 – 10^8 organisms/100 ml. Initial concentrations of virus are estimated at 0-10^5 pfu (plaque forming unit)/ml. Viruses are episodically present at high levels only when being shed by the users of the wastewater system.

1. The intermittent sand filter –

   An intermittent sand filter with an application rate of 1 gallon/sqft/day is an extremely stable system. Assuming that the design incorporates a pump station to provide the pressure distribution of the effluent, a power failure would stop the flow of effluent into the sand filter under most circumstances. The pump station could be designed to prevent such a discharge under all circumstances. An organic overload would clog the surface of the sand thereby reducing the flow through the filter, which if anything, would enhance the treatment. If the organic overload was large, the clogging would cause the sand filter to backup to the point where the alarm system would be triggered. Careful design would prevent untreated effluent from moving beyond the sand filter to the disinfection system. A short term hydraulic overload is the main area of concern. With a high loading rate, the effectiveness of the sand filter at removing fecal coliform and viruses would be reduced, with viral removal being more sensitive to high flow rates.

A 1997 article in the Small Flows Journal, entitled Shallow Intermittent Sand Filtration: Microorganisim Removal, by Emerick, Test, Tchobanoglous, and Darby reports the results of viral removal at different loading rates in intermittent sand filters. They found about 2.8 log removal when loaded at 1 gallon/sqft/day and 0.9 log removal when loaded at 4 gallons/sqft/day.

Of particular concern is the level of TSS removal because low effectiveness at removal could result in the disinfection process being less effective. Carefully designed, 1 gallon/sqft/day, intermittent sand filters appear to be capable of removing both BOD_5 and TSS to less than 5 mg/l which is considered the level needed for proper disinfection. The systems are sensitive to loading rates and hydraulic overloading could lead to increased levels of BOD_5 and TSS passing through the filter.

It is possible, and should be required, to design a pump based dosing system that will preclude hydraulic overloading of the system that is not easily bypassed.

2. The disinfection system –

Disinfection for small wastewater treatment systems is usually based on chlorination or the use of ultraviolet (UV) light. There are concerns with either approach. Chlorination is effective, including when the level of BOD_5 and TSS is too high for use of UV disinfection. Chlorination systems require maintenance to ensure that the supply of chlorine is adequate and there are concerns about by-products entering the ground or surface water. UV does not have by-products that are of concern but the wastewater must be extremely clean in order for the system to be effective. Either system is effective at inactivating bacteria and viruses. Attached is fact sheet #4 from the **OWTSM, 2002.**

The TAC has primarily focused on UV disinfection methods because of the concerns related to chlorine by-products, and because automatic monitoring of the effectiveness of UV disinfection is more readily available than for disinfection by chlorination. The **OWTSM, 2002** indicates that effluent clarity is a critical factor. Any system serving single family residences, or other buildings with small design flows, will not have daily on-site inspections by a licensed operator and will not routinely have the effluent tested for presence of pathogens. The system must therefore be designed to remotely monitor UV transmittance and must automatically prevent release of effluent into the environment whenever the UV is not operating as designed, without an easy “manual over-ride” that would allow an owner to circumvent the automatic shutdown mechanism.

The treatment processes used prior to disinfection must be stable and effective; otherwise the remote monitoring will frequently indicate a failure to maintain the required level of transmittance. This requirement is the main reason the TAC proposes to require use of a low rate, intermittent flow sand filter in all systems.

3. Failure modes -

   A. Power failure - If the water supply is powered by the same electrical system as the wastewater system only a small amount of effluent will be discharged to the system. Assuming relatively brief outages of a few hours, the system would function properly as soon as power was restored. The system should be designed so that in situations where the water system remains functional, the wastewater will not be discharged to the intermittent sand filter. Health risks with either situation are expected to be low.

   B. Organic overload - Short term organic overloads could exceed the sand filter's capacity to treat the wastewater to the level required for full disinfection. However, this should cause the measured transmittance level in the UV disinfection system to fall below its required level which would cause the system to cease discharge to the environment and to send a notification of the failure through the remote monitoring system. Long term organic overloads would result in a clogging layer on the application surface of the sand filter. This layer would eventually result in a high water condition in the sand filter that would also stop the discharge to the environment and trigger the remote monitoring system.

   C. Hydraulic overload - The most likely scenario is intentional or unintentional continuous water flow from the house. It is possible to design the systems so that any hydraulic overload would be detected. The system could be designed to both trigger the alarm systems and to cease pumping effluent to the disinfection system. A specific plan in the operations manual would be required with directions on how to restore the system to use. A determination that the effluent quality and quantity allows for proper disinfection would be required by a licensed operator familiar with the system.

   D. Summary –

      With proper design, and assurance that operational requirements are met, there is a low risk of untreated effluent being discharged to the disposal portion of the system. The operations manual, and the permit for the system, should address the actions required for the rare situation when untreated effluent is discharged; including any overflows from pump stations or storage tanks.

Year-round surfacing is not acceptable –

The TAC considered the question of whether it would be acceptable to build a system with an expectation that the system would have a surface discharge on a year-round basis and concluded that the risk associated with this concept is too great. While a final recommendation of the parameters has not been developed, something along the line of requiring at least 9” of soil with a percolation rate of 120 min/inch or less and a minimum slope of 3% are being considered. Some areas otherwise meeting these requirements would be wetlands and therefore unacceptable for new development. Some factor may be required for the rare situation when the slope and soil requirements are met, the site is not a wetland, but there is a permanent water table such that year-round surfacing would occur.

The neighbors –

Unless the designs are restricted to sites where the effluent will not leave the property, or do so only subject to a permanent easement granted by the neighbor/s, the quality of the effluent reaching the neighbors must be explicitly addressed.

TAC believes that a system designed, constructed, operated, and maintained with oversight as discussed in option #2 above, and that uses the components included in the list on page 7 of this document, would reliably produce effluent that has an acceptable low public health risk.

Excerpt from: The Onsite Wastewater Treatment Systems Manual, February, 2002

Table 3-19. Wastewater constituents of concern and representative concentrations in the effluent of various treatment units

Constituents of concern	Example direct or indirect measures (Units)	Tank-based treatment unit effluent concentration					SWIS percolate into ground water at 3 to 5 ft depth (% removal
		Domestic STE[1]	Domestic STE with N-removal recycle[2]	Aerobic unit effluent	Sand filter effluent	Foam or textile filter effluent	
Oxygen demand	BOD_5 (mg/L)	140-200	80-120	5-50	2-15	5-15	>90%
Particulate solids	TSS (mg/L)	50-100	50-80	50-100	5-20	5-10	>90%
Nitrogen	Total N (mg N/L)	40-100	10-30	25-60	10-50	30-60	10-20%
Phosphorus	Total P (mg P/L)	5-15	5-15	4-10	<1-10[4]	5-15[4]	0-100%
Bacteria (e.g., Clostridium perfringens, Salmonella, Shigella)	Fecal coliform (organisms per 100 mL)	10^6-10^8	10^6-10^8	10^3-10^4	10^1-10^3	10^1-10^3	>99.99%
Virus (e.g., hepatitis, polio, echo, coxsackie, coliphage)	Specific virus (pfu/mL)	0-10^5 episodically present at high levels)	0-10^5 episodically present at high levels)	0-10^5 episodically present at high levels)	0-10^5 episodically present at high levels)	0-10^5 episodically present at high levels)	>99.9%
Organic chemicals (e.g., solvents, petro-chemicals, pesticides)	Specific organics or totals (µg/L)	0 to trace levels (?)	0 to trace levels (?)	0 to trace levels (?)	0 to trace levels (?)	0 to trace levels (?)	>99%
Heavy metals (e.g., Pb, Cu, Ag, Hg)	Individual metals (µg/L)	0 to trace levels	0 to trace levels	0 to trace levels	0 to trace levels	0 to trace levels	>99%

[1] Septic tank effluent (STE) concentrations given are for domestic wastewater. However, restaurant STE is markedly higher particularly in BOD_5, COD, and suspended solids while concentrations in graywater STE are noticeably lower in total nitrogen.

[2] N-removal accomplished by recycling STE through a packed bed for nitrification with discharge into the influent end of the septic tank for denitrification.
[3] P-removal by adsorption/precipitation is highly dependent on media capacity, P loading, and system operation.

Source: Siegrist, 2001 (after Siegrist et al., 2000)

Excerpt from: The Onsite Wastewater Treatment Systems Manual, February, 2002

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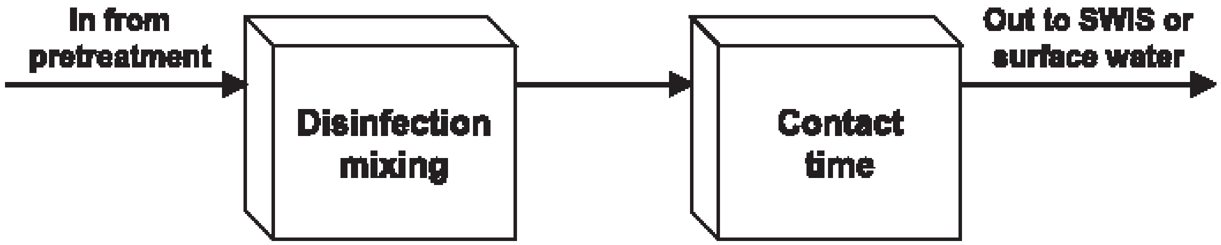
Onsite Wastewater Treatment Systems Technology Fact Sheet 4

Effluent Disinfection Processes

Description

The process of disinfection destroys pathogenic and other microorganisms in wastewater. A number of important waterborne pathogens are found in the United States, including some bacteria species, protozoan cysts, and viruses. All pretreatment processes used in onsite wastewater management remove some pathogens, but data are scant on the magnitude of this destruction. The two methods described in this section, chlorination and ultraviolet irradiation, are the most commonly used (figure 1). Currently, the effectiveness of disinfection is measured by the use of indicator bacteria, usually fecal coliform. These organisms are excreted by all warm-blooded animals, are present in wastewater in high numbers, tend to survive in the natural environment as long as or longer than many pathogenic bacteria, and are easy to detect and quantify.

Figure 1. Generic disinfection diagram



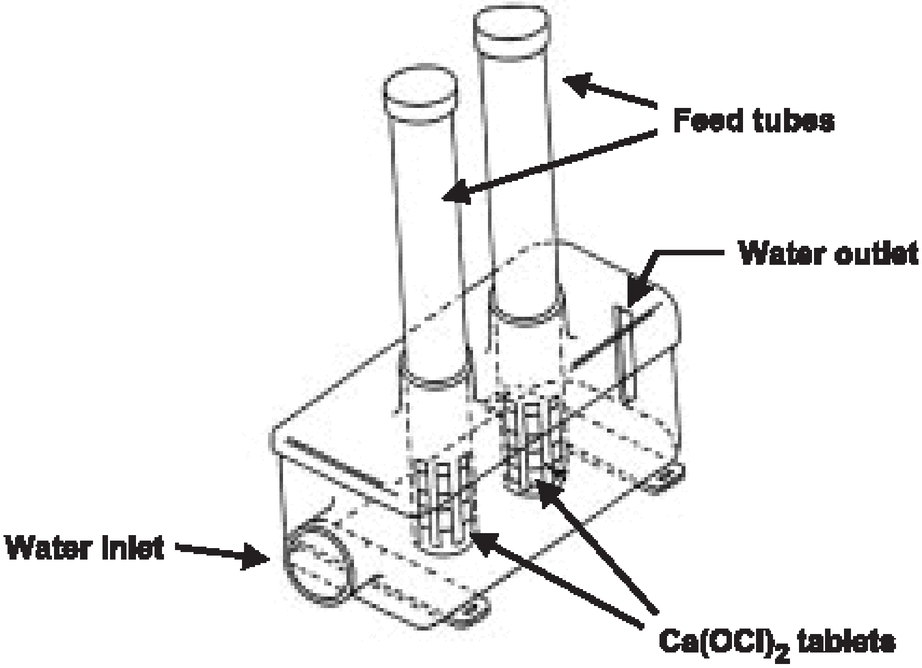
A number of methods can be used to disinfect wastewater. These include chemical agents, physical agents, and irradiation. For onsite applications, only a few of these methods have proven to be practical (i.e., simple, safe, reliable, and cost-effective). Although ozone and iodine can be and have been used for disinfection, they are less likely to be employed because of economic and engineering difficulties.

Chlorine

Chlorine is a powerful oxidizing agent and has been used as an effective disinfectant in water and wastewater treatment for a century. Chlorine may be added to water as a gas (Cl_2) or as a liquid or solid in the form of sodium or calcium hypochlorite, respectively. Because the gas can present a significant safety hazard and is highly corrosive, it is not recommended for onsite applications. Currently, the solid form (calcium hypochlorite) is most favored for onsite applications. When added to water, calcium hypochlorite forms hypochlorous acid (HOCl) and calcium hydroxide (hydrated lime, $Ca(OH)_2$). The resulting pH increase promotes the formation of the anion, OCl-, which is a free form of chlorine. Because of its reactive nature, free chlorine will react with a number of reduced compounds in wastewater, including sulfide, ferrous iron, organic matter, and ammonia. These nonspecific side reactions result in the formation of combined chlorine (chloramines), chloro-organics, and chloride, the last two of which are not effective as disinfectants. Chloramines are weaker than free chlorine but are more stable. The difference between the chlorine residual in the wastewater after some time interval (free and combined chlorine) and the initial dose of chlorine is referred to as chlorine demand. The 15-minute chlorine demand of septic tank effluent may range from 30 to 45 mg/L as Cl; for biological treatment effluents, such as systems in Technology Fact Sheets 1, 2, and 3, it may range from 10 to 25 mg/L; and for sand filtered effluent, it may be 1 to 5 mg/L (Technology Fact Sheets 10 and 11).

Calcium hypochlorite is typically dosed to wastewater in an onsite treatment system using a simple tablet feeder device (figure 2). Wastewater passes through the feeder and then flows to a contact tank for the appropriate reaction. The product of the contact time and disinfectant residual concentration (Ct) is often used as a parameter for design of the system. The contact basin should be baffled to ensure that short-circuiting does not occur. Chlorine and combined chlorine residuals are highly toxic to living organisms in the receiving water. Because overdosing (ecological risk) and underdosing (human health risk) are quite common with the use of tablets, long swales/ditches are recommended prior to direct discharge to sensitive waters.

Figure 2. Example of a stack-feed chlorinator



Use of simple liquid sodium hypochlorite (bleach) feeders is more reliable but requires more frequent site visits by operators. These systems employ aspirator or suction feeders that can be part of the pressurization of the wastewater, causing both the pump and the feeder to require inspection and calibration. These operational needs should be met by centralized management or contracted professional management.

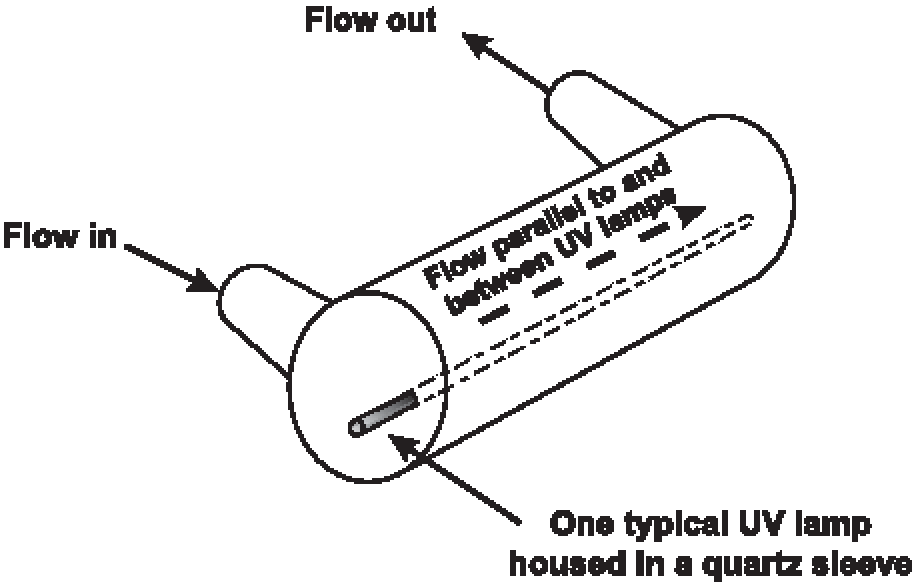
Ultraviolet irradiation

The germicidal properties of ultraviolet (UV) irradiation have been recognized for many years. UV is germicidal in the wavelength range of 250 to 270 nm. The radiation penetrates the cell wall of the organism and is absorbed by cellular materials, which either prevents replication or causes the death of the cell. Because the only UV radiation effective in destroying the organism is that which reaches it, the water must be relatively free of turbidity. 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 quantity of UV irradiation required for a given application is measured as the radiation intensity in microWatt-seconds per square centimeter ($mW\text{-}s/cm^2$). For each application, wastewater transmittance, organisms present, bulb and sleeve condition, and a variety of other factors will have an impact on the $mW\text{-}s/cm^2$ required to attain a specific effluent microorganism count per 100 mL. The most useful variable that can be readily controlled and monitored is Total Suspended Solids. TSS has a direct impact on UV disinfection, which is related to the level of pretreatment provided.

Many commercial UV disinfection systems (figure 3) are available in the marketplace.

Each has its own approach to how the wastewater contacts UV irradiation, such as the type of bulb (medium or low pressure; medium, low, or high intensity), the type of contact chamber configuration (horizontal or vertical), or the sleeve material separating the bulb from the liquid (quartz or teflon). All can be effective, and the choice will usually be driven by economics.

Figure 3. Wastewater flow in a quartz UV unit



Typical applications

Disinfection is generally required in three onsite-system circumstances. The first is after any process that is to be surface discharged. The second is before a SWIS where there is inadequate soil (depth to ground water or structure too porous) to meet ground water quality standards. The third is prior to some other immediate reuse (onsite recycling) of effluent that stipulates some specific pathogen requirement (e.g., toilet flushing or vegetation watering).

Design assumptions

Chlorination units must ensure that sufficient chlorine release occurs (depending on pretreatment) from the tablet chlorinator. These units have a history of erratic dosage, so frequent attention is required. Performance is dependent on pretreatment, which the designer must consider. At the point of chlorine addition, mixing is highly desirable and a contact chamber is necessary to ensure maximum disinfection. Working with chlorinator suppliers, designers should try to ensure consistent dosage capability, maximize mixing usually by chamber or head loss, and provide some type of pipe of sufficient length to attain effective contact time before release. Tablets are usually suspended in open tubes that are housed in a plastic assembly designed to increase flow depth (and tablet exposure) in proportion to effluent flow. Without specific external mixing capability, the contact pipe (large-diameter Schedule 40 PVC) is the primary means of accomplishing disinfection. Contact time in these pipes (often with added baffles) is on the order of 4 to 10 hours, while dosage levels are in excess of those stated in table 1 for different pretreatment qualities and pH values. The commercial chlorination unit is generally located in a concrete vault with access hatch to the surface. The contact pipe usually runs from the vault toward the next step in the process or discharge location. Surface discharges to open swales or ditches will also allow for dechlorination prior to release to a sensitive receiving water.

Table 1. 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 20ºC. Increase contact time to 2 hours at 10ºC and 8 hours at 5ºC for comparable efficiency. Dose = mg/L as Cl. Doses assume typical chlorine demand and are conservative estimates based on fecal coliform data.			

The effectiveness of UV disinfection is dependent upon UV power (table 2), contact time, liquid film thickness, wastewater absorbance, wastewater turbidity, system configuration, and temperature. Empirical relationships are used to relate UV power (intensity at the organism boundary) and contact time. Table 2 gives a general indication of the dose requirements for selected pathogens. Since effective disinfection is dependent on wastewater quality as measured by turbidity, it is important that pretreatment provide a high degree of suspended and colloidal solids removal.

Table 2. Typical ultraviolet (UV) system design parameters

Design parameter	Typical design value
UV dosage	20 - 140 mW/-s/cm^2
Contact time	6 - 40 seconds
UV intensity	3 - 12 mW/-s/cm^2

Wastewater UV transmittance	50 - 70%
Wastewater velocity	2 - 15 inches per second

Commercially available UV units that permit internal contact times of 30 seconds at peak design flows for the onsite system can be located in insulated outdoor structures or in heated spaces of the structure served, both of which must protect the unit from dust, excessive heat, freezing, and vandals. Ideally, the unit should also provide the necessary UV intensity (e.g., 35,000 to 70,000 mW-s/cm^2) for achieving fecal coliform concentrations of about 200 CFU/100 mL. The actual dosage that reaches the microbes will be reduced by the transmittance of the wastewater (e.g., continuous-flow suspended-growth aerobic systems [CFSGAS] or fixed-film systems [FFS] transmittance of 60 to 65 percent). Practically, septic tank effluents cannot be effectively disinfected by UV, whereas biological treatment effluents can meet a standard of 200 cfu/100 mL with UV. High-quality reuse standards will require more effective pretreatment to be met by UV disinfection. No additional contact time is required. Continuous UV bulb operation is recommended for maximum bulb service life. Frequent on/off sequences in response to flow variability will shorten bulb life. Other typical design parameters are presented in table 2.

Performance

There are few field studies of tablet chlorinators, but those that exist for post-sand-filter applications show fecal coliform reductions of 2 to 3 logs/100 mL. Another field study of tablet chlorinators following biological treatment units exceeded a standard of 200 FC/100 mL 93 percent of the time. No chlorine residual was present in 68 percent of the samples. Newer units managed by the biological unit manufacturer fared only slightly better. Problems were related to TSS accumulation in the chlorinator, tablet caking, failure of the tablet to drop into the sleeve, and failure to maintain the tablet supply. Sodium hypochlorite liquid feed systems can provide consistent disinfection of sand filter effluents (and biological system effluents) if the systems are managed by a utility.

Data for UV disinfection for onsite systems are also inadequate to perform a proper analysis. However, typical units treating sand filter effluents have provided more than 3 logs of FC removal and more than 4 logs of poliovirus removal. Since this level of pretreatment results in a very low final FC concentration (<100 CFU/100 mL), removals depend more on the influent concentration than inherent removal capability. This is consistent with several large-scale water reuse studies that show that filtered effluent can reach essentially FC-free levels (<1 CFU/100 mL) with UV dosage of about 100 mW-s/cm^2, while higher (but attainable) effluent FC levels require less dosage to filtered effluent (about 48 mW-s/cm^2) than is required by aerobic unit effluent (about 60 mW-s/cm^2). This can be attributed to TSS, turbidity, and transmittance (table 3). Average quartz tube transmittance is about 75 to 80 percent.

Table 3. Typical (UV) transmittance values for water

Wastewater treatment level	Percent transmittance
Primary	45 - 67
Secondary	60 - 74
Tertiary	67 - 82
Source: USEPA, 1986.	

Management needs

Chlorine addition by tablet feeders is likely to be the most practical method for chlorine addition for onsite applications. Tablet feeders are constructed of durable, corrosion-free plastics and are designed for in-line installation. Tablet chlorinators come as a unit similar to figure 2. If liquid bleach chlorinators are used, they would be similarly constructed. That unit is placed inside a vault that exits to the contact basin. The contact basin may be plastic, fiberglass, or a length of concrete pipe placed vertically and outfitted with a concrete base. Baffles should be provided to prevent short-circuiting of the flow. The contact basin should be covered to protect against the elements, but it should be readily accessible for maintenance and inspection.

The disinfection system should be designed to minimize operation and maintenance requirements, yet ensure reliable treatment. For chlorination systems, routine operation and maintenance would include servicing the tablet or solution feeder equipment, adding tablets or premixed solution, adjusting flow rates, cleaning the contact tank, and collecting and analyzing effluent samples for chlorine residuals. Caking of tablet feeders may occur and will require appropriate maintenance. Bleach feeders must be periodically refilled and checked for performance. Semiskilled technical support should be sufficient, and estimates of time are about 6 to 10 hours per year. There are no power requirements for gravity-fed systems. Chemical requirements are estimated to be about 5 to 15 pounds of available chlorine per year for a family of four. During the four or more inspections required per year, the contact basin may need cleaning if no filter is located ahead of the unit. Energy requirements for a gravity-fed system are nil. If positively fed by aspirator/suction with pumping, the disinfection unit and alarms for pump malfunctions will use energy and require inspection. Essentially unskilled (but trained) labor may be employed. Safety issues are minimal and include wearing of proper gloves and clothing during inspection and tablet/feeder work.

Commercially available package UV units are available for onsite applications. Most are self-contained and provide low-pressure mercury arc lamps encased by quartz glass tubes. The unit should be installed downstream of the final treatment process and protected from the elements. UV units must be located near a power source and should be readily accessible for maintenance and inspection. Appropriate controls for the unit must be corrosion-resistant and enclosed in accordance with electrical codes.

Routine operation and maintenance for UV systems involves semiskilled technician support. Tasks include cleaning and replacing the UV lamps and sleeves, checking and maintaining mechanical equipment and controls, and monitoring the UV intensity. Monitoring would require routine indicator organism analysis. Lamp replacement (usually annually) will depend upon the equipment selected, but lamp life may range from 7,500 to 13,000 hours. Based on limited operational experience, it is estimated that 10 to 12 hours per year would be required for routine operation and maintenance. Power requirements may be approximately 1 to 1.5 kWh/d. Quartz sleeves will require alcohol or other mildly acidic solution at each (usually four per year) inspection.

Whenever disinfection is required, careful attention to system operation and maintenance is necessary. Long-term management, through homeowner-service contracts or local management programs, is an important component of the operation and maintenance program. Homeowners do not possess the skills needed to perform proper servicing of these units, and homeowner neglect, ignorance, or interference may contribute to malfunctions.

Risk management issues

With proper management, the disinfection processes cited above are reliable and should pose little risk to the homeowner. As mentioned above, a potentially toxic chlorine residual may have an important environmental impact if it persists at high concentrations in surface waters. By-products of chlorine reactions with wastewater constituents may also be toxic to aquatic species. If dechlorination is required prior to surface discharge, reactors containing sulfur dioxide, sodium bisulfate, sodium metabisulfate, or activated carbon can be employed. If the disinfection processes described above are improperly managed, the processes may not deliver the level of pathogen destruction that is anticipated and may result in some risk to downstream users of the receiving waters. The systems described are compact and require modest attention. Chlorination does not inherently require energy input; UV irradiation and dosage pumps do consume some energy (>1kWh/day). Both processes will require skilled technical support for the monitoring of indicator organisms in the process effluents.

Chlorination systems respond to flow variability if the tablets are feeding correctly. UV does not do so and is designed for the highest flow scenario, thus overdosing at lower flows since there is no danger in doing so. Toxic loads are unlikely to affect either system, but TSS can affect both. Inspections must include all pretreatment steps. UV is more sensitive to extreme temperatures than chlorination, and must be housed appropriate to the climate. In extremely cold climates, the UV system can be housed inside the home with minimal danger to the inhabitants. Power outages will terminate UV disinfection and pressurized pumps for both systems, while causing few problems for gravity-fed chlorination units. There should be no odor problems during these outages.

Costs

Installed costs of a complete tablet chlorination unit are about $400 to $500 for the commercial chlorinator unit and associated materials and $800 to $1,200 for installation and housing. Operation and maintenance would consist of tablets ($30 to $50 per year), labor ($75 to $100 per year), and miscellaneous repairs and replacements ($15 to $25 per year), in addition to any analytical support required.

Installed costs of UV units and associated facilities are $1,000 to $2,000. O/M costs include power ($35 to $40 per year), semiskilled labor ($50 to $100 per year), and lamp replacement ($70 to $80 per year), plus any analytical support.

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EXCERPT FROM WASTEWATER SYSTEM AND POTABLE WATER SUPPLY RULES, EFFECTIVE JANUARY 1, 2005

§1-502 Minimum Site Conditions

(a) No site may be improved by the construction of wastewater system unless the site meets one of the following three sets of requirements regarding the minimum requirements for the site. Please note that these are only the requirements for the site and that requirements related to any specific type of leachfield must also be met. Also note that if a site meets these minimum requirements, non-naturally occurring soils may be used in certain types of wastewater system designs in order to meet the requirements for separation distance to bedrock or the seasonal high water table.

(b) Prescriptive Approach

(1) Sites that meet the following requirements can be improved using a prescriptive approach.

   (A) There shall be at least 24” of naturally occurring soil with a percolation rate of 120 min/inch or less over bedrock.

   (B) There shall be at least 24” of naturally occurring soil with a percolation rate of 120 min/inch or less above the seasonal high water table.

   (C) The maximum ground slope shall not exceed 30% for wastewater systems on subdivided lots in existence before June 14, 2002. The maximum ground slope shall not exceed 20% for wastewater systems on lots that are subdivided on or after June 14, 2002. The maximum ground slope shall not exceed 30% for replacement wastewater systems no matter when the lot was created.

(c) Enhanced Prescriptive Approach

(1) Sites that meet the following requirements can be improved using the enhanced prescriptive approach.

(A) There shall be at least 18” of naturally occurring soil with a percolation rate of 120 min/inch or less over bedrock.

(B) The site must have at least 12”, or the thickness of the “A” soil horizon plus 4”, whichever is greater, of naturally occurring soil above the seasonal high water table. Sites with less than 18” of naturally occurring soil above the seasonal high water table must lower the water table as described below:

(i) A site may be approved without pre-testing of the drain when a designer prepares a plan incorporating drainage of the site and asserts that the drainage will lower the seasonal high water table to provide at least 18” of permeable soil below the surface of the naturally occurring soil, and the Secretary agrees with the designer’s assertion; or

(ii) if the Secretary does not agree, the designer may demonstrate through construction of a drainage system and the performance of groundwater monitoring in accordance with §1-506 below, that the seasonal high water table is lowered to at least 18” below the surface of the naturally occurring soil.

(C) The ground slope is at least 3% but does not exceed either 30% (for wastewater systems on subdivided lots in existence before June 14, 2002 and replacement systems on lots created at any point in time) or 20% (for wastewater systems on lots that are subdivided on or after June 14, 2002).

(D) The linear loading rate is not more than 2 gal/day/ft.

(E) The approvable site conditions must continue at least 25’ downhill from the system or the toe of any fill used as part of a system.

(d) Performance Based Approach

(1) Sites that meet the following requirements may be improved using the performance-based approach.

(A) There shall be at least 18” of naturally occurring soil above bedrock.

(B) Sites that do not meet the above requirements for prescriptive designs or enhanced prescriptive designs for depth to seasonal high water table may demonstrate compliance with the rules, based on a detailed and site specific analysis. The analysis must demonstrate that the system will function during all portions of the year while maintaining at least 6” of naturally occurring unsaturated soil above the calculated level of the effluent plume. The analysis may be based on site specific hydraulic conductivity testing or on a desktop hydrogeologic analysis. All desktop hydrogeologic analyses shall be based on conservative assumptions. The level of information required in order to determine compliance with the rules will be related to site specific conditions with more “limited” sites requiring more detailed information.

(C) The maximum ground slope shall not exceed 20% for wastewater systems that are on lots subdivided on or after June 14, 2002. For systems built on other lots, including replacement systems, the

§1-502(d)(1)(C) Minimum Site Conditions

maximum ground slope shall not exceed 30%, unless the Secretary has granted a specific approval to exceed 30%.

(D) A site specific approval to construct a wastewater system on a subdivided lot in existence before June 14, 2002 with a ground slope exceeding 30% in the area of the wastewater system may be granted by the Secretary upon a request from a designer that:

(i) provides specific instructions on the method of construction;

(ii) Explains how the stability of the site will be maintained during and after construction with specific attention to erosion control; and

(iii) Provides site-specific guidance as needed for safe construction.

(e) Erosion control

An erosion control plan shall be submitted with each application involving construction of a wastewater system when the ground slope exceeds 20%. The plan shall address site stability in the area of the wastewater system before, during, and after construction. The plan shall include specifications for construction, surface water diversions if needed, and re-vegetation to prevent soil erosion.

(f) Restrictions

(1) Notwithstanding the requirements of any other subsection of this section, until July 1, 2007 the enhanced prescriptive and performance based approaches may not be used for wastewater systems on lots that are subdivided on or after June 14, 2002, unless the project is located in a municipality that has:

(A) a planning process confirmed under 24 V.S.A. §4350; and

(B) zoning bylaws.

(2) The enhanced prescriptive and performance based approaches may be used for wastewater systems on lots created after June 13, 2002 but before November 1, 2002 that are ten acres or greater in size without meeting the planning and zoning prerequisites listed above.

(3) The Agency of Commerce and Community Development shall maintain a list of all municipalities that meet the criteria of subdivision (f)(1) of this section. Once a municipality has been listed, it shall only be removed from the list if it has repealed its zoning bylaws or the bylaws have otherwise become invalid.