Forest Service Handbook
National Headquarters -Washington Office
Washington, DC

Forest Service Handbook 7409.11 – Sanitary Engineering and Public Health Handbook

Chapter 50 - Wastewater

Amendment: 7409.11-Amendment-10

Effective date: October 1979

Duration: This amendment is effective until superseded or removed.

Superseded Directive:

Approved by:

Date approved:

Responsible Staff:

Explanation of changes:

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59 - Disinfection and Liquid Disposal

59.1 - Disinfection

When wastewater or treated effluents are discharged to bodies of water which are, or may be used as a source of public water supply, for recreational purposes, or where a public health hazard may be created by the effluent, treatment for the destruction of pathogens is required. Such treatment is known as disinfection. Disinfection must be a continuous process as it would be hazardous to discharge untreated effluent even for a short period of time. Neither primary nor secondary methods of wastewater treatment can remove completely from the wastewater the pathogens which are always potentially present.

59.11 - Chlorination

59.11a - General

Chlorine is the most widely used substance for disinfection. Chlorination for disinfection is practiced so that essentially all of the pathogens in the wastewater plant effluent would be destroyed. Many, but not all of the saprophytic organisms, are also destroyed. No attempt is made to sterilize wastewater. Sterilization is the destruction of all living organisms, which is not only unnecessary, but impractical. Chlorination as commonly practiced is not adequate to inactivate all of the enteric (intestinal) viruses which may be present in wastewater.

To accomplish disinfection, sufficient cholorine must be added to satisfy the chlorine demand and leave a residual chlorine that will destroy bacteria. Laboratory experiments and actual plant operational experience have shown that adequate disinfection can be obtained if sufficient chlorine is added to the wastewater so that one hour after the chlorine has been added there will remain a residual chlorine concentration of not less than 0.2 milligrams per liter.

The range of chlorine dosage needed for disinfection, mg/l, is as follows:

Raw Sewage	6-12
Septic Raw Sewage	12-25
Settled Sewage	5-10
Septic Settled Sewage	12-40
Chemical Precipitation Effluent	3-10
Trickling Filter Effluent	3-10
Activated Sludge Effluent	2-8
Sand Filter Effluent	1-5

See section 42.21 for properties of chlorine, and handling and safety procedures for chlorine use.

59.11b - Feeding Equipment

Chlorine dispensing equipment is designed to control and measure chlorine and to apply it either as a gas or as an aqueous chlorine solution.
Gaseous feed permits accurate flow regulations, either manual or automatic. Gas can be metered with variable area or fixed orifice type flow meters, with or without recording instruments; and chlorine gas can then be diffused into water.

1. Direct Feed Equipment

a. Direct feed equipment involves metering of dry chlorine gas and conducting it under necessary pressure conditions to the water being chlorinated.

b. In direct feed equipment, chlorine gas direct from the cylinder passes through a pressure compensating valve and then to a back pressure regulating and check valve designed to maintain a constant downstream metering pressure and to prevent liquid from entering the chlorine in event of shutdown or the development of excessive back pressures at the point of application. These machines require no power, air, or water, and can be installed in remote locations. Their use is limited to small installations, and particular care must be taken to provide suitable diffusion of the gas at an adequate depth of submersion to prevent the loss of free chlorine. Usual practice is to provide not less than 4 feet submergence. Because of safety hazards, this type of equipment is not recommended except under special conditions which prevent the use of solution-feed chlorinators.

2. Solution Feed Equipment

a. Solution feed equipment involves metering of dry chlorine under vacuum or pressure and dissolving it in a small amount of water so that a high strength solution is applied.

b. There are two types of solution feeders, the pressure-feed type and the vacuum-feed type. The pressure-feed type uses a mechanical-diaphragm chlorine control valve to reduce the cylinder pressure ahead of the metering device. The metered chlorine gas is fed into an eductor where it is mixed with water and fed to the point of application.

The vacuum-feed type reduces the cylinder pressure ahead of the metering device to a vacuum on the outlet side of the metering device. This places the chlorine gas under a partial vacuum throughout the system and up to the discharge eductor, which lessens the possibility of a chlorine leak. If the vacuum fails in this type of chlorinator for any reason, the flow of chlorine gas is automatically checked. If the vacuum chamber is broken, the flow of gas is automatically stopped.

The vacuum-feed type of chlorinator is now in general use as it incorporates all safety features required to prevent the accidental discharge of chlorine gas.

The range of feed rates available in chlorinators depends on the type of metering element used. Orifice control gives a 6-to-1 range for any given orifice.

In general, machines using orifice controls are designed so that orifices of varying capacity are interchangeable. The maximum 24 hr. capacity of this type of machining is usually specified, together with the desired maximum meter capacity. Rotameter-type control gives a usual range of 10 to 1 and provides a visible indication of the flow of chlorine gas. These variable are rotor-type meters are interchangeable in a given machine to provide a wide range of flow control. Chlorinators can be obtained in a wide range of feed-rate capacities varying from 3 to 8,000 pounds per 24 hour.

3. <u>Hypochlorite Feeders</u>

a. Liquid hypochlorite feeders are simply chemical feed pumps, diaphragm, piston, or positive displacement type, which will inject hypochlorite solutions with feed rates from 0.001 to 1400 sal./day for discharge pressures up to 125 psi using diaphragm elements, 500 psi using plunger elements, and 40 psi using positive displacment type pumps.

b. Solid hypochlorite feeders are simple one-piece systems which operate on the flow-through principle to provide a constant, controlled dosage of chlorine to the liquid. The feed rates are controlled by their plates and the number of charged tubes. Solid chlorine compounds are charged into the feed tubes and dissolved by the passing fluid. The units are self-proportioning and need no adjustments as flow fluctuates. Chlorinators can feed up to 1400 lb. per 24 hour.

59.11c - Chlorine Detention Facilities

1. A special contact chamber of intermixing and detention of the chlorinated effluent is necessary to provide adequate time for disinfection.

2. A contact time of not less than 30 minutes at maximum flow rates with residual of not less than 0.5 milligrams per liter is recommended. (This criteria may vary by individual state. State regulations should be checked for requirements.)

3. Careful design of chlorination facilities is essential, because it usually is difficult for the operator to adjust the initial mixing, the actual contact (short-circuited) time, the method of controlling the chlorine dosage, or the pH after construction. Efficient operation of the prior treatment processes may minimize or eliminate some interfering substances, such as ammonia, calcium bicarbonates, SS, COD, and turbidity. It is particularly important in wastewater treatment pond systems that the removal of SS in the form of algae and other microbial cells be relatively complete before chlorination, if disinfection is to be effective. Turbidities should be kept below 1 TU and preferably below 0.1 TU, if chlorination is to inactivate viruses effectively.

4. The chlorine contact unit should be designed to keep the chlorine residual in the effluent at a minimum level, consistent with meeting coliform removal standards. This condition can best be accomplished by providing an initial rapid mix, for making quick and complete contact between the chlorine and the pathogens, and followed by plug-type flow (each particle in a cross section of flow moves at the same velocity) through the contact chamber.

5. In designing a chlorination system, some essential factors to be considered are:

a. Selecting a reliable chlorine feed control system, keyed, if possible, to meet chlorine demand variations.

b. Selecting a diffusor that doses the chlorine uniformly throughout the influent stream.

c. Providing excellent mixing (mechanical mixer, hydraulic jump, etc.) at the inlet end of the contactor to homogenize the chlorine and wastewater within 3 to 5 seconds of dosing.

d. Providing longitudinal baffles and turning vanes, if necessary, to achieve plug flow after the initial complete mixing and actually obtain the required contact time.

e. Training operating personnel thoroughly.

f. Providing a means of pH control, if necessary.

g. Providing dechlorination, if downstream ecology will be significantly affected by chlorinated byproducts.

h. Providing nonsettling velocities in the contact chamber.

i. Making adequate provision for easy cleaning of contact basin, because accumulated solids interfere with disinfection.

j. Monitoring the chlorine residual.

6. The contact unit should be designed so plug flow can be obtained to a major degree by using a pipe designed to flow full to provide contact time; using a long, narrow, concrete-lined channel; and placing endaround baffles with guide vanes at turns in the contact chamber. The pipe is the best type of chlorine contact unit for small plants. Length-to-width ratios of 60 to 70 have proven most effective.

59.12 - Ozone

59.12a - General

Ozone used to disinfect wastewater, or as tertiary treatment, does not increase the odor, color, or salt content of the plant effluent. In relatively pure potable water, ozone has a half life from about 20 to 80 minutes, depending on the COD remaining in the water. At normal temperature, ozone residuals rapidly disappear if any COD is present. Although it is twice as powerful as oxidizing agent as hypochlorite ion, ozone has relatively little disinfecting power until the initial ozone demand of the wastewater has been satisfied. After this point has been reached, it reacts very rapidly, essentially to complete disinfection of both bacterial and viral pathogens within 5 minutes. If normal amounts of oxidizable materials are present, as in secondary effluent, the dosage required may be between 5 and 20 mg/l. Ozone treatment does not reduce the total

dissolved nitrogen. At pH above 10, ammonia also is oxidized to nitrate. CODs of 30 to 50 mg/l can be reduced about 50 to 70 percent with ozone in one to two hours of actual contact time.

For domestic wastewaters, the relations between feedwater COD, product COD, feedwater pH, reaction time, dissolved ozone concentration, and the quantity of ozone dissolved are discussed in "A Review of Ozone and Its Application to Domestic Wastewater Treatment" by McCarthy, J.S. and Smith, C.H., Journal American Water Works Association (December 1974). If dechlorination is required, the costs of ozonation may become more competitive with the costs of chlorination, especially if liquid oxygen is available onsite. It takes about 2.5 to 3.5 killowatt hour to produce 1 lb. of ozone, using oxygen feed, and 6 to 9 kwh using air feed.

59.12b - Ozone Advantages

1. It eliminates odors; reduces oxygen demanding water; removes most colors, phenolics, and cyanides; reduces turbidity and surfactants; and increases dissolved oxygen.

2. Ozonation can also be used as a tertiary treatment process for oxidation of residual carbon compounds and for odor control.

3. A person working near an ozone-handling area should be able to detect the presence of ozone at concentrations far below the MAC. The Maximum Allowable Concentration (MAC) of ozone in air, as established by the American Council of Governmental Industrial Hygienists, is 0.1 ppm by volume for continuous human exposure. The threshold odor of ozone is 0.01 to 0.02 ppm.

4. Ozone can be generated from air, making its supply dependent only on a source of power. Production of ozone from oxygen should be considered where oxygen is used in conjunction with biological treatment, because less energy is used.

59.12c - Ozone Disadvantages

The primary objections to ozone use are:

1. High cost.

2. Possible air pollution from escaping ozone.

3. High electrical consumption.

59.12d - Ozone Generators

The two most efficient types of ozone generators are the water-cooled tube and the air-cooled, Lowther-plate ozonators. The Lowther-plate ozonator (generally more efficient) with a once-through air feed system will require about 6.3 to 8.8 kwh/lb, while with a recycled-pure-oxygen feed system, it will require about 2.5 to 3.5 kwh/lb. There are four general systems to apply ozone to wastewater:

1. Cooled and dried air is fed to the ozonator and the resultant air-ozone solution (1.3 percent ozone by weight) is mixed with wastewater in a contactor. This system is limited to very small wastewater systems (because of its inefficiency) and for use in odor control.

2. An oxygen-enriched feed replaces the air feed in the water-cooled or air-cooled tube ozonator. A pressure-saving separator is used to remove nitrogen.

3. Oxygen feed replaces the air feed in water or air-cooled ozonator and oxygen-rich offgas is recycled to the front of the loop. Nitrogen is removed from the waterwater before ozonation.

4. Air is enriched to about 40 percent oxygen at starting. In each successive cycle the recycled gas is cleaned, dried, and enriched in oxygen.

59.12e - Contractors

Three general types of contractors are usually used. These are the packed bed, the sparged column, and the sparged column with mixing. The most efficient contractor design for a particular wastewater at a particular location
is apt to be different from the best for another wastewater with different local conditions. The design of an ozonation sytem for a municipal wastewater treatment facility requires thorough knowledge of the local conditions and of ozonation to optimize the design.

59.13 - Other Disinfectants

59.13a - Bromine and Bromamine

Bromination would be accomplished the same as Chlorination. However, bromine is more effective as a disinfectant than chlorine.

Bromine chloride is 12 times more water-soluble than chlorine and its lower vapor pressure makes it safer.

When added to water, the chemical hydrolyzes almost immediately and completely to one of the most active disinfectant species, hypobromous acid, and retains the disinfectant activity at a high pH typical of most wastewater. Bromine chloride reacts indirectly with ammonia in sewage to form bromamines, which have a higher bactericidal and vericidal activity than chloramines.

Diatamic bromine, like iodine but unlike chlorine, can exist in natural water pH range. Data shows that both cells and virus are rapidly inactivated by Br_2, but that virus is particularly susceptible. It also shows that when almost all of the freebromine is HOBr cells and more completely inactivated than virus. E. coli, being a cell, is readily inactivated by HOBr. Bromine, as chlorine, fail as a cysticide in water containing nitrogenous substances. Bromine compounds are much less stable and become harmless in less than an hour. Residuals are very low, thus less hazardous to fish and wildlife.

Chlorbromination appears to be the best alternative to current chlorination practices. Although more expensive than cholorination, bromine chloride is cost-competitive with sulfur dioxide dechlorination and less costly than systems using ozone or ultraviolet light.

59.13b - Iodine

Iodine possesses the highest atomic weight of the four halogens and is the least soluble in water (and the least hydrolyzed by water); it has the lowest oxidation potential, and reacts least readily with organic compounds. Although these somewhat negative characteristics might at first sight appear to be limiting factors with respect to iodine's use for the disinfection of water, just the reverse is the case.

Taken collectively, these characteristics mean that low iodine residuals should be more stable and, therefore, persist longer in the presence of organic pollutants than corresponding residuals of any of the other halogens. The high chemical reactivity of chlorine; its ability to react with organic material by oxidation, by substitution, or by addition, constitutes perhaps the greatest drawback to its effectiveness for water disinfection. The ideal water disinfectant would be some material that is chemically weak and unable to participate in such reactions, but at the same time, possessing bactericidal, cysticidal, and virucidal properties equal or superior to those of chlorine.

Ammonia in water rapidly ties up the chlorine to form the chloramines. Ammonia added to water containing an iodine residual does not affect the iodine residual or its ability to destroy micro-organisms.

AT pH5, about 99% is present as elemental iodine and only 1% as hypoiodous acid; at pH7, the two species are present in almost equal, concentrations; and at pH8, only 12% is present as elemental iodine and 88% as hypoiodous acid.
Both of these species are effect germicidal agents. Iodine will provide disinfection of waters across a relatively wide pH range.

On a weight basis, iodine can inactivate virus more completely over a wide range of natural waters than either chlorine orbromine since inhibitory amines are not formed with iodine. Iodine can be stored practically indefinitely in the drum in which shipped with very little loss of the element. Iodine is shipped in paper drums in approximately 45 kg lots.

Iodine can be fed at present by one of the following three methods:

1. Meter gaseous iodine directly to the water.

2. Meter a strong solution of iodine to the water and oxidize I to I_2 as needed.

3. Meter a saturated aquous solution of I_2 to the water. All three of these methods will work for specific applications. Method Number 3 has proved to be easy for all modestly trained individuals to initiate and operate. In this method, a saturated solution of iodine (I^2) is formed by passing water through a bed of elemental iodine crystals. Retention in the iodine bed is maintained long enough to reach either saturation or the desired strength of iodine. This iodine

solution is then pumped into the water by chemical metering pumps. Any desired dose can be readily attained and maintained by this method with a minimum of skill on the part of the system operator. Even if iodine crystals are dropped on the floor, there is no danger to personnel who may be near. Iodine can compete with chlorine and may be the cheaper of the two disinfectants, depending upon the conditions of use.

59.13c - Ultraviolet

Ultraviolet has been known for decades as the most powerful sterilizing agent for small to moderate volumes of industrial liquids and air, killing most micro-organisms quickly, and now at a reasonable cost. But the application to secondary treated sewage has taken many years to achieve, because of the large volumes and the suspended solids.

The loss of infectivity of Poliovirus 1, 2, and 3; Echovirus 1 and 11; coxsackievirus A-9 and B-l; and Reovirus 1 has 99% or greater after 30 seconds of UV exposure to 116 ergs per mm^2 per second. Reduction of Fecal Coliform reduction after 2.7 seconds of UV exposure to 2.5×10^6 ergs per mm^2 per second was over 99.99%, and after 2.7 seconds at 1.0×10^6 per ergs per mm^2 per second was over 99.9% on secondary wastewater effluent.

The inactivation of poliovirus 1 was 99% after 17 seconds, 99.9% after 24 seconds, and 99.99% after 32 seconds of UV exposure to 830 ergs per mm^2 per second.

Older units required frequent checking for light intensity and cleaning of the lamps. However, new units on the market have automatic wipers and range in size fom 2 gallons to 250 gallons per minute, contained in a pressure vessel, and can be supplied with fail-safe controls.

1. Advantages

a. Better kill rates.

b. Broader range of micro-organisms killed (virtually all bacteria and viruses).

c. Much smaller space needed.

d. No casrcinogenic effects.

e. No hazard to personnel or to the neighborhood.

f. Better dispersion of disinfection.

g. No chemical products to upset stream ecology.

h. Never a need to dechlorinate.

i. Immune to heavy ammonia leadings.

j. No operation to change lamps (approx. every 8000 hrs.).

2. Disadvantages

a. No residual disinfectant.

b. A source of electric power is needed.

c. Getting local repairman could be difficult.

d. Solids in the effluent greatly reduce effectiveness.

59.13d - Other Disinfection Methods

1. Gamma Radiation, and Beta Radiation for information, see Sandia Laboratories, Albuquerque, New Mexico, or the Deer Island, Mass. facilities under the direction of Massachusetts Institute or Technology.

2. Peat Sand Filters. If properly designed, installed, and operated, a peat bed should produce an effluent with no fecal coliform, and little coliform.

There is little maintenance and little to change in the quality of effluent. However, pressure is required to distribute the effluent on the bed which normally means electrical power is necessary. The availability of peat an file sand may be a problem in some areas.

59.2 - Disposal

59.21 - Direct Discharge

Direct discharge should be used only as a last resort. If it is necessary to have a discharge, an NPDES permit is required. Public law 95-217 requires alternative methods, unless the life cycle cost of the alternative treatment works exceeds the life cycle cost of discharge by more than 15 percent. Alternative methods for wastewater treatment utilizing innovative treatment processes and techniques, including but not limited to, methods using land treatment and recycle and reuse techniques must be evaluated.

59.22 - Subsurface Disposal

See sections 55.22c and 55.22d.

59.23 - Spray Irrigation

The successful use of spray irrigation requires a careful investigation of the proposed disposal site. A variety of factors affect spray field operation. These include the slope of the surface, application rate, surface soil permeability, subsurface soil characteristics, type of cover vegetation, period of time of application, total quantity of waste applied during one time period, the chemical composition of the soil, and the characteristics of the waste applied.

Insofar as the vegetation itself is concerned, there is a limit on the amount of water that can be applied to most plants and still result in beneficial growth. It may be that the soil is unsuited for spray irrigation, or that the existing cover must be replaced.

The area to be sprayed should be divided into sections and the piping and valves arranged in a manner that one section is dosed one day at a time in sequence. Thus, each section has six days without wastewater being applied. During this idle time, bacterial and other microbial action takes place that aids in the treatment process and also keeps down buildup of undesirable dissolved solids in the soil.

The spray system should be of the medium-pressure type in order to operate most economically by keeping pumping costs down. Spray nozzles must be of a type that will minimize clogging.

Application rates, combined with precipitation, must exceed evapotranspiration rates to ensure that soluble salts are leached form the soil. Good subsurface drainage is desirable, as is a rather deep water table, to minimize groundwater evapotranspiration losses and a resulting salinity buildup. In arid to semiarid regions, considerable attention must be given to site land management to be assured the irrigation area will not be chemically degraded. In humid regions, a rate of .25 inches per hour and 2 inches per week should be considered maximum. However, in arid to semi-arid regions, a higher rate will probably be needed due to the high evaporation and salt buildup.

It is desirable, therefore, in site selection studies to consider those aspects of the soils, geologic, and hydrologic conditions that will help to maximize and prolong the renovation process, hopefully, indefinitely.

Control of nitrate concentrations in groundwater at irrigation sites is one of the main challenges that users of the irrigation system face. Nitrate removal can be one of the weakest links in the irrigation concept. For example, poorly drained soils may actually provide a higher degree of nitrate removal than compared to better drained soil.

Wastewater effluent must infiltrate into soil and be retained for a sufficient period within the biologicall active zone to be acted upon by renovation agents.

Where highly permeable sand and gravel, mechanically weathered bedrock, fractured bedrock, conduits and cavity systems are present beneath the soil, little if any additional treatment except dilution and dispersion should be anticipated. Renovation must be achieved within the overlying soil.

All wastewater irrigation projects must contain appropriate monitoring facilities so that the design assumptions and expectations can be verified through actual experience. Pressure-vacuum lysimeters are the single best approach to sampling soil-water or water under tension. They are inexpensive, easy to install, provide samples long after other sampling devices fail, as the moisture content is reduced and can be used at depths of 6 inches to more than 20 feet.

Area must be signed to warn persons of the site use, and in some incidences, fenced to keep unauthorized personnel out.

59.24 - Rapid Infiltration

In rapid infiltration land treatment, most of the applied wastewater percolates through the soil, and the treated effluent eventually reaches the groundwater. The wastewater is applied to rapidly permeable soils, such as sands and loamy sands, and is treated as it travels through the soil matrix. There is little or no consumptive use by plants.

The principal objective of rapid infiltration is wastewater treatment. Other benefits include:

1. Ground water recharge.
2. Recovery of renovated water by wells of underdrains with subsequent reuse or discharge.
3. Recharge of surface streams by interception of groundwater.
4. Temporary storage of renovated water in the aquifer.

Removals of wastewater constituents by the filtering and straining action of the soil are excellent. Suspended solids, bod, and fecal coliform are almost completely removed in most cases.

Nitrogen removals are generally poor unless specific operating procedures are established to miximize denitrification. Nitrogen removals of up to 30% may be achieved. Although total nitrogen removals may be poor, rapid infiltration is an excellent method for achieving a nitrified effluent.

Phosphorus removals can range from 70 to 99%, depending on the physical and chemical characteristics of the soil. The primary removal mechanism is absorption with some chemcial precipitation, so the long-term capacity is limited by the mass of soil in contact with the wastewater. Removals are also related to the residence time of the wastewater in the soil and the travel distance.

59.25 - Overland Flow

In overland flow land treatment, wastewater is applied to relatively impermeable soils and allowed to flow across a vegetated surface to runoff collection ditches. The wastewater is renovated by physical, chemical, and biological means as it flows overland in a thin film.

The objectives of overland flow are wastewater treatment, and to a minor extent, crop production. Treatment objectives may be either (1) to achieve secondary or better effluent quality from a primary treatment waste stream, or (2) to achieve high levels of nitrogen and bod removals from secondary treated wastewater. The treated water is collected in ditches and can either be reused or discharged to surface water.

Biological oxidation, sedimentation, and plant filtration are the primary removal mechanisms for oganics and suspended soils. Up to 95% removal of bod and SS can be excepted.
Nitrogen removal is attributed primarily to denitrification. Plant uptake of nitrogen can also be a significant removal mechanism. Permanent nitrogen removal by plant uptake is only possible if

the crop is harvested. Nitrogen removals range 75 to 90% with runoff nitrogen being mostly in the nitrate form.

Phosphorus is removed by absorption and precipitation. Treatment efficiencies are somewhat limited because of the incomplete contact between the wastewate and the absorption sites within the soil. Phosphorus removals range from 30 to 60% on a concentration basis.

59.26 - Pond Evaporation

Complete containment (retention) may be practiced if the combined evaporation and percolation overflow rates are equal to, or more than, the precipitation and wastewater inflow. The complete containment system is usually feasible only in the drier parts of the western plains and desert regions.

These systems should be located well away and downwind from habitations, and the pond designed, constructed, and operated to prevent conditions that might lead to fly, mosquito, and odor muisances.

1. Process description

a. Facultative lagoon with no overflow.

b. Balance made between inflow and outflow.

2. Design Parameters

a. Wastewater flow.

b. Precipitation.

c. Evaporation.

d. Wind.

e. Sunlight.

f. Temperature.

g. Seepage.

Wastewater flow + precipitation = evaporation + seepage.

Seepage should be minimized. Consideration should be given not only to a potential groundwater pollution problem, but also seepage and formation of springs in the immediate area resulting from a perched water zone beneath the ponds.

3. Pros and Cons

a. Pros

(1) No effluent.

(2) Little operation and maintenance.

(3) Low costs if land cost is low.

b. Cons

(1) Large land areas required.

(2) Design parameters not measurable with any accuracy except flow.

59.27 - Evapotranspiration

The ET system is a shallow system employing the concepts of evaporation of effluent to the atmosphere and transpiration of effluent by plants. It is impossible to determine the true amount of ET versus infiltration of wastewater into the subsurface when an installation employs a combination of these two concepts. It should be assumed that total ET of the wastewater will be needed for design purposes. When soil infiltration is excluded from ET, climatic factors become much more critical. ET processes can theoretically remove significant volumes of effluent from subsurface disposal systems in late spring, summer, and early fall, particularly if high-silhouette, good-transpiring bushes and trees are present. However, the effectiveness of ET is determined by the difference between ET and preceipitation - the net ET loss. In humid regions, the net ET loss is inadequate for disposal of effluent from a typical household.

The decrease of ET in winter at middle and high-altitudes greatly limits ET for winter disposal; under freezing conditions, ET is totally inadequate.

A simple procedure for estimating the maximum ET from disposal fields for the nonadvective conditions, such as found in the U.S. east of the Mississippi, can be found in "Influence of Climate on Subsurface Disposal of Sewage Effluent," by Champ B. Tanner and Johannes Bouma; in "Individual Onsite Wastewater Systems, Proceedings of the Second National Conference 1975," by Ann Arbor Science Publishers, Inc., Ann Arbor, MI. 48106.