Lagoons are generally rectangular in shape though it is not absolutely essential. Natural land contours may be followed to the extent possible to save on earthwork. Lagoon units may be built with different length-width ratios and arrangement of internal baffles to promote desired mixing conditions. Lagoons may also be provided as two or three stage systems with the subsequent units placed at a lower level than the first if desired.

Construction techniques for aerated lagoons are similar to those used in case of oxidation ponds with earthen embankments. Pitching of the embankment is desirable to protect it against erosion. In cases where soil percolation is expected, suitable lining may have to be provided to maintain the design level in the lagoon and avoid ground water pollution.

13.6.2 Substrate Removal Rates

As shown in Table 13.2 for facultative aerated lagoons the overall substrate removal rate K for sewage varies from 0.6 - 0.8 per day (soluble BOD basis) at 20 deg. C. At other temperatures in lagoons the values are obtained from:

$$(K)_{T°C} = (K)_{20°C} \times (1.035)^{T-20} \qquad (13.12)$$

The temperature in a lagoon TL is estimated from the following equation:

$$\frac{\Theta}{h} = \frac{T_i - T_L}{f\,(T_L - T_a)} \qquad (13.13)$$

in which Θ = detention time, days, h = depth of lagoon, meters, while T_i and T_a are the temperatures (°C) of influent wastewater and ambient air respectively and the heat transfer coefficient f = 0.49 m/day for aerated lagoons. The average winter month temperature is critical for determining the detention time required. As stated earlier, the detention time to be provided in a lagoon can be determined from Eq.13.11 or Fig 13.4 for any desired efficiency for the computed temperature and mixing conditions in the lagoon.

13.6.3 Power Level

The power input in facultative aerated lagoons has to be adequate only to diffuse dissolved oxygen uniformly in the system; no effort is made to keep the solids in suspension. Hence, a minimum power level of 0.75 Watts per cu.m lagoon volume should be adequate, but this should be checked with the aeration equipment supplier for its oxygenation characteristics and compatibility with proposed depth and shape of lagoon.

For treating domestic sewage the power requirement varies from 12 - 15 kWh/person/year or 2 - 2.5 HP per 1000 population equivalent. The oxygenation capacity of aerators is reported to range from 1.87 to 2.0 kg. Oxygen/kWh at standard conditions for power delivered at shaft. Spacing of aerators should be adequate for uniform aeration all over the lagoon area without much overlap of the circle of influence of adjoining aerators as specified by the manufacturers. A minimum of two aerators would be desirable to provide to make up the total power requirement.

Aerators ranging from 3 HP to 75 HP are now readily available in the country. They can be either floating or fixed type. Floating aerators are mounted on pontoons (which should be corrosion-free). They have the advantage of being able to adjust themselves to actual levels obtaining in the lagoons due to seepage and/or fluctuating inflows. Fixed aerators are mounted on structural columns and carefully levelled with regard to the outlet weir level to ensure required submergence of aerator

blades to give the design oxygenation capacity.

13.6.4 Effluent Characteristics

The effluent is generally made to flow over an outlet weir. As the concentration of solids passing out in the effluent may be nearly the same as that in the lagoon the BOD corresponding to the volatile fraction of these solids (assumed as 0.77 mg per mg VSS in effluent) should be added to the value of the soluble BOD, S, obtained by use of Eq.13.11 or Fig.13.4. Thus, the final effluent BOD is given by:

Final BOD, mg/l = S, mg/l + (0.77) (VSS in effluent), mg/l

It is because of the suspended solids (expected to range from 40 to 60 mg/l in case of domestic sewage) in the final effluent that the total effluent BOD is difficult to reduce below 30 - 40 mg/l in winter. At other times of the year BOD less than 30 mg/l may be possible. This range of BOD is more than adequate for irrigational purposes, but for river disposal the applicable standards should be ascertained and design made accordingly. Where necessary, further reduction of BOD can be achieved either by a small increase in detention time or by more efficient interception of solids flowing out (e.g. deeper baffle plate ahead of outlet weir) or by provision of an additional treatment unit.

Nitrification is not likely to occur in aerated lagoons. Coliform removal shows considerable seasonal variation (60 - 90% removal).

13.6.5 Sludge Accumulation

Sludge accumulation occurs at the rate of 0.03 - 0.05 cu.m per person per year as in the case of oxidation ponds and is manually removed once in 5 - 10 years and used as good agricultural soil. The depth of the lagoon may be increased a little to allow for sludge accumulation, if desired.

13.7 CONCLUSION

The removal efficiencies in terms of power input are comparable to some of the other aerobic treatment methods seen earlier in this chapter but the greatest advantage with aerated lagoons lies in their simplicity and ruggedness in operation, the only moving piece of equipment being the aerator. Civil construction mainly entails earthwork, and land requirement is not excessive.

AEROBIC ATTACHED GROWTH SYSTEMS

CHAPTER 14

AEROBIC ATTACHED GROWTH SYSTEMS

14.1 GENERAL CONSIDERATIONS

Biological unit processes are broadly classified as suspended growth systems or attached growth systems depending on whether the microbial population remains suspended in the liquid medium or attached to inert support medium. Bioreactors in which biomass grows attached to inert medium such as rocks, slag or specially designed ceramic, plastic material or synthetic materials under aerobic conditions constitute aerobic attached growth systems. Trickling Filters and Rotating Biological Contactors are examples of such systems. These systems, also referred to as fixed film reactors, have been widely employed for removal of organic pollutants and for nitrification.

14.2 TRICKLING FILTERS

Trickling filters are used for the biological treatment of domestic sewage and industrial wastes which are amenable to aerobic biological processes. They find use for complete treatment of moderately strong wastes and as roughing filter for very strong wastes prior to activated sludge units. Trickling filters possess a unique capacity to handle shock loads and provide dependable performance with a minimum of supervision.

The trickling filter consists of a permeable bed of medium through which the sewage or liquid waste is allowed to percolate. The materials used as filter medium include crushed or broken rock, gravel, blast furnace slag or inert synthetic materials such as plastics and ceramics. Randomly packed solid media like rock, gravel and slag are characterised by lower porosities (40-60%), lower specific surface areas (40-70 m^2/m^3) and lower depths of 0.9 to 2.5 m. Plastic media of various shapes possess very high porosities (94-97%), and higher specific surface areas (80-200 m^2/m^3). While conventional filters usually employ rocks, gravel and slag as filter medium, plastic media are generally used in super rate filters which operate at much higher hydraulic and organic loading rates and are much deeper (upto 12 m) compared to conventional filters. The deep filters containing plastic media are referred to as biotowers and have been used for both domestic and strong industrial wastewaters. The trickling filters may be generally circular but square or rectangular shapes may also be used. The sewage is evenly distributed on the surface of filter medium and the treated effluent is collected by the underdrains.

The trickling filter is preceeded by primary sedimentation so that the settleable solids in the sewage may not clog the filter. The sedimentation tanks should have skimmers to remove the scum. The trickling filter is always followed by a final settling tank to remove from the filter effluent the settleable organic solids produced in the filtration process. In some cases, it may be advantageous to provide skimming devices for the final settling tanks also. The trickling filter serves both to oxidise and bioflocculate the organic material in sewage and their efficiency is assessed on the total reduction in BOD effected through the filter and the subsequent settling tank, since the effluent quality is reckoned after the settlement of the bioflocculated solids.

14.2.1 Process Description

As the wastewater trickles through the filter media, biomass grows attached to the media surfaces, normally in a period of two weeks, making the filter ready for operation. During operation, the organic material present in wastewater is metabolised by the biomass attached to the contact medium. The attached biomass is referred to as the biological film or slime layer. The biological slime grows in thickness as the organic matter abstracted from the flowing wastewater is synthesized into new cellular material. The grown slime layer which usually has a total thickness between 0.1 and

2.0mm consists of both aerobic and anaerobic layers. The thickness of the aerobic layer is limited by the depth of penetration of oxygen into microbial layer which depends upon the coefficient of diffusivity of oxygen in the film, the concentration of oxygen at the solid-liquid interface and the overall oxygen utilization rate of microorganisms present in the slime layer.

Utilisation of substrate by the micro-organisms results in increased thickness of the slime layer and the organic matter removed from wastewater is metabolised before it can reach the microorganisms near the medium face. As a result of having no external organic source available for cell carbon, the microorganisms near the media face enter into endogenous phase of growth and loose their ability to cling to the media surface. The liquid then washes the slime off the medium and a new slime layer starts to grow. This phenomenon of losing the slime layer is called sloughing'.

The sloughed off film and the treated wastewater are collected by an underdrainage system which also allows circulation of air through filter. The collected liquid is passed to a settling tank used for solid-liquid separation.

Filter sloughing aids ventilation by keeping the filter medium open. It also continuously renews the biota, maintaining it active which is essential for the efficient functioning of the filter. The degree of filter sloughing will depend on the organic loading which will control the growth of the slime and the hydraulic loading which will influence its scour.

14.2.2 Types of Filters

Trickling filters may be categorised as low rate, high rate and super rate, primarily based on hydraulic and organic loading rates. Although there is no well demarcated practice, some important distinguishing design criteria and features for the three types of filters are presented in Table 14.1.

TABLE 14.1
DESIGN FEATURES FOR TRICKLING FILTERS

Sl.No.	Design Feature	Low Rate Filter	High Rate Filter	Super Rate or Roughing Filter
1.	Hydraulic loading, m^3/m^2. d	1 - 4	10 - 40 (including recirculation)	40 - 200 (including recirculation)
2.	Organic loading, kg BOD_5 / m^3. d	0.08 - 0.32	0.32 - 1.0 (excluding recirculation)	0.8 - 6.0 (excluding recirculation)
3.	Depth, m	1.8 - 3.0	0.9 - 2.5	4.5 - 12
4.	Recirculation ratio	.0	0.5 - 3.0 (domestic wastewater) upto 8 or more for strong industrial wastes	1 - 4
5.	Filter media	Rock, gravel, slag etc.,	Rock, slag, synthetic materials	Plastic media

The hydraulic loading rate is the total flow including recirculation applied on unit area of the filter in a day, while the organic loading rate is the 5-day 20^0 C BOD, excluding the BOD of the recirculant, applied per unit volume in a day. Much higher organic loadings than indicated above have been used in roughing filters.

Recirculation is not generally adopted in low rate filters. Media depths for low rate filters range from 1.8m to 3.0m . They require larger media volumes than high rate filters. However, they are easy to operate and give consistently good quality of effluent and are preferred when plant capacities are small as in the case for institutions.

In contrast to the low rate filters, in high and super rate filters a part of the settled or filter effluent is recycled through the filter. Recirculation has the advantage of bringing the organic matter in the waste in contact with the biological slime more than once, thus increasing the efficiency of the filters. It enables higher hydraulic loading and thereby reduces filter clogging and aids uniform distribution of organic load over the filter surface. It also helps to dampen the variations in the strength and the flow of sewage applied on the filter. The ratio of the recycled flow to the sewage flow is known as the recirculation ratio. Recirculation ratios usually range from 0.5 to 3 and values exceeding 3 are considered to be uneconomical in the case of domestic sewage but ratios of 8 and above have been used with industrial wastes and super high rate filters, may be single stage or two stage. Media depths of 0.9 to 2.5 m have been used for high rate filters with an optimum range of 1.5m to 2.0m for the first stage and 1 to 2m for the second stage filters. Single stage units consist of a primary settling tank, the filter, secondary settling tank and facilities for recirculation of the effluent. Various patterns of recirculation are given in (a), (b) and (c) of Fig.14.1 A.

Two stage filters consist of two filters in series with a primary settling tank, an intermediate settling tank which may be omitted in certain cases and a final settling tank. Recirculation facilities are provided for each stage. The effluent from the first stage filter is applied on the second stage filter either after settlement or without settlement. Some of the common flow diagrams are shown in Fig.14.1 B. In 14.1 B(a), an intermediate clarifier is used for settling the first stage effluent before it is applied to the second stage filter and the recirculation is only through the settling tanks. In 14.1 B(b) the intermediate settling is omitted and the recirculation flows are settled. In 14.1 B(c), which is known as the series-parallel system, part of the settled raw sewage is applied directly to the second stage filter increasing the efficiency of that stage. In 14.1 B(d), there is neither intermediate settling nor settling of filter effluent prior to recirculation.

Two stage filtration will provide a higher degree of treatment than the single stage for the same total volume of media. Two-stage units are used for strong sewage when the effluent BOD has to be less than 30 mg/l.

A well operated low rate trickling filter in combination with secondary sedimentation tank may remove 75 to 90 percent BOD and produce highly nitrified effluent. It is suitable for treatment of low to medium strength domestic wastewaters. The high rate trickling filter, single stage and two stage, are recommended for medium to relatively high strength domestic and industrial wastewaters. The BOD removal efficiency is around 75 to 90 percent but the effluent is only partially nitrified. The super rate or roughing filters find application for high-strength wastewaters. They have also been used as roughing filters to reduce the BOD of high strength wastewaters for further treatment. The effluent from these filters may be partially nitrified only when low organic loadings are employed.

14.2.3 Process Design

The rational design of any biological treatment unit is normally contemplated employing the Monod's equation and associated biokinetic coefficients as used in the design of completely-mixed activated sludge process. The evaluation of kinetic coefficients involves determination of microorganism concentration and the hydraulic flow pattern which have not yet been adequately and precisely evaluated. Therefore completely theoretical kinetic or mechanistic model has not been developed that will accurately predict filter performance due to the unstable characteristics of the slime layer and complex inter-relationships between process variables.

Various empirical design equations based on experience and analysis of data have been developed. These include Rankin's Equation, National Research Council (NRC) of Canada and Gotaas equation. Equations developed by Velz, Eckenfelder and Atkinson have been derived from principles governing the performance of trickling filter. The latter type of equations involves some constants which should be preferably evaluated by conducting laboratory/pilot plant studies. In case it is not possible to conduct experimental studies, empirical design equations may be used.

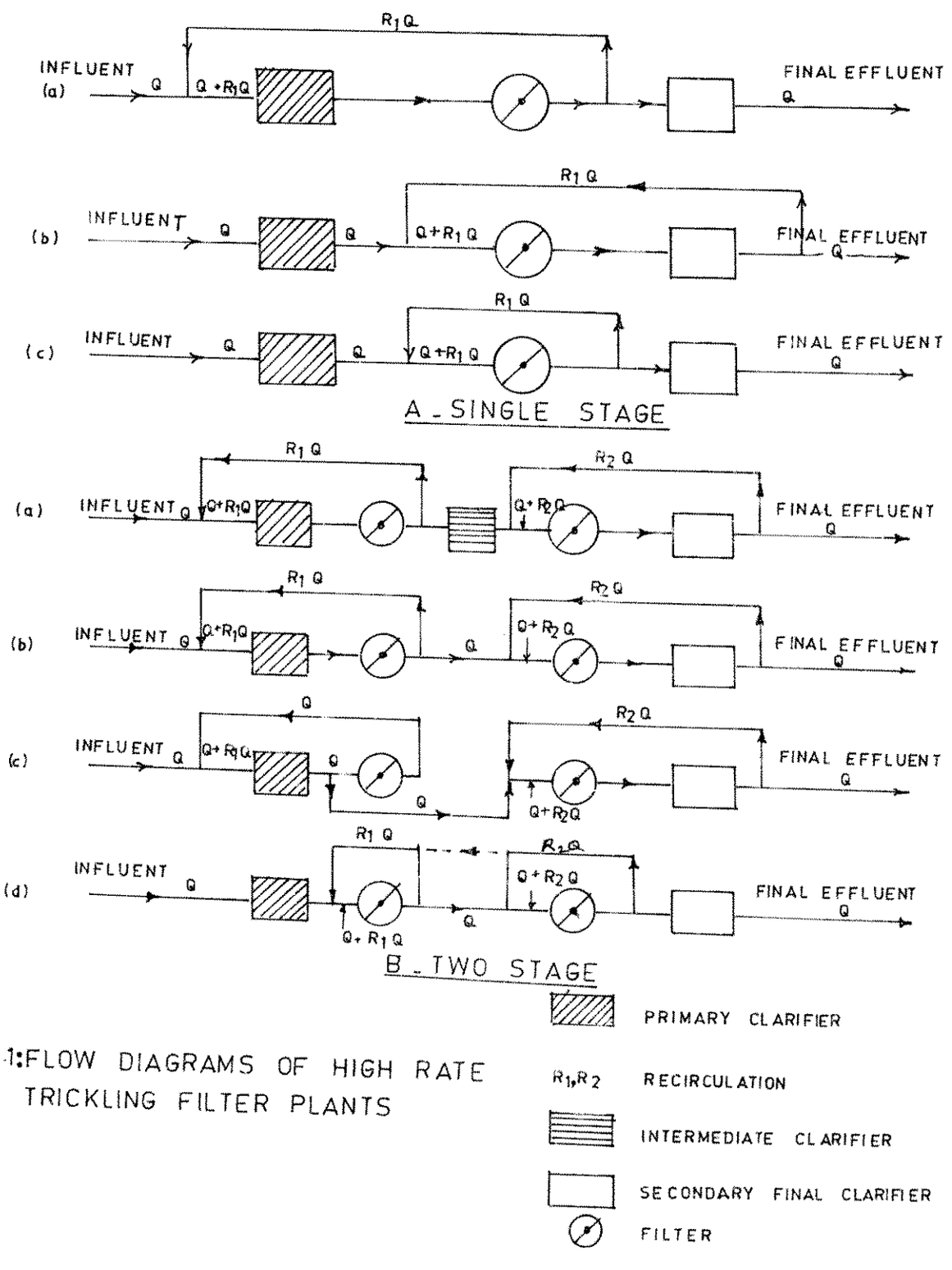

FIG.14.1:FLOW DIAGRAMS OF HIGH RATE TRICKLING FILTER PLANTS

14.2.3.1 RANKIN'S EQUATION

Rankin developed a set of equations for the performance of high rate filters of various flow diagrams based on the requirements of the Ten State Standards of U.S.A. The basic principle is that the BOD of the influent to the filter including recirculation shall not exceed three times the BOD of the required settled effluent.

14.2.3.2 NATIONAL RESEARCH COUNCIL (CANADA) EQUATION

The NRC equation for trickling filter performance are empirical expressions developed from a study of the operation results of trickling filters serving military installations in U.S.A. These equations are applicable to both low rate and high rate filters.

The efficiency of single stage or first stage of two stage filters E_2 is given by:

$$E_2 = \frac{100}{1+0.44\sqrt{\frac{W_1}{V_1F_1}}} \qquad (14.1)$$

For the second stage, the efficiency

$$E_3 = \frac{100}{1+\frac{0.44}{(1-E_2)}\sqrt{\frac{W_1(1-E_2)}{V_2F_2}}} \qquad (14.2)$$

$$= \frac{100}{1+\frac{0.44}{(1-E_2)}\sqrt{\frac{W_2}{V_2F_2}}}$$

Where

E_2 = percentage efficiency of BOD removal of the single stage or first stage of the two stage filter

E_3 = percentage efficiency of second stage filter

W_1 = BOD loading of settled raw sewage in the single stage or first stage of the two stage filter in kg/day

W_2 = $W_1 (1-E_2)$ = BOD loadind on second stage filter in kg/day

V_1 = Volume of first stage filter in m^3

V_2 = Volume of second stage filter in m^3

F_1 = Recirculation factor or number of effective passes for first stage filter

$$= \frac{1 + R_1}{[1 + (1 - f) R_1]^2}$$

R_1 = recirculation ratio for the first stage filter

f = treatability factor (0.9 for sewage),

F_2 = recirculation factor or number of effective passes for second stage filter

$$= \frac{1 + R_2}{[1 + (1-f)R_2]^2}$$ and

R_2 = recirculation ratio for the second stage filter.

14.2.3.3 ECKENFELDER EQUATION

Eckenfelder assumed that trickling filter can be represented as a plugflow reactor and that substrate utilisation follows the first order kinetics. He considered the effect of time of contact between wastewater and microorganisms through the measurable variables of depth of filter media and surface hydraulic loading as well as of microorganism concentration which is related to the specific surface area of the filter media and other factors. Eckenfelder's equation can be written as:

$$\frac{L_e}{L_o} = \exp\left[\frac{-K_o D}{(Q/A)^n}\right] \qquad (14.3)$$

Where

L_e - soluble BOD of filter effluent, mg/l

L_o - influent BOD (including recirculation), mg/l

K_o - treatability factor min^{-1}

D - filter media depth, m

Q/A - hydraulic surface loading $m^3/m^2.min$

n - constant

For design of trickling filter, treatability studies to evaluate the constant involved in the rational design equation such as those of Eckenfelder and Atkinson based on pilot plant model's performance are most desirable and should receive due attention especially with industrial wastewater treatment. A brief procedure to conduct treatability studies and to evaluate constant in Eckenfelder's approach is described in following paragraph.

A bench-scale cylindrical column (typical dimensions being 200 mm diameter, 2 m or more in height), preferably of plexiglass, having adequate number (minimum three) of sampling ports, is filled with filter medium. Suitable arrangements for feeding the wastewater at 3 to 4 hydraulic surface

loadings are made.

The filter is fed with wastewater to be treated to generate slime layer on the filter medium which may take from a few days to several weeks depending on the nature of the wastewater. The filter is operated at several hydraulic surface loadings by changing the flow rate and steady state effluent substrate concentration (BOD or COD) remaining at different depths is determined. Percent BOD (or COD) remaining versus sampling depths is plotted on semilog paper for each of the hydraulic loadings and the slope of each straight line is determined. A log-log plot of slope versus surface loading is drawn. The slope of the line gives the value of constant, n.

$$\frac{L_e}{L_o} = Exp[\frac{-K_o D}{(\frac{Q}{A})^n}]$$

or

$$2.303\log(\frac{L_e}{L_o}) = \frac{-K_o D}{(\frac{Q}{A})^n}$$

$$Slope = \frac{-K_o(\frac{Q}{A})^{-n}}{2.303}$$

or

$$\log(2.303 x slope) = -\log K_o - n\log(\frac{Q}{A})$$

A table of [D / (Q/A)^n] versus (L_e / L_o) x 100 for various values of D and (Q/A) is constructed and on a semilog graph paper (L_e / L_o) x 100 versus [D / (Q/A)^n] is plotted. The slope of the straight line gives the value of treatability factor, K_o.

The values of treatability factor, K_o, range from 0.01 to 0.1. Average values for municipal wastewater for filters using plastic media have been reported to be around 0.06 at 20° C. The coefficient n for plastic media, modular construction, can be assumed as 0.5 without significant error.

14.2.3.4 Applicability of the Different Equations

The Eckenfelder equation is based on rational approach as it considers the effect of specific surface area of filter medium and time of contact between wastewater and microorganisms. This approach is versatile and applicable to low rate, high rate and super rate filters using plastic media. The application of this equation requires that bench or pilot scale treatability studies should be conducted or the values of treatability factor, K, and constant n should be known. If it is not possible

to conduct treatability studies or values of K_s and n cannot be assumed, empirical equations may be used. However, considerably different filter volumes are obtained by using different empirical equations for any given situation. In general, Rankin's approach has been found to give fairly satisfactory results in Indian conditions. The NRC equations would seem to apply when recirculation is not considered, when seasonal variations in temperatures are not large and when sewage load is highly variable and of high strength.

14.2.4 Constructional Features

14.2.4.1 Shape of Filter

Filters may have circular, rectangular or square shape. If fixed nozzles or nozzles mounted on moveable arms are used for flow distribution, rectangular or square shapes are employed. For rotary distribution, circular shape is used. The circular shape also has the advantage of structural economy.

14.2.4.2 Provision for Filter Flooding

Provision for flooding the filters is useful for controlling filter flies and ponding. To enable flooding, the filter walls must be designed for the internal water pressure and the main collecting channel must be placed inside the filter and provided with gate valves. An overflow pipe leading from the filter to the main collecting channel down-stream from the gate valve is also necessary.

Provision for filter flooding should always be made in the case of small filters, especially the low rate filters. Such a provision in large filters would not only increase the cost but is also likely to cause hydraulic problems with the sudden discharge of large volumes of sewage when the flooded filter is drained. In such cases alternate methods may be required for controlling filter flies and ponding.

14.2.4.3 Filter Walls

Filter walls may be of reinforced concrete, brick or stone masonry or hollow concrete blocks. For flooding operation, reinforced concrete is preferred.

14.2.4.4 Filter Floor

The filter floor is designed to support the under-drainage system and the superimposed filter media. The usual practice is to provide a nominally reinforced cement concrete slab, 10-15 cm thick, over a proper levelling course. The floor should slope between 0.5 and 5% towards the main collecting channel. The flatter slopes are used in larger filters.

14.2.4.5 Under-Drainage System

The underdrainage system is intended to collect the trickling sewage and sloughed solids and to convey them to the main collecting channel and also to ventilate the filter media. The underdrains cover the entire floor of the filter to form a false bottom and consist of drains with semi-circular or equivalent inverts. They will be formed of precast vitrified clay or concrete blocks, complete with perforated cover or they may be formed insitu with concrete or brick and covered with perforated precast concrete slabs.

The slope of the underdrains should be the same as that of the floor. The drains shall be so sized that flow occupies less than 50% of the cross-sectional area with velocities not less than 0.6 mps at average design flow. The cover over the drains shall be perforated to provide a total area of inlet openings into the drains not less than 15% of the surface area of the filter. Underdrains may be open at both ends so that they may be inspected easily and flushed out if they become clogged.

14.2.4.6 Main Collecting Channel

The main collecting channel is provided to carry away the flow from the underdrains and to admit air to the filter. In a circular filter, the main channel may be located along the diameter with a slight offset from the centre. Alternatively the channel may be provided along the outer periphery of the filter. If inside the filter, the channel shall be provided with perforated covers to enable drainage and also ventilation of the filter media above the channel. The channel should be extended outside the filter, both at the upper end and lower ends with vented manholes to facilitate ventilation and access for cleaning.

The channels shall have semicircular or other rounded inverts. The velocity in the channels shall not be less than 0.6 mps for the average hydraulic loading. The flow shall be only half-depth particularly where recirculation is low. At the peak instantaneous hydraulic loading, the water level in the channel should not rise above the inverts of the underdrains at their junctions with the channel.

14.2.4.7 Ventilation

Adequate natural ventilation can be ensured by proper design of the underdrains and effluent channels. For filters larger than 30 m dia., a peripheral head channel on the inside of the filter with vertical vents is desirable to improve ventilation. 1 m^2 of open grating in ventilating manholes and vent stacks should be provided for 250 m^2 of filter area. The vertical vents can also be used for flushing the underdrains.

In extremely deep or heavily loaded filters there may be some advantage in forced ventilation if it is properly designed, installed and operated. Such a design should provide for an air flow of 1m^3/min/m^2 of filter area in either direction.

It may be necessary during periods of extremely low air temperature to restrict the flow of air through the filter to keep it from freezing. However a minimum air flow of 0.1 m^3/min/m^2 of filter area should be provided.

14.2.4.8 Filter Media

The requirements for filter media are high specific surface area, high percent void space, resistance to abrasion or disintegration during placement, insolubility in sewage or other waste water and resistance to spalling and flaking.

The most commonly used filter media is broken stone (trap rock, granite or limestone), slag or gravel of size 25 to 75mm. The filter material should be washed before it is placed in position. The Brinell Hardness number of the medium should be 12. Such media should be round or cubical in shape and free of thin, elongated and flat pieces. Not more than 5% of the media (by weight) should have the longest dimension greater than 3 times the smallest dimension.

Stones less than 25 mm dia, do not provide sufficient pore space between them to permit free flow of sewage and sloughed solids and also lead to plugging of media and ponding of filters. Large size stones greater than 100mm dia, overcome the plugging problem but due to relatively smaller surface area per unit volume cannot support as large a microbial population as the smaller size stones.

The size of the filter media is of considerable significance as the specific surface area decreases with increase in media size but the percent void space increases as given in Table 14.2.

TABLE 14.2

RECENT VOID SPACE FOR VARIOUS FILTER MEDIA

Media	Size (in mm)	Specific Surface area m^2/m^3	% Void Space
Granite	25 - 75	62	46
Granite	100	43	60
Blast furnance slag	30 - 75	65	49
Plastic		80 - 200	97

The recent trend is towards the use of larger media especially for high rate filters. The current specification for stone media is that when mechanically graded over vibratory screens:

100% should pas through 110 mm square mesh

95-100% should be retained on 75mm sq.mesh

0.2% alone should pass through 50mm sq.mesh

0.1% alone should pass through 25mm sq.mesh

(% given are by weight)

Media shall be placed and packed by hand for at least a height of 30 cm above the underdrains to avoid damage to the underdrainage system. The remainder of the material may be placed by means of wheel barrows or boxes or by belt conveyors. They should not be dumped or tipped from lorries.

14.2.4.9 PLASTIC MEDIA

The above criteria do not apply to plastic synthetic media which have high specific surface area, high void space and low weight. Synthetic filter media have of late been used successfully in super rate filters for the treatment of strong industrial wastes or sewage mixed with strong industrial wastes having hydraulic loading rates in the range of 40-200 $m^3/d/m^2$ and organic loading rates of 0.8-6.0 kg $BOD/d/m^3$. The media consists of interlocking sheets of plastics which are arranged in a honeycomb fashion to produce a porous and nonclog filter media. The sheets are corrugated so that a strong, lightweight media is obtained. Filters as deep as 12 m have been used with this type of synthetic media.

14.2.4.10 FILTER DOSING

In the case of low rate filters, the minimum flow rate of sewage inflow may not be sufficient to rotate the distributor and discharge sewage from all nozzles. Hence, when adequate head is available dosing tank is provided to collect the settled sewage and dose the filter through a siphon intermittently. When head is inadequate, a collection well is provided to store the sewage and a suction level controlled pump, intermittently pumps the sewage to the filter. The dosing siphons are designed to dose the filters once in about 5 minutes under average flow conditions. In the case of high rate filters, there is no need for the special dosing device since continuous dosing is possible.

14.2.4.11 FLOW DISTRIBUTION

Fixed nozzle distributors are not preferred because of the elaborate piping requirement and the necessity of dosing tanks, siphons or motor operated valves to obtain variable dosing rates. Among the moving types, the longitudinally travelling distributors are not common because of the long resting period associated with their time of travel from one end of the bed to the other and the need for a reversing gear at each end of the bed to change the direction of motion.

The present practice is to use only reaction type rotary distributors. Rotary distributors are commercially available in the country upto 60 m dia. The piping to the distributor is generally taken below the filter floor and in rare case through the filter media just above the underdrains. The pipe should be designed for a peak velocity of not greater than 2.0 mps and an average velocity not less than 1 mps.

The reaction type rotary distributor consists of a feed column at the centre of the filter, a turn table assembly at the top and two or more hollow radial distributor arms with orifices. The turntable should be provided with antitilt devices and also arrangements for correcting the alignment to obtain balanced rotation. The turntable assembly is provided with a mercury or mechanical water seal at its base. The current trend is to discourage mercury seals because of the chances of causing mercury pollution. Facilities should be available for draining the central column of the flow distributor for attending to repairs and maintenance.

The distributor arms are generally two in number, multiples of two also being adopted. When multiple arms are provided, low flows are distributed through two arms only and as flow increases, it is distributed by the additional arms. This is achieved by overflows from weirs incorporated in the central column diverting the higher flows into the additional arms. The peak velocities in the distributor arms should not exceed 1.2 mps. The distributor arms are generally fabricated of steel and are liable to rapid corrosion. They should be fabricated and bolted together in such lengths as to fecilitate dismantling for periodic repainting of their inside surfaces. The orifices in the distributor arms should be composed with aluminium orifice plates. Spreader plates, preferably of aluminium, should be provided below the orifices to spread out the discharge. The clearance between the distributor pipe and the top of the filter media should be greater than 15 cm.

Distributor arms should have gates at the end for flushing them. Atleast one end plate should have arrangement for a jet impinging on the side wall to flush out fly larvae. The distributor arms may be of constant cross section for small units but in larger units, they are tapered from the centre towards the end to maintain the minimum velocity required in the arms.

The distribution arrangements should ensure uniform distribution of the sewage over the filter surface for which the size and spacing of the orifices in the distributor arms have to be varied carefully from the centre towards the end. Under average flow conditions, the rate of dosing per unit area at any one point in a filter should be within ± 10% of the calculated average dosing rate per unit area for the whole filter. The distributors should also ensure that the entire surface of the filter is wetted and no area is left dry.

Reaction type rotary distributors require adequate hydraulic head for operation. The head required is generally 1 to 1.5 m measured from the centre line of distribution arms to the low water level in the distribution well or the siphon dosing tank preceding the filter. Alternatively, the rotary distributor driven by electric motor may be used. This type is particularly advantageous where adequate head is not available. The speed of rotation of the distributors shall ensure that the intervals of successive dosings is between 15 and 20 seconds.

14.2.5 Multiple Units

In a single stage plant, it is advisable to split the required filter volume into two or more units so that when one filter is taken out of operation for maintenance or repairs, the entire sewage can be passed through the remaining units, overloading them temporarily.

In a two stage plant, if multiple units are proposed in each stage, the entire sewage may be routed through the remaining units of the stage when one filter in that stage is taken out of operation. However, the recirculation flow is maintained at the original level, operating the stage at a lower recirculation ratio. If, instead, only one filter is proposed for each stage a bypass should be provided for each stage. It is customary in the design of two stage filters to use two filters of equal size.

14.2.6 Plant Hydraulics

The feed pipe to the filter, the distributor, the underdrains and the main collection channel should be designed for the peak instantaneous hydraulic loading on the filter. In low rate filters, the peak loading will be the peak discharging capacity of the dosing siphon or the dosing pump. In the case of high rate filters, the peak loading on the filters will be the sum of the peak rate of sewage flow and the constant recirculation rate.

When multiple units are used for the high rate filters in any stage, the hydraulics of the plant should be checked for peak loading with one filter out of operation, the entire flow routed through the remaining units. A reduced recirculation ratio is adopted for this condition so as to reduce the peak loading and avoid oversizing of the piping.

When multiple units are used care should be taken to ensure that the flow is divided properly between the various filters.

14.2.7 Pumping Arrangements

In a high rate filter, pumping is required for recirculation. Pumping may also be required for lifting the filter effluent to the settling tank or to the next stage filter.

Except in the case of small plants, recirculation pumps should be installed in multiple units so that the recirculation rate can be changed as found necessary.

Pumps for lifting the flow-through sewage should have adequate capacity to pump the peak flows through the plant. The pumps should be installed in multiple units to take care of diurnal variations in flow which will approximately be the same as the sewage inflow to the plant. It will further be necessary to provide storage in the suction well equal to about 10 min of discharge capacity of the lowest duty pump. Float control arrangements are desirable in the suction well for controlling the number of pumps in operation.

In all the cases, at least one pump should be provided extra as a standby. Also, in the case of recirculation pumps, flow measuring and recording devices are desirable on the discharge line so that a record can be kept of the recirculation ratio actually employed in the plant.

14.2.8 Operational Problems

Ponding or clogging of the filter media is one of the important operational problems in trickling filters. Ponding decreases filter ventilation, reduces the effective volume of the filter and lessens filter efficiency. Ponding or clogging is due to excessive organic loading, inadequate hydraulic loading and inadequate size of media. Remedies consist of raking or forking the filter surface, washing the filter by applying a high pressure stream of water at the surface, stopping the distributor to allow continuous heavy point by point dosing or chlorinating the influent with a dose not exceeding 5 kg/100 m^2 of filter area.

Filter flies pose another serious operational problem in trickling filters. The problem is more intense in the case of low rate filters. In high rate filters fly breeding occurs mainly on the inside walls of the filter. The problem can be reduced by (a) removing excessive biological growth by the previously discussed methods (b) flooding the filter for 24 hours at weekly or biweekly intervals, (c) jetting down the inside walls of the filter with a high pressure hose, (d) chlorinating the influent (0.5 to 1.0 mg/l) for

several hours at one to two week intervals and (e) applying insecticides. The insecticide should be applied to the filter side walls and surface at intervals of 4-6 weeks. Development of resistant strains should be guarded against.

Filter odours also present a problem in trickling filter operation. Odours are most serious when treating septic effluents in low rate filters. Odours can be controlled by providing recirculation and maintaining a well ventilated filter.

In conditions of extreme cold weather, ice cover may form on the surface of the bed. Reduction of the recirculation flow, adjustment of nozzles or construction of wind breakers are methods used to reduce icing problems.

14.3 ROTATING BIOLOGICAL CONTACTOR

Rotating Biological Contactor (RBC) is one of the relatively recent addition to the family of biological treatment devices. It has been widely used abroad but not in India for the treatment of both industrial and domestic wastewaters, especially for small and medium-scale units. This is a relatively simple attached growth system operating on the principle of moving media. The RBC units can be adopted for small and medium towns.

The advantages claimed for RBC include (i) low food to microorganism ratio resulting in higher efficiencies of organic matter removal (ii) low hydraulic retention periods minimizing tank volume and capital costs (iii) low head loss and lower power requirements (iv) inherent simplicity and low operational and maintenance cost (v) ability to resist shock loads and (vi) ability to lend itself to modular fabrication to suit required effluent quality.

14.3.1 Process Description

The Rotating Biological Contactor unit consists of a series of closely spaced vertical discs mounted on a horizontal shaft rotating at slow speeds, normally less than 10 rpm, the movement of the discs being perpendicular to the wastewater movement in a cylindrical vessel. The discs, also called biodiscs, support biomass and are partially (40 - 60%) submerged in the wastewater. The rotation of the biodiscs causes the biomass to be alternatively submerged in wastewater to absorb food and to pick up a thin layer of wastewater and then raised out of the liquid into the air to oxidise the absorbed substrate and to allow the wastewater film to slide down the biomass. It has been suggested that the orthogonal rotational motion of biomass on discs relative to horizontal liquid movement results in ideal shear and turbulence conditions at solid - liquid interface to cause exceptionally high transfer of substrate and oxygen into biological slime and waste products from it.

Excess biomass growing on the disc surfaces is sheared off and sloughed biomass is kept in suspension by the mixing action of the discs and carried out of the cylindrical tank alongwith the effluent. Both the substrate utilisation within the microbial film and the sloughing of excess biomass are continuous processes which help in maintaining a constant thickness of microbial film on the discs. Thickness of biofilm may reach upto 2 to 4 mm depending upon the strength of wastewater and rotational speed of the discs.

The basic process flow sheet of wastewater treatment system may consist of primary sedimentation following screening and grit removal, aerobic biological treatment in RBC unit and secondary settling for solid - liquid separation of sloughed film from treated wastewater. The settled sludge from primary and secondary sedimentation has to be suitable treated and disposed.

14.3.2 Constructional Features

The RBC unit essentially consists of

i) cylindrical bottomed horizontal flow tank usually divided into an appropriate number of

stages which are hydraulically connected. The tank may be constructed of steel, fibre glass, concrete or masonry.

ii) circular discs of PVC, asbestos cement or any inert light material of high durability mounted on shaft of sufficient rigidity. The disc diameters usually vary between 1 to 4 m and thickness upto 10 mm.

iii) A driving mechanism comprising of a motor and a reduction gear.

A reactor module consists of a tank with circular discs mounted on a shaft driven by motor through reduction gear. Several modules may be arranged in parallel and/or in series to meet the flow and effluent quality requirements.

14.3.3 Design And Operational Parameters

Several process parameters affect the performance of RBC as a biological treatment device. Some of the important parameters include (i) hydraulic loading (ii) hydraulic retention time (iii) influent substrate loading (iv) disc rotational speed (v) disc area available for biological growth and (vi) disc submergence.

The hydraulic loading rates vary depending upon the influent substrate concentration and desired quality of effluent, with typical value around 110 litres per day per sq.m. of surface area of the discs for primary settled domestic wastewater. The corresponding organic loading may be 0.022 Kg BOD_5/sqm of surface area/Day for BOD_5 of 200 mg/l for primary settled wastewater. The hydraulic retention period of 1 to 1.5 hr. can result in 90% BOD removal efficiency. The disc rotational speed usually varies from 2 to 6 rpm. The disc submergence is usually between 40 and 60%.

Reductions of 90 % in BOD and SS could be expected at detention periods of 1 - 1.5 hours in the disc chamber and about one hour in the settling basin. The energy consumption varies from 0.6 to 1.2 kWh per kg. of BOD removed with a loss of head of less than 2.5 cm through the unit. This energy consumption corresponds to about 6.6 to 13.2 kwh per person per year in comparison to 10-16 kwh/person/year for other biological treatment units like ASP, oxidation ditch or lagoons.

CHAPTER 15

STABILIZATION PONDS

Stabilization ponds are open, flow-through earthen basins specifically designed and constructed to treat sewage and biodegradable industrial wastes. Stabilization ponds provide comparatively long detention periods extending from a few to several days. During this period putrescible organic matter in the waste is stabilized in the pond through a symbiotic relationship between bacteria and algae. Pond systems, in which oxygen is provided through mechanical aeration rather than algal photosynthesis are called aerated lagoons. These are discussed in chapter 13. Lightly loaded ponds used as tertiary step in waste treatment for polishing of secondary effluents and removal of bacteria are called maturation ponds.

Under many situations in warm climate countries pond systems are cheaper to construct and operate compared to conventional methods. They also do not require skilled operational staff and their performance does not fluctuate from day to day. The only disadvantage of pond systems is the relatively large land that they require, but this is sometimes over-emphasized. In addition, land on the outskirts of a growing city can be a worthwhile investment. Pond systems must be considered as an alternative when treatment of wastewater or upgrading of existing facilities are planned and the life time costs of various other treatment system should be calculated and compared.

15.1 CLASSIFICATION

15.1.1 Aerobic

Aerobic ponds are designed to maintain completely aerobic conditions. They are used for soluble wastes (primary effluent) which allow penetration of light throughout the liquid depth. The ponds are kept shallow with depth less than 0.5 m and BOD loadings of 40-120 kg/ha.d. The pond contents may be periodically mixed. Such ponds develop intense algal growth and have been used on experimental basis only.

15.1.2 Anaerobic

Completely anaerobic ponds are used as pretreatment for high strength industrial wastes and sometimes for municipal wastewaters. They are also used for digestion of municipal sludges. Depending on temperature and waste characteristics, BOD load of 400-3000 kg/ha. d and 5-50 day detention period would result in 50-85 percent BOD reduction. Such ponds are constructed with a depth of 2.5-5m to conserve heat and minimize land area requirement. Usually they have an odour problem.

15.1.3 Facultative

The facultative pond functions aerobically at the surface while anaerobic conditions prevail at the bottom. The aerobic layer acts as a good check against odour evolution from the pond. The treatment effected by this type of pond is comparable to that of conventional secondary treatment processes. The facultative pond is hence best suited and most commonly used for treatment of sewage. The discussion in this Chapter is, therefore, confined to facultative ponds.

15.2 MECHANISM OF PURIFICATION

The physical, chemical and biological reactions in engineered pond systems are controlled by the design criteria. The functioning of a facultative stabilization pond and symbiotic relationship in the pond are shown schematically in Fig.15.1. Sewage organics are stabilized by both aerobic and anaerobic reactions. In the top aerobic layer, where oxygen is supplied through algal photosynthesis, the non-settleable and dissolved organic matter in the incoming sewage is oxidized to carbon dioxide

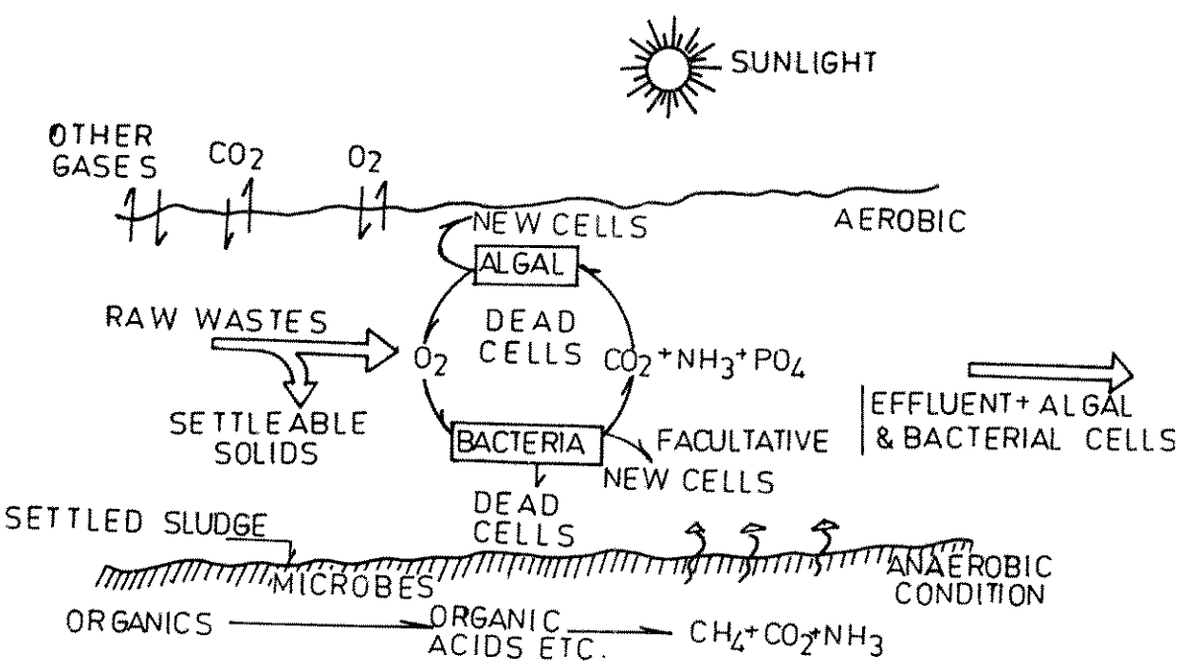

FIG. 15.1: SYMBIOTIC RELATIONSHIP AND FUNCTIONING OF A FACULTATIVE STABILIZATION POND.