United States
Environmental Protection
Agency

Wastewater Technology Fact Sheet

Rock Media Polishing Filter for Lagoons

DESCRIPTION

Rock filters are often used to remove algae from lagoon effluents. These systems consist of submerged beds of rocks, 75 to 200 mm (3 to 8 in) in size, through which lagoon effluent is passed horizontally or vertically. Vertical flow rock filters generally provide the highest level of performance.

In rock filters, algal solids are expected to settle on or become attached to the rock where biologically active surfaces induce decomposition. Well designed systems can usually produce a final effluent with 5-day biochemical oxygen demand (BOD_5) and total suspended solids (TSS) concentrations of less than 30 mg/L. Rock filters are neither as successful nor as reliable in the removal of ammonia (NH_3-N) as other methods of filtration. Nonetheless, their low cost and simple operation make them attractive for small communities that are not subject to ammonia limits.

The concept of the rock filter was developed in Kansas in the early 1970s. There are about 20 operating systems in the United States with most constructed between 1970 and 1985. The design flow of these operational systems ranges from 150 to 19,000 m^3/d (0.04 to 5.0 MGD). New applications of the rock filters have diminished in recent years based on the problems with ammonia removal and the emergence of constructed wetlands to upgrade lagoon performance.

Most rock filter operating systems were designed for horizontal flow with the rock bed placed at or near the effluent end of the final cell in the lagoon system. In general, vertical flow systems, such as ones located in Veneta, Oregon and West Monroe, Louisiana, perform better than horizontal flow systems. In some systems, effluent is collected by a manifold buried in the rock bed while in other systems effluent is discharged from an open water area on the downstream side of the filter bed. Significant after growth of algae has been observed when open water downstream of the discharge is used. It is better to discharge the effluent without exposure to sunlight, but this may be difficult where reoxygenation is required before discharge. Filter beds typically extend about 0.3 m (1 foot) above the maximum water level. Hydraulic loadings range from 250 to 1,200 L/m^3 d (2 to 9 gal/ft^3 d). Hydraulic loading rates that exceed 250 L/m^3 d of media (1.9 gal/ft^3 d) do not appear to provide the consistent effluent quality observed at Veneta, Oregon.

Common Configurations

The most common configuration for rock media polishing is the horizontal flow system. If constructed within an existing lagoon, the configuration depends in part on the location of the effluent pipe. Vertical flow systems as well as some horizontal flow systems have been constructed in a separate basin. For example, a configuration used in Illinois provides open water zones in the horizontal flow bed. Aerators are then placed in these open water zones to increase dissolved oxygen levels in the water flowing through the bed. The Illinois designs produced wide variations in effluent quality.

APPLICABILITY

The rock filter may find continued use for low-cost, low-maintenance polishing of wastewater treatment lagoon effluents. The Veneta, Oregon system produced an effluent of 30 mg/L (or less) BOD and TSS for more than 20 years, but the process will not reliably remove ammonia. In many cases, ammonia concentrations in the final effluent exceed that in the influent to the rock filter. This is due to the anaerobic decomposition of the algae trapped in the bed. This is a seasonal response, with the highest loss of ammonia occurring during the warmest summer months.

The systems in Oregon and West Monroe, Louisiana, are designed as upflow vertical filter beds. Influent is delivered to a buried perforated pipe along the center line of the filter basin and effluent is collected in weirs on the side of the bed, near the top of the rock surface. The Louisiana system has a filter bed 1.8 m (6 feet) deep composed of rocks 50 to 120 mm (2 to 5 in) in size. Pumps deliver the lagoon effluent to the rock filter at an average rate of 400 L/m^3 d (3.0 $ga./ft^3$ d) of media. The hydraulic loading rate at the Oregon system was 250 L/m^3 d of media which is much lower than the 400 L/m^3 d of media hydraulic loading rate used at the Louisiana system. This difference in loading rate may be related to the more consistent effluent quality observed at the Oregon system.

ADVANTAGES AND DISADVANTAGES

Some advantages and disadvantages of rock filters are listed below:

Advantages

- Provides a method to improve some aspects of facultative lagoon effluent at the lowest possible cost.
- Simple operation and low costs are attractive to small communities that do not face ammonia limits.
- Provides low maintenance polishing of wastewater treatment lagoon effluents.

Disadvantages

- Significant ammonia (NH_3-N) removal should not be expected. In some cases, ammonia content may be increased.
- The process is impractical for communities with strict ammonia limits.
- The final effluent ammonia concentration can exceed that in the influent to the rock filter.
- Many designs have not been able to consistently or reliably meet a 30 mg/L discharge standard for BOD and TSS.
- Rock filters may accumulate a heavy concentration of slime and *Psychoda* fly larvae.
- No provisions exist for cleaning rock filters.

DESIGN CRITERIA

While systems have been in operation for about 20 years, there is still no consensus on design procedures. There are no equipment requirements for operation of a typical horizontal flow rock filter bed. Vertical flow beds may require a pump for influent delivery to the filter bed. A 25 L/s (400 gpm) pump was used at the 760 m^3/d (200,000 gallon per day) system in Oregon.

State of Illinois

The State of Illinois Department of Environmental Protection published a set of guidelines for the design of horizontal flow rock filters, but performance has varied widely, perhaps because allowable hydraulic loading rates are too high. Based on the successful operation of rock filters with hydraulic loading rates of less than 250 L/m^3 d of media (2 gal/ft^3 d), it appears prudent to design systems accordingly.

Hydraulic loading rate: 800 L/m^3 d (6 gal/ft^3 d). It should be noted that hydraulic loading rates of less than 250 L/m^3 d of media provide better and more consistent effluent quality.

Rock Characteristics: 75 to 150 mm (3 to 6 in) diameter. Rock should be free of fines, soft-weathering stone, and flat rock.

Bed Depth: Top of bed must extend 0.3 m (one foot) above maximum water surface.

Post Aeration: Typically required to meet dissolved oxygen discharge limits.

Disinfection: If required by discharge permit.

Veneta, Oregon

Design data from the 760 m^3/d (200,000 gallons per day) vertical flow rock filter in operation in Veneta, Oregon include:

Hydraulic loading rate: 0.29 cubic meters per day per cubic meter (2.2 gallons per day per cubic foot).

Pump Capacity: 25 L/s (400 gpm).

Rock Size: 75 to 200 mm (3 to 8 in).

Bed Porosity: 42 percent.

Operations

With horizontal flow through the filter media, pumps and their related energy requirements may not be required. Pumps are usually necessary for vertical up-flow type filter beds. Energy requirements depend on site-specific factors.

PERFORMANCE

In general, rock filter systems perform adequately; however, effluent from these systems occasionally exceeds 30 mg/L BOD and TSS. The Veneta, Oregon, system has performed consistently better than the Louisiana system with respect to these parameters. The only difference between these systems is the hydraulic loading rate. The Oregon system received 200 L/m^3 d (1.9 gal/ft^3 d) while the Louisiana system received 290 L/m^3 d (2.7 gal/ft^3 d). Thus, the better performance in Oregon may be attributable to the lower hydraulic loading rate.

Overall, rock filters can provide effective BOD and TSS removal most of the time. The low cost and ease of operation also make them attractive for non-critical applications.

Limitations

A major limitation of rock media polishing filters is their capability to meet a consistent 30 mg/L discharge standard for BOD and TSS. After an extensive study of rock filters in Illinois, the states concluded that such systems could meet an effluent limitation of 30 mg/L BOD and 37 mg/L TSS. The Illinois study also found that rock characteristics were very important. Flat rocks, excess fines, soft-friable rocks, and rock sizes of less than three inches in diameter should all be avoided to prevent plugging problems. If stringent ammonia limits prevail, presently designed rock filters may not produce an acceptable effluent.

OPERATION AND MAINTENANCE

Residuals generated

Inorganic solids, biological slime, and non-degradable residues of biological activity will accumulate in void spaces in the filter bed. The rate of accumulation depends on remaining biological activity and transport of inert materials. The frequency of plugging varies from every few years to never. Provisions for cleaning do not exist in present systems. In the worst case, it might be necessary to remove the rock media, dredge out accumulated detritus, and replace the rock.

COSTS

Construction costs include excavation when necessary, rock placement, inlet and outlet piping, land and pumps, for vertical flow beds. Operation and maintenance (O & M) costs are minimal for both horizontal and vertical flow beds. Power and pump maintenance costs are additional expenses for vertical flow type beds.

REFERENCES

Other EPA Fact Sheets can be found at the following web address:

http://www.epa.gov/owm/mtb/mtbfact.htm

1. Middlebrooks, E.J., September 1988. *Review of Rock Filters for Upgrade of Lagoon Effluents.* Journal WPCF, 60(9), 1657-1662.

2. Middlebrooks, E. J., December 1995. *Upgrading Pond Effluents: An Overview*. Water Research, 31 (12), 353-368.

3. Reed, S.C., et al., 1995 2nd Ed. *Natural Systems for Waste Management and Treatment*. McGraw Hill Book Co., New York, NY.

4. U.S. EPA, 1983. *Design Manual - Municipal Wastewater Stabilization Ponds*. EPA - 625/1-83-015, US EPA CERI, Cincinnati, OH.

5. WPCF, 1990. MOP FD-16, *Natural Systems for Wastewater Treatment*. WPCF, Alexandria, VA.

ADDITIONAL INFORMATION

Richard H. Bowman, P.E.
West Slope Supervisor
Colorado Dept of Public Health and Environment
Water Quality Control Division
222 South 6th Street, Room 232
Grand Junction, CO 81502

E. Joe Middlebrooks, Ph.D., P.E., DEE
Environmental Engineering Consultant
360 Blackhawk Lane
Lafayette, CO 80026-9392

Sherwood Reed
Principal
Environmental Engineering Consultants (EEC)
50 Butternut Road
Norwich, VT 05055

Office of Water
EPA 832-F-02-023
September 2002

For more information contact:

Municipal Technology Branch
U.S. EPA
1200 Pennsylvania Avenue, NW
Mail Code 4204M
Washington, D.C. 20460