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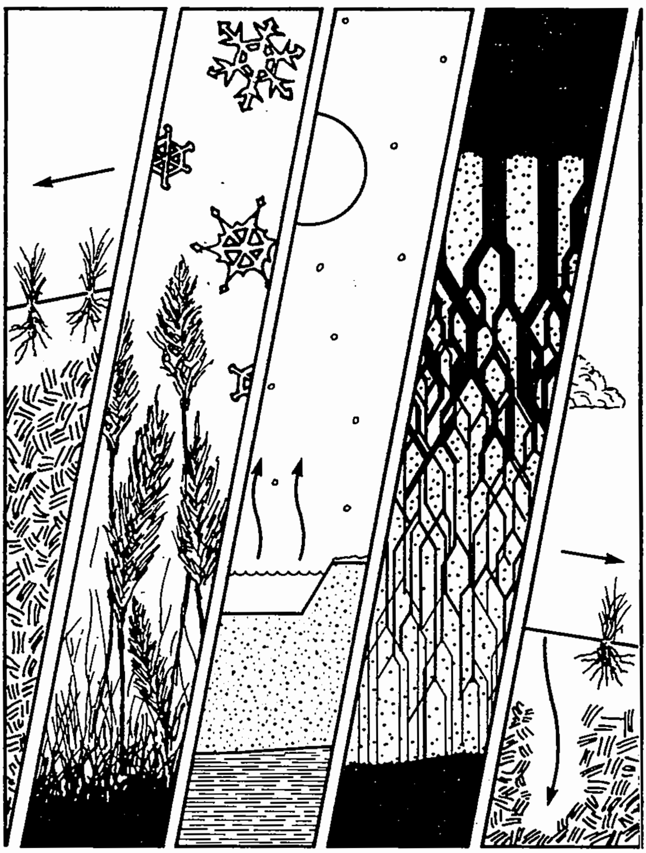
Natural Systems for Wastewater Treatment in Cold Climates



Natural Systems for Wastew[illegible]

The Concepts

The term natural systems refers to wastewater treatment systems which have minimal dependence on mechanical elements to support the wastewater treatment process.In contrast, activated sludge utilizes a natural biological sludge but depends on mechanical elements for mixing, aeration, and sludge pressing. Natural systems such as facultative ponds, rapid infiltration, or wetlands treatment, depend directly on natural components for treatment with minimal mechanical assistance or energy inputs.

These natural systems are especially well suited for small communities in rural areas where land may be available and where it is important to keep construction and O&M (operating and maintenance) costs as low as possible. A potential concern with these systems, however, is their susceptibility to operating problems and icing during the winter. In natural systems, dormant vegetation, the slow reaction rate for soil or aquatic microbes at low temperatures, and/or the presence of an ice cover, may reduce both physical and biological activity, and thus affect system performance on a seasonal basis. Therefore, it is important to include consideration of winter conditions when evaluating these systems for use in a cold climate.

Pond Systems

Facultative ponds are used for wastewater treatment throughout the United States. They depend on surface reaeration and algal photosynthesis for oxygen, natural die-off of pathogens, and on the contained biota for treatment. A number of design models are available [1], most of which include rate constant adjustments for low temperature conditions. However, the effect of long-term ice cover on the pond or lagoon is not always given adequate consideration. The presence of an ice cover for long periods eliminates significant surface reaeration and, since algae are also dormant, the oxygen levels in the liquid can decrease to zero. The effluent quality during such periods can deteriorate to primary treatment levels.In some cases, supplemental winter aeration may resolve the problem.

A "controlled discharge" approach is used in Canada and the North-Central United States to provide sufficient detention time to eliminate the need to discharge during the critical winter months. The discharge is programmed for once or twice per year. Each cell is isolated in turn and prepared for discharge.

Overland Flow (OF) Land Treatment

In overland flow, partially treated wastewater is applied to relatively impermeable soils at the top of a gentle (2-8%) grass covered slope. Treatment by vegetation and surface microbial biota occurs as the wastewater moves via sheet flow down the slope. The treated effluent is then collected at the toe of the slope and typically discharged to surface water. The hydraulic loading of an OF system can be 2 to 4 times higher than an SR system, depending on treatment goals and influent characteristics. Design details can be found in References 2 and 3.

The vegetation is a critical treatment component in OF systems; since perennial grasses are commonly used, the operating season can usually be longer than the typical SR system. The length of the OF operating season can also be influenced by the level of nitrogen removal required. If nitrogen is not a parameter of concern, then the operating season may extend well beyond the growing season for the project area. A detailed map showing suggested wastewater storage needs for OF can be found in Reference 3. Figure 1 presents a simplified approximation of storage requirements. Note the storage requirements north of the 40 day line on Figure 1 are essentially the same for both OF and SR systems.

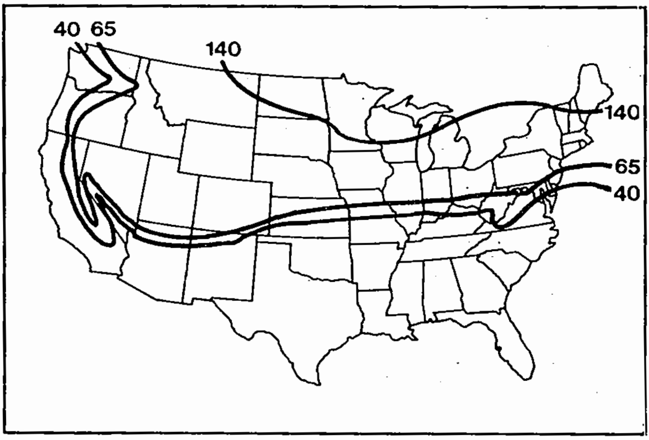


Figure 1. Winter Wastewater Storage for OF Systems, Days.

Constructed Wetland Treatment Systems

Constructed wetlands are a relatively new concept for wastewater treatment [4,5]. Yet a variety of systems involving natural and constructed wetlands have been investigated and sucessfully utilized as a part of wastewater treatment systems. Constructed wetlands are typically installed for wastewater treatment at a site where a wetland did not previously exist. There are several advantages to this approach since greater control of flow, therefore improved treatment efficiency involving a smaller area is possible with a constructed wetland, rather than with a naturally occurring wetland. Additionally, natural wetlands are often considered to be part of the receiving waters rather than a part of the treatment system. As a result, regulations may restrict the allowable inputs to a natural wetland.

Partially treated wastewater is introduced at the head end of the shallow constructed wetland and treatment occurs during the several days of residence in the system. Extensive work in Ontario, Canada has developed engineering criteria for year-round operation of constructed wetlands in cold climates [4,5]

A system designed for BOD, SS, and significant nitrogen removal would typically consist of an 8 to 10 day detention time in a partial-mix aerated lagoon with a settling zone, followed by a wetland area constructed as long, narrow channels (e.g., L:W = 10:1). The design detention time in the summer is typically 7 days with a 10 cm water depth, at a hydraulic loading of about 200 m^3/ha/yr. The water depth is increased to about 30 cm at the onset of winter to allow for an adequate treatment zone beneath the winter ice cover. Most of the nitrogen in the effluent will be in the ammonia form and additional pre-or-post treatment may be required if the discharge permit requires low ammonia levels. Similarly, if phosphorus removal is required, pre-or-post treatment may be required.

Emergent vegetation (e.g., cattails, reeds, and rushes) is planted in constructed wetlands to form a dense cover. The plants themselves provide little treatment but the stalks and root nodules provide a substrate for the extensive microbial growth which is thought to be responsible for most of the treatment activity. Since the plants are not the major factor in treatment, year-round operation of the system without plant harvest is possible. Performance can be sustained at consistently high levels as shown in Table 3, which presents results from a system in Canada.[4,5]

The performance, and many of the treatment responses in constructed wetlands are similar to those

Parameter mg/L		
BOD_5	SS	Total N
7	9	6

Table 3. Quality of Wastewater following Wetland Treatment.

occurring in OF systems. The water depth is greater in the wetland and this, plus the insulating ice cover, allows operation under conditions that would cause complete surface freezing of an OF slope.
A uniform flow under the wetland ice cover is essential to avoid development of anaerobic conditions and the resulting deterioration in performance.

The major factor influencing cost effectiveness of a constructed wetland versus OF is the amount of land required for each of the concepts. If extensive winter storage is required for an OF system then the wetland is likely to be the more economical system. The 65 day line on Figure 1 is the approximate dividing line, with respect to land requirements, for the two concepts. Overland flow systems will usually require less land area south of that line, while constructed wetlands may be more cost effective to the north. It should also be remembered that OF systems have a proven record of reliable performance while constructed wetlands are just emerging from the developmental stage.

Conclusions

The natural wastewater treatment systems described in this text can be successfully used in cold climates. The major winter concerns are dormant vegetation, low reaction rates, freezing of equipment, and ice formation on the surface of the treatment system.

In non-forested natural systems where vegetation is a critical treatment component, it may be necessary to store wastewater during the winter months. Forested slow rate and rapid infiltration systems and constructed wetlands, however, can all operate through the winter with proper care of the wastewater distribution network.

Forested systems can also be operated successfully through the winter if freezing is prevented in the mechanical equipment (pumps, pipes, sprinklers, etc). The ground surface in forests freezes more slowly than exposed agricultural soils and once a deep snow fall occurs, the soil might not freeze at all, permitting wastewater to infiltrate all winter long. As shown in Table 2, performance can be excellent on a year-round basis in a forested SR system.

Time	BOD_5 mg/L	SS mg/L	Total P mg/L	Total N mg/L	Fecal Coli #/100 ml
Winter (Nov-Mar)	3	3	0.3	7.4	60
Summer (April-Oct)	1	1	0.2	2.5	57

Note: percolate samples obtained in cut-off ditch at toe of treatment slope.

Table 2. Winter and Summer Performance of a Forested SR System in Central Vermont.

Maintenance of the wastewater distribution network for continuous winter operations of an SR system can be labor intensive. In some situations, where low cost land is available, it may be more cost effective to provide for winter wastewater storage. This, however, will also require a larger treatment area for summer application of the total flow.

Rapid Infiltration (RI) Land Treatment

Rapid infiltration involves the application of partially treated wastewaters to shallow basins in highly permeable soils. The hydraulic loading rates are usually at least an order of magnitude greater than SR systems, but it is still possible to achieve a very high quality percolate. Design criteria can be found in References 2 and 3. Since vegetation is not used as a treatment component there are no seasonal limitations and an RI system can operate on a year-round basis. Freezing must be prevented in the piping system but ice formation in the basins is not usually a problem when the applied wastewater is relatively warm. Icing may become a problem if very cold effluent from a long detention time lagoon is applied to an RI basin in a very cold climate. Reference 3 provides a detailed discussion on this topic.

When water quality in the cell and in the receiving stream are compatible , the entire cell is discharged over a period of several days to several weeks. Excellent performance is possible. Table 1 presents results from a controlled discharge pond in Michigan.

Discharge Period Date	Days	Effluent Quality, mg/L BOD$_5$	SS	NH$_3$-N	NO$_3$-N
May	5	7.7	18.4	2.1	1.0
Oct.	12	1.2	3.5	0.6	0.3
Nov.	8	0.6	1.6	3.8	0.5

Table 1. Performance, Controlled Discharge Ponds.

Pond systems combined with various aquatic plants (water hyacinths, duck weed, etc.) in aquaculture systems are capable of high levels of treatment during the growing season. Use of these concepts in colder climates would probably require covers and additiona' heat for sustained winter performance. It is not likely that these extra protective elements will be cost effective.

Slow Rate (SR) Land Treatment

In SR systems, partially treated wastewater is applied to a vegetated soil surface, followed by infiltration and percolation through the soil.Sometimes it is followed by gravity drain recovery and surface discharge of the treated effluent. The vegetation, soil, and microbial biota all contribute significantly to treatment. If properly designed and managed it is possible to achieve drinking water quality in the treated wastewater after a few feet of travel in the soil. Complete design details can be found in Reference 2.

The operational period for a particular system will depend on the type of vegetation selected for the system. The use of agricultural crops (grasses, hay, corn and small grains) typically requires wastewater storage during the winter months. Storage time might range from 20 days in North Carolina and northern Arizona, to 160 days in northern Wisconsin and Maine. Reference 2 provides complete details.

Grass-covered systems can typically be operated for a longer period than row crop systems. If nitrogen is not a critical parameter, grass covered systems might be operated into the winter as long as general ice build-up on the ground surface does not interfere with infiltration.

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