PDHonline Course C696 (2 PDH)

An Introduction to Trickling Filter Wastewater Treatment Plants

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(Figures, tables and formulas in this publication may at times be a little difficult to read, but they are the best available. **DO NOT PURCHASE THIS PUBLICATION IF THIS LIMITATION IS UNACCEPTABLE TO YOU.)**

1. GENERAL CONSIDERATIONS. Trickling filter plants have been justified by their low initial cost, low operating and maintenance costs, and relative simplicity of operation. Although the effluent from trickling filter plants of earlier design was of poorer quality than that from activated sludge plants, the performance of trickling filters designed more recently is comparable to that of activated sludge plants. Both processes offer certain advantages, with trickling filters providing good performance with minimal operator care and few, if any, energy requirements.

2. DESIGN BASIS AND CRITERIA. The designer will provide preliminary and primary treatment ahead of the filters, and circular or rectangular settling tanks with mechanical sludge removal equipment following the filters. Design criteria for settling tanks are discussed below. Chapter 4 of EPA*s process design manual, *Upgrading Existing Wastewater Treatment Plants*, provides design theory for trickling filters, as do published reports EPA-R-2-73-199. Table 1 gives design data for the trickling filter process. The designer normally will use the average of the hydraulic or organic loading ranges presented in table 1 for the design of each filter class unless special conditions warrant the use of values other than the average.

Item	Filter Classification: Low-Rate	Intermediate-Rate[3]	High-Rate	Super-Rate[3,4]
Hydraulic loading[1] gpd/sq ft	25-90	90-230[6]	230-690	690-3,440[6]
Organic loading[2] lbs BOD/day/1,000 cu ft	5-20	15-30	30-60	50-100
BOD Removal Efficiency, percent	75-85	70-85	70-85	30-70
Temperature coefficient, θ	1.02-1.06	1.02-1.06	1.02-1.04	1.02-1.04
Depth, ft	5-7	5-7	3-6	20-40
Recirculation ratio, R/Q	None	1:1 to 2:1	1:1 to 4:1[5]	1:1 to 4:1
Packing material	Rock, slag, random-placed plastic[8]	Rock, slag, random-placed plastic[8]	Rock, slag, plastic[7,8]	Plastic[7] or redwood
Dosing interval	Not more than 5 minutes	Not more than 5 minutes	Continuous	Continuous
Sloughing	Intermittent	Intermittent	Continuous	Continuous
Nitrification	Usually highly nitrified	Usually nitrified at lower loadings	Not fully nitrified	Not fully nitrified

[1] Hydraulic loading range rates based on plant average flow, expressed as gallons per day per square foot.

[2] Loading range (not including recirculation) to produce highest quality effluent after settling.

[3] This filter class will not be used without prior approval of HQDA (DAEN-MCE-U) WASH DC 20314 and HQ USAF/LEEEU WASH DC 20332.

[4] Also referred to as a roughing filter.

[5] Refer to Paragraph 10-2 for design recirculation rate.

[6] Includes recirculation flow.

[7] Stacked plastic media may be used when installed according to manufacturer's recommendations at proper depth.

[8] Random-placed plastic media.

Table 1

Design data and information for trickling filter processes

2.1 FILTER DEPTH. Stone media trickling filters will be designed with depths of 5 to 7 feet for low-rate and depths of 3 to 6 feet for high-rate applications. Synthetic media manufacturers recommend depths of 10 to 40 feet for columnar or stacked module media. Randomly placed polypropylene media filters are designed within the depth ranges of the low and intermediate-rate filters. The deeper trickling filters can improve nitrification potential and can be used as the second stage in two-stage biological system designs for nitrification.

2.2 RECIRCULATION. This is a recommended method of increasing the biochemical oxygen demand removal efficiency of high-rate trickling filter processes. Figure 1 shows acceptable recirculation systems for single-stage and two-stage trickling filters treating domestic wastewater. Table 2 lists recommended recirculation rates for high-rate filters. Whether to use recirculation and the amount to be recycled when used are matters of economics which may involve either first cost or annual costs of various designs providing equal treatment. Unless other conditions control, recirculation should provide continuous dosing at a minimum surface application rate of 10 million gallons per acre per day. In flow diagrams B, C and D (fig 1), fluctuations in the organic loading applied to the filter are dampened. Filter sloughings are recycled to the filter in flow diagram A but little, if any, dampening of variations in organic loading is provided. Flow diagram E may include a low- rate filter for the second stage unit. Intermediate settling tanks will always be provided between first and second stage filters. Flow diagrams G and H attempt to improve treatment by developing greater biological activity on the second stage filter but are not acceptable for military installations because there are no intermediate clarifiers. Flow diagrams E, F, G and H require inclusion of the recirculated flow in the forward flow used for design of any tanks through which it passes.

Single Stage

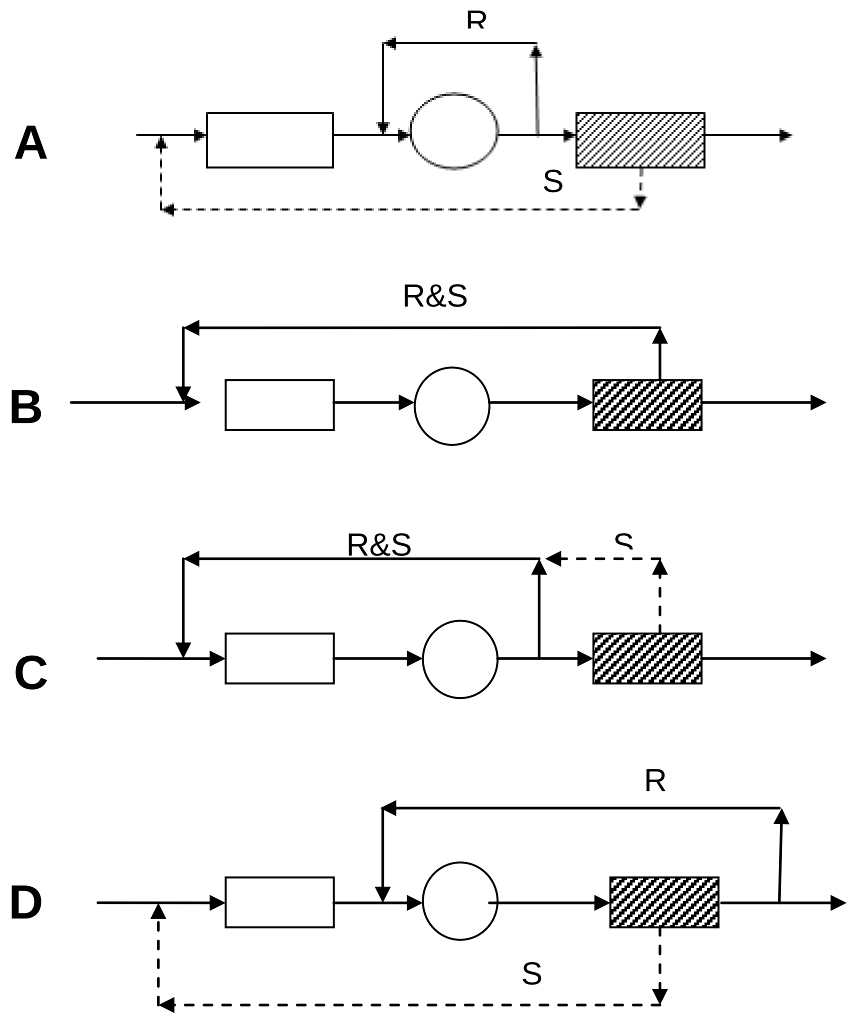

Figure 1

Common flow diagrams for trickling filter plants

Two stage

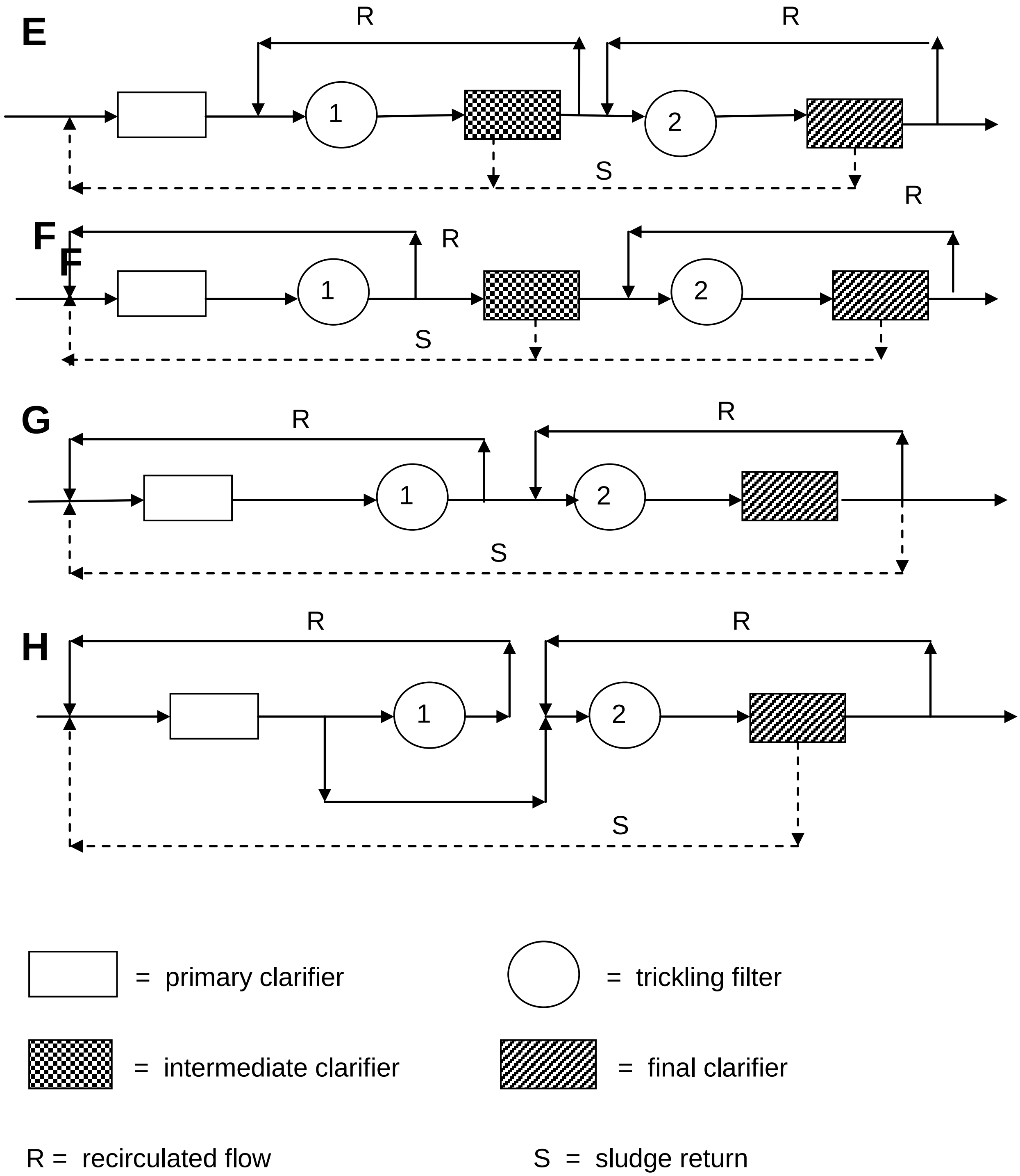

Figure 1 (continued)

Common flow diagrams for trickling filter plants

Raw Sewage BOD, mg/L	Recirculation[1] Single–Stage	Two–Stage[2]
Up to 150	1.0	0.5
150 to 300	2.0	1.0
300 to 450	3.0	1.5
450 to 600	4.0	2.0

[1] Ratio of recirculated flow to raw wastewater flow.
[2] Ratio for each stage; one half of the single–stage rate.

Table 2

Design recirculation rates for high-rate filters

2.3 HYDRAULIC AND ORGANIC LOADINGS. Loading rate is the key design factor whether the surface application is continuous, intermittent, constant rate, or varying rate. The BOD removal efficiencies obtainable for specific wastewater organic and hydraulic loading from typical trickling filter installations can be compared when the loadings are within the ranges presented in table 1 and the trickling filter performance formula described is utilized.

2.4 VENTILATION. Ventilation provides aerobic conditions required for effective treatment. Design for ventilation will provide the following:

— Underdrains and collecting channels designed to flow half full at maximum design flow;
— Ventilating manholes with open grate covers installed at both ends of the central collecting channel;
— Branch collecting channels with ventilating manholes or vent stacks installed at the filter periphery for units over 50 feet in diameter;
— Open area of slots in the top of the underdrain blocks not less than 15 percent of the area of the filter;
— Peripheral duct (or channel) interconnecting vent stacks and collecting channels;

— One square foot of gross area of open grating in the ventilating manholes and vent stacks for each 250 square feet of filter surface; and

— When the trickling filter is constructed with top of media or distributor arms at or near grade, with under-drain system more than 3 feet below grade or when normal climatic conditions do not include adequate air movement, ventilation shafts will be provided.

2.5 TEMPERATURE. The performance of trickling filters will be affected by temperature changes in the wastewater and filter films. Filter efficiency changes attributed to temperature variations are expressed by equation 1.

$$E_1 = E_{20} \text{ x } \quad ^{t\ 20} \qquad \text{(eq 1)}$$

where:

E_t = BOD removal efficiency at T^{o} C
E_{20} = BOD removal efficiency at 20^{o} C
θ. = Constant equal to 1.035
T = Wastewater temperature, ^{o}C

Winter conditions—In areas that experience prolonged cold and/or icing, windbreaks or dome covers for trickling filters to prevent freezing problems will be considered.

2.6 PLANT EFFICIENCIES. Performance efficiencies, given as biochemical oxygen demand removal, or singlestage and two-stage filters are to be estimated using formulas in the following section.

2.6.1 NATIONAL RESEARCH COUNCIL (NRC) FORMULAS. The NRC formulas have resulted from extensive analysis of operational records from stone-media trickling filter plants serving typical installations. Based on its data analyses, NRC developed the following formulas for predicting the stone-media trickling filter performance at 20 ^{o} C.

First of Single Stage:

$$E_1 = 100/(1 + 0.0085\ [W/VF]^{0.5} \qquad \text{(eq 2)}$$

Second Stage (includes intermediate clarifier):

$$E_2 = 100/(1 - 0.0085/\{1 – E_1\ [W/VF]^{0.5}\} \qquad \text{(eq 3)}$$

where:

E_1 = Percent BOD removal efficiency through the first or single-stage filter and clarifier;
W = BOD loading (lb/day) to the first or single-stage filter, not including recycle;
V = Volume of the particular filter stage (acre-ft);
F = Recirculation for a particular stage, where:

$$F = (1+R)/(1+0.1R)^2$$

R = Recirculation ratio = (recirculation flow/plant influent flow);
E_2 = Percent BOD removal through the second-stage filter and clarifier;
W' = BOD loading (lbs/day) to the second-stage filter, not including recycle.

2.6.2 OTHER DESIGN FORMULAS. Other design formulas have been developed and used for design of trickling filters and for performance prediction. Such expressions include the Ten-States Standards Formula and those of Velz, Schulze, Germain, Galler and Gotaas, and Eckenfelder. Detailed descriptions and evaluations of these formulas are presented in the Manual of Practice No. 8, published by the Water Pollution Control Federation. Although the NRC formula is usually appropriate for design of stone-media filters, but check Manual of Practice No. 8 for stacked synthetic media filters.

2.7 ROUGHING FILTERS. This type of super-rate filter is generally used for very strong wastewaters and is not applicable to domestic wastewater treatment plants at some installations.

3. HYDRAULIC COMPONENTS.

3.1 INFLUENT DISTRIBUTORS. Rotary reaction distributors consisting of two or more horizontal pipes supported by a central column are available for dosing filter beds ranging from 20 to more than 200 feet in diameter. Distributors will be sealed by pressurized oil, neoprene gaskets or air-gap “non-seal” methods. Hydraulic head requirements for distributors are gradient usually 12 to 24 inches above the centerline of the distributor arms at minimum flow. Distributor design must provide: 1) a means for correcting alignment; 2) adequate structural strength; 3) adequate pipe size to prevent velocities in excess of 4 feet per second at maximum flow; 4) bearings; 5) drains for dewatering the inflow column; and 6) pipe and openings at the end of each arm for ease of removing ice buildups during winter operation. A minimum clearance of 6 inches between media and distributor arms will be provided. Motor-driven rotary distributors will be used only if the minimal hydraulic head to drive the distributor is not available. Positive drive will be provided by a totally enclosed electric motor and gear arrangement.

3.2 DOSING SIPHONS. Wastewater may be applied to the filters by pumps, by gravity discharge from preceding treatment units when suitable flow characteristics have been developed, and by siphons. Frequently during the day the flow will be less than the minimum set by the distributor. If this is the case, a dosing tank and alternating siphons will be required for each filter unit. Each siphon will have a dosing tank with a volumetric capacity equal to the average flow rate for a 4-minute period so that dosing is nearly continuous.

3.3 HEAD LOSS COMPUTATIONS. The net available head on the horizontal centerline of the distributor arms will be calculated by deducting the following applicable losses from the available static head:

- Entrance loss from the primary settling tank.

- When using dosing siphons: the drop in tank level dosing as distributor pipes are filled; the friction losses in the siphon itself; and the velocity head imparted from the siphons.
- Friction losses in piping and fittings.
- Loss through distributor column rise and center port.
- Friction loss in distributor arms and velocity head of discharge through nozzles necessary to start reactor- type rotary distributors in motion.

The hydraulic head requirements of distributors are specified by the manufacturers. The major head loss is the elevation difference between the distributor arms and the lowest water surface in the main underdrain channel. Approximately 8 feet of head is lost in a 6-foot deep filter. Detailed computations and charts for head losses in pipes are available in the technical literature.

4. SECONDARY SEDIMENTATION TANKS. The purpose of secondary sedimentation tanks is to allow the biological solids in the wastewater leaving the trickling filter to settle out. This produces an effluent for discharge, and the settled solids can be recirculated to the trickling filter to enhance its performance.

4.1 DESIGN PHILOSOPHY. The tanks will be designed for either the average daily flow rate or the daily flow equivalent to the peak 3-hour flow rate, whichever is greater. All of the appurtenant piping, channels, inlets, outlets and weirs will be designed to handle the peak flow rate. If there are no data for peak flow rates available, then a value of 3 times the average flow rate will be used. Two tanks, operating in parallel, will be used in all treatment plants with a design capacity greater than 0.1 million gallons per day. Each tank will be designed to treat 67 percent of the design flow. A single tank may be used in treatment plants with design capacity less than 0.1 million gallons per day but an equalization tank or holding basin must be provided to provide some settling capacity for those times when the secondary sedimentation requires maintenance.

4.2 DESIGN CRITERIA. The sedimentation tanks should be designed for either the average flow rate or peak flow rate, whichever requires the largest surface area. The following table presents the design criteria for various size treatment plants:

Plant Design Flow mgd	Surface Loading Rate Average Flow	gpd/sq ft Peak Flow
0.00– 0.01	100	200
0.01– 0.1	300	500
0.1 –1.0	400	600
1.0 –10.0	500	700
above 10	600	800

Table 3

Surface loading rates for secondary sedimentation tanks

Note that the surface area calculated from table 3 must sometimes be increased to allow for inlet and outlet inefficiencies.

Filter Component	Design Requirement
Underdrains	The underdrains will have a minimum slope of 1 percent. Use the larger size openings for high rate filters.
Drainage Channel	Either central or peripheral drainage channels will be used. The channels will be designed to provide 2 feet per second minimum velocity at the average daily application rate to the filter and so that no more than 50 percent of their cross-sectional area will be submerged under the design hydraulic loading.
Wind Break* (if utilized)	The windbreak will be constructed on the side of the prevailing winter wind. Its length will be three filter diameters for each filter diameter it is located away from the filter's near edge. Its height will be a minimum of 10 feet above the surface of the filter, plus an additional 0.1 times the filter diameter for each filter diameter it is located away from the filter's near edge.
Dome Cover (if utilized)	Consult approved manufacturers.

Table 4

Miscellaneous filter component design criteria

5. OTHER FILTER COMPONENTS. Table 4 gives a list of other components normally associated with trickling filters and for which design requirements are specified. Trickling filter design must include provisions for flooding the filter and the filter walls, and appurtenances must be able to structurally withstand the resulting hydrostatic pressure forces when the filter is flooded. In northern regions that are subject to extreme and/or prolonged freezing conditions, including high wind chill factors, design considerations must be given to providing filter dome covers or windbreaks. Figure 2 is a sectional view of a trickling filter.

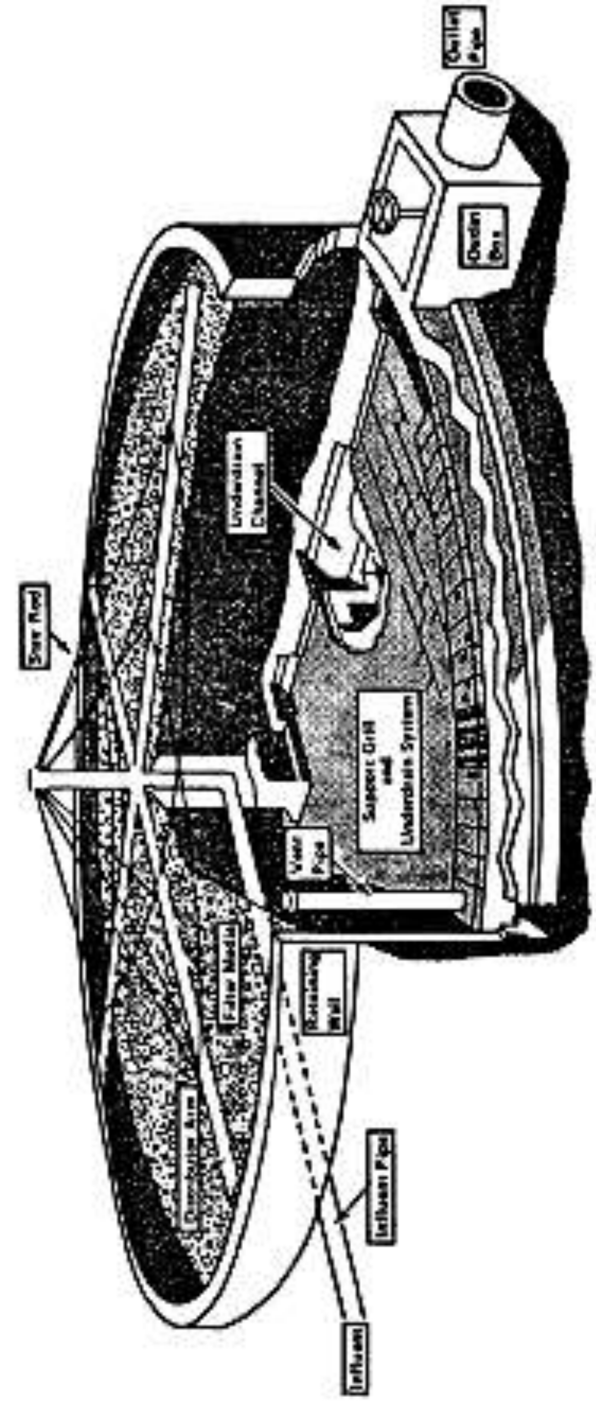

Figure 2

Trickling filter sectional view

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TM 5-814-6 Industrial Wastes

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625/1-75-003a Process Design Manual for Suspended Solids Removal (Jan 75)

625/1-76-001a Process Design Manual For Phosphorus Removal (Oct 71)

625/1-80-012 Process Design Manual for Onsite Wastewater Treatment and Disposal Systems (Oct 80)

625/1-81-013 Process Design Manual for Land Treatment of Municipal Wastewater (Oct 81)

625/1-82-014 Process Design Manual for Dewatering Municipal Wastewater Sludges (Oct 82)

625/1-83-015 Process Design Manual for Municipal Wastewater Stabilization Ponds (Oct 83)

Process Design Manual for Carbon Absorbtion (Oct 73)

Process Design Manual for Nitrogen Control (Oct 75)

Process Design Manual for Upgrading Exist-Wastewater Treatment Plants (Oct 75)

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6666 West Quincey Avenue, Denver CO 80235

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