EPA

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Environmental Protection
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Wastewater Technology Fact Sheet

Rapid Infiltration Land Treatment

DESCRIPTION

Rapid Infiltration (RI), which is also known as soil aquifer treatment, is one of the three major land treatment techniques that uses the soil ecosystem to treat wastewater. However, the RI process can treat a much larger volume of wastewater on a much smaller land area than other land treatment concepts. In RI systems, wastewater is applied to shallow basins constructed in deep and permeable deposits of highly porous soils. Wastewater application can be by flooding, or occasionally by sprinklers. Treatment, including filtration, adsorption, ion exchange, precipitation, and microbial action, occurs as the wastewater moves through the soil matrix. Phosphorus and most metals are retained in the soil while toxic organics are degraded or adsorbed.

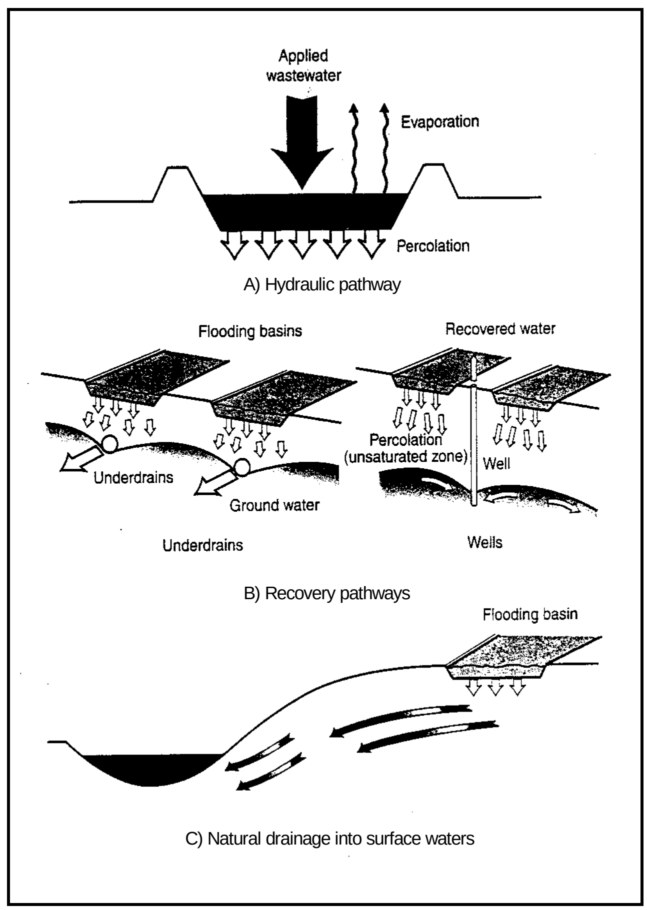
As wastewater percolates through the soil, it can be collected, or it can flow to native surface water or groundwater aquifers. Where the groundwater table is relatively shallow, the use of underdrains allows control of groundwater mounding and recovery of the renovated water. In areas with deeper groundwater, wells are used to recover the renovated water. This recovered water can be for irrigating crops or for industrial uses. This is known as “beneficial reuse.” Water that is not recovered can recharge groundwater aquifers. The typical hydraulic pathways for water treated by RI are shown in Figure 1.

Common Modifications

Concerns regarding increased nitrogen levels in aquifers near RI systems have prompted several modifications to the general system design. RI sites may be located next to rivers or other surface water bodies, particularly if hydrogeological studies show that the percolate will flow to the surface water system and will not impact the general groundwater quality. When using underdrains or wells, an alternative is to design for a discharge rate that only slightly exceeds the percolation rate. This prevents any adverse impact on the adjacent groundwater. It is also possible to use special management approaches that maximize the nitrification and denitrification reactions, or to recycle the portion of the percolate with the highest nitrate concentration.

APPLICABILITY

RI is a simple and low cost wastewater treatment concept that has been used for more than 100 years. It is applicable for either primary or secondary effluent, and it has been used for treating municipal and some industrial wastewaters. Industries which have successfully used RI to treat their wastewater



Source: Crites, et al., 2000.

FIGURE 1 HYDRAULIC PATHWAYS FOR RAPID INFILTRATION

include breweries, distilleries, food processing plants, paper mills, and wool scouring plants.

RI can be used in a variety of different climates and at varied site locations. Unlike other land treatment and aquiculture concepts, RI systems do not have any special seasonal constraints, and they have been successfully operated throughout the winter months in the northern United States and southern Canada. RI is also very flexible in terms of site location. Unless groundwater recharge and recovery is intended, the most desirable sites are located immediately adjacent to surface waters to minimize any impact on the general groundwater quality. An underdrained system can be located wherever suitable soil and groundwater conditions exist.

There are more than 350 RI systems operating in the United States. However, the potential difficulty in identifying appropriate sites for the construction of RI systems and more stringent standards that must be met before the effluent can be applied to RI basins have led to a decrease in the use of RI as a treatment process for primary wastewater. Instead, many of the systems currently in use in the U.S. are used to polish secondary effluent. Other systems serve primarily as a wastewater disposal method, or as a method to replenish groundwater supplies. For example, the Landis Sewerage Authority in New Jersey operates an 3,100 m^3/day (8.2 MGD) advanced wastewater treatment facility (AWTF). After being processed in the AWTF, all of the water is discharged back to the groundwater through a RI basin, recharging the aquifer. RI basins have also recently been installed to dispose of treated effluent from an industrial area consisting of a hospital and a retirement home in Chester County, Pennsylvania. There are several basins covering a total of 1.2 ha (3 acres) in the system, and wastewater is applied by spraying it into each basin on a rotating schedule. Once the basins have reached their design effluent capacity, they are allowed to dry. The effluent then infiltrates through the soil and into the groundwater, further improving its quality and recharging the aquifer (Satterthwaite and Associates, 2003).

The town of Lake George, New York, has been using a RI system for over 60 years. The use of RI basins at Lake George stems from a 1942 New York state law that forbids discharge of wastewater to Lake George or any of its tributaries. Therefore, in order to dispose of its wastewater, the town discharges to natural basins consisting of more than 30 m (100 ft) of glacial sand deposits. The wastewater then percolates into the soil. After percolation, the sand is raked and/or rototilled to aerate the soil, and the beds can be reused.

Currently, the Lake George WWTP discharges 1.3 MGD during the summer, and between 0.5-0.6 MGD in the winter. Treatment consists of equalization, clarification, and trickling filters. After secondary settlement, wastewater is discharged to one of 26 RI basins. Each basin is filled to just below the spillway, and the water is then allowed to infiltrate into the soil. During peak flow periods in the summer, approximately one basin is filled per day. The basins take approximately 5 days to drain, and then each basin is raked and is ready for reuse.

Because of the concerns that using these basins could load high concentrations of nitrogen and phosphorous into the groundwater, the town's NPDES permit requires groundwater monitoring for increased nutrient concentrations. Nitrogen can be a particular problem during the winter months when nitrogen-fixing bacteria are less active.

ADVANTAGES AND DISADVANTAGES

Advantages

- Gravity distribution methods consume no energy.

- No chemicals are required.

- RI is a simple and economical treatment.

- The process is not constrained by seasonal changes.

- Effluent is of excellent quality.

- The process is very reliable with sufficient resting periods.

- RI provides a means for groundwater recharge, controlling groundwater levels, recovering renovated water for reuse or discharge to a particular surface water body, and temporary storage of renovated water in the aquifer.

- The process is suitable for small plants where operator expertise is limited.

Disadvantages

- As typically operated, RI systems will not usually meet the stringent nitrogen levels required for discharge to drinking water aquifers.

- Requires long term commitment of a significant land area for treatment, with minimal secondary benefits such as are possible with other natural treatment systems (i.e., crop or forest production, habitat enhancement, etc.).

- Requires annual removal of accumulated deposits of organic matter on the infiltration surfaces in the basins.

- May require occasional removal and disposal of the top few inches of soil to expose clean material.

- Clogging can occur when influent is received at high application rates from algal laden facultative lagoons and polishing ponds.

DESIGN CRITERIA

Most RI failures are due to improper or incomplete site evaluation. Therefore, the primary design consideration for an RI system is site selection. Soil depth, soil permeability, and depth to groundwater are the most important factors in site evaluation. All of these factors must be very carefully evaluated during site investigation, regardless of system size, to ensure a successful design.

Once a suitable site has been selected, hydraulic loading rates, nitrogen loading rates, organic loading rates, land area requirements, hydraulic loading cycle, infiltration system design, and groundwater mounding must all be taken into account in designing the RI system. General design parameters for RI systems are shown in Table 1.

As described above, the RI process is entirely dependent on the soil and hydrogeological characteristics at a particular site, and these characteristics must be carefully considered before choosing the site for a RI system. The soil must have sufficient hydraulic capacity to allow the wastewater to infiltrate, then percolate and move either to the groundwater or into underdrains. Any fine textured top soil must be removed from the site so as to utilize the underlying coarse soils as the basin bottom and percolation media. In addition, the top 1.5-3 m (5-10 ft) of soil beneath the basin must be unsaturated at the start of the flooding cycle to allow the expected treatment to occur. There must be suitable subsurface conditions (i.e., slope and/or hydraulic gradient) to ensure that the percolate can flow away from the site at expected rates. The use of RI basins on fill material is not recommended because of potential damage to soil structure and hydraulic capacity during

TABLE 1 DESIGN CRITERIA

Item	Range
Basin Infiltration Area	0.3-5.5 ha/$10^3$$m^3$/d (3-56 acres/MGD)
Hydraulic Loading Rate	6-90 m/yr (20-300 ft/yr) [6-92 m^3/m^2/yr (150-2250 gal/ft^2/yr)]
BOD Loading	22-112 kg/ha/d (20 to 100 lb/acre/d)
Soil Depth	at least 3-4.5 m (10-15 ft)
Soil Permeability	at least 1.5 cm/hr (0.6 in/hr)
Wastewater Application Period	4 hrs to 2 wks
Drying Period	8 hrs to 4 wks
Soil Texture	coarse sands, sandy gravels
Individual Basin Size (at least 2 basins in parallel)	0.4-4 ha (1-10 acres)
Height of Dikes	0.15 m (0.5 ft) above maximum expected water level
Application Method	flooding or sprinkling
Pretreatment Required	primary or secondary

Source: Crites, et al., 2000.

construction. Exceptions may be possible for very coarse textured soils, but only if the hydraulic capacity is tested in a full scale fill. Performance limitations relate to removal of nitrogen, as discussed previously.

Some system designs include an underdrain, which is used to collect renovated water. In order for percolating water to move down through the soil and into an underdrain, the soil must be saturated. Therefore, the use of an underdrain pipe network for percolate recovery is not feasible unless the native groundwater is less than 3 m (10 ft) deep beneath the bottoms of the basins. This should allow for soil saturation during the flooding cycle.

Once the proper site is chosen, a preliminary estimate of the treatment area required for an RI system can be made with the following equation:

$$A = (0.250)(Q)/(L)(P)$$

Where: A = RI treatment area in acres; Q = wastewater flow, gal/d; L = annual hydraulic loading into the basin, ft/yr (typical range 6-90 m [20-300 ft]; higher values for coarse soils and secondary treated wastewater); P = number of weeks per year the system is operated.

If the RI system operates on a year-round basis, the equation reduces to:

$$A = (0.0048)(Q)/(L)$$

This is an estimate of the basin treatment area. The total site area would also include dikes and berms, access roads, etc.

Design of an RI basin must include mechanical equipment. Typical equipment associated with RI systems includes distribution piping or troughs, pumps, underdrain piping (if used), well piping and pumps (if used), and storage tanks or lined basins (if needed). Sprinklers or pumped groundwater recovery will require appropriate energy sources.

PERFORMANCE

RI systems produce effluent of excellent quality with sufficient travel distance through soil. The use of primary versus secondary level influent influences the hydraulic loading rate but not the expected performance of the system. Table 2 shows expected removal percentages for typical pollution parameters using RI.

OPERATION AND MAINTENANCE

RI has excellent reliability. With proper operation and management, several systems in the northeastern United States have operated continuously for more than 50 years without problems.

Operation

Preapplication treatment can be used to reduce the concentration of excess solids in the wastewater prior to introduction of the wastewater into the RI basin. Use of secondary effluent will allow a higher hydraulic loading rate and therefore a smaller RI basin system. RI basins receiving influent at high application rates from algal laden facultative lagoons and polishing ponds often experience rapid clogging.

Proper operation of a RI system requires a periodic cycle of flooding and drying of each basin at the site. First, wastewater is added to a dry bed in the "flooding" stage. The length of the flooding stage is determined by the design infiltration rate and the treatment requirements. After the bed is flooded for the appropriate period, it is allowed to dry. During the drying stage, wastewater infiltrates into the soil or is evapotranspired into the atmosphere. The drying period is essential to restore aerobic conditions in the soil profile and to allow for desiccation and decomposition of the organic solid matter retained on the soil surface. The drying period can range from several hours to several

TABLE 2 EFFLUENT QUALITY

Parameter	Percent Removal
BOD_5	95 to 99 percent
TSS	95 to 99 percent
TN	25 to 90 percent
TP	0 to 90 percent
Fecal Coliform	99.9 to 99.99+ percent

Source: Crites, et al., 2000.

weeks depending on the flooding period selected and the type of wastewater applied. Typically, the drying period is at least equal to the flooding period and may be twice as long. In cold climates, the drying period may be extended and the flooding period shortened during the winter months to compensate for the lower rate of treatment during that season.

Maintenance

The same maintenance requirements used at any earthen basin are applicable to RI systems. Special requirements for RI systems pertain to preserving the design infiltration capacity of the basins. The operator should perform daily inspections and record drainage time for the basins so that the infiltration rate can be tracked. Restoration of the infiltrative surface may be necessary when the infiltration rate decreases. Accumulated organic deposits are typically removed at least annually, and the infiltration surface is raked, disked or tilled to restore infiltration capacity. On a more extended interval, it may be necessary to remove the top few inches of soil to expose clean material. These maintenance activities should only occur when the basin bottom is dry to avoid soil compaction. Dikes and berms should also be monitored for signs of decay or erosion.

COSTS

With suitable soil and hydrogeologic conditions, RI systems can produce a percolate that is essentially equal in quality to that produced by more conventional advanced wastewater treatment processes, at a fraction of the cost. General equations for estimating preliminary costs for construction and O&M of RI systems are shown in Table 3. The following assumptions were made in developing the equations:

- Costs are based on May 2001 data (ENR Index 6318).
- Basin construction costs include field preparation, no seasonal storage, assumed hydraulic loading of 60 m/yr (200 ft/yr) [61 $m^3/m^2/yr$ (1496 $gal/ft^2/yr$),] gravel service roads, and stock fence around site perimeter.
- O&M includes the annual tillage of infiltration surfaces, and the repair of dikes, fences, and roads every 10 years.
- Construction for underdrained case also includes drain pipes at 2.5 m (8 ft) depth on 120 m (400 ft) spacing, with drains connecting to an interception ditch at the edge of the site.
- Construction of the recovery well case includes gravel packed well, vertical turbine pumps, simple shelter over well, and a 15 m (50 ft) vertical pumping head.
- Special O&M for underdrains includes jet cleaning of pipes every five years, and annual cleaning of interceptor ditch.
- Equations in Table 3 are valid for up to 3785 m^3/d (10 MGD) wastewater flow and use the following notation: C = costs in million of dollars; Q = wastewater flow in MGD.

Costs of preliminary treatment, monitoring wells, and transmission from preliminary treatment facility to the RI site are not included.

TABLE 3 COST ESTIMATION EQUATIONS

Construction ($)	Operation and Maintenance ($)
Case I Rapid Infiltration - No Underdrains, No Recovery Wells	
$C=0.580(Q)^{0.888}$	$C=0.054(Q)^{0.756}$
Case II Rapid Infiltration with 50 ft Deep Recovery Wells	
$C=0.597(Q)^{0.857}$	$C=0.058(Q)^{0.756}$
Case III Rapid Infiltration with Underdrains	
$C=0.683(Q)^{0.886}$	$C=0.075(Q)^{0.641}$

Source: Crites, et al., 2000

REFERENCES

Other Related Fact Sheets

Slow Rate Land Treatment
EPA 832-F-02-12
September 2002

Other EPA Fact Sheets can be found at the following web address:
http://www.epa.gov/owm/mtb/mtbfact.htm

1. Crites, R. W. and G. Tchobanoglous, 1998. Small and Decentralized Wastewater Management Systems. McGraw Hill.

2. Crites, R. W., S. C. Reed, and R. K. Bastian, 2000. Land Treatment Systems for Municipal and Industrial Wastes. McGraw-Hill.

3. Satterthwaite Associates, Inc., 2003. Internet site at http://www.wbsatterthwaite.com/ accessed August, 2003.

4. U.S. EPA, 1980. Innovative and Alternative Technology Assessment Manual. U.S. EPA MERL, Cincinnati, Ohio.

5. U.S. EPA, 1981. Process Design Manual: Land Treatment of Municipal Wastewater. U.S. EPA CERI, Cincinnati, Ohio.

6. U.S. EPA, 1984. Process Design Manual: Land Treatment of Municipal Wastewater, Supplement on Rapid Infiltration and Overland Flow. U.S. EPA CERI, Cincinnati, Ohio.

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