18.3 SLUDGE PUMPS

Sludge-pumps have to be resistant to abrasion as sludges quite often contain sand and grit. The sludge-pumps should be slow speed machines to contain the rate of wear and tear.

Since a sludge-pump may have to run intermittently or continuous, a sludge-pump has to be dependable in respect of satisfactory trouble-free opertion, whether under the fatigue of the intermittent operation or with the endurance desired for long continuous operation.

The type of pumps generally used for pumping sludges are:

i) Centrifugal pumps

ii) Air Lift pumps

iii) Screw pumps

iv) Reciprocating pumps of the plunger type or of diaphragm type

Table 18.2 shows the typical applications of pumps of these different types and the types of sludges handled by them.

TABLE 18.2
TYPICAL APPLICATIONS OF SLUDGE PUMPS

Type of Pump	Max. Suction Lift (m)	Max.% Solids generally handled	Typical applications
Centrifugal			
(a) non-clog	4.5	2	Primary settled sludge, secondary settled sludge, chemically treated sludge, incinerator slurries
(b) vortex flow	4.5	6	Sludge recirculation
Air Lift	0	6	Return sludge
Screw Pump	0	6	Return sludge
Positive displacement, plunger or diapharagm pump	6.5	10	Primary settled sludge, thickened sludge, digested sludge, incinerated sludge, heat conditioned sludge, chemically treated sludge, slurries

There are specific considerations to be borne in mind in the use of the different types of pumps for handling sludge.

18.3.1 Centrifugal Pumps

The centrifugal pumps for handling sludge must be of the non-clog type. They should be of robust construction and should have easily accessible hand-holes for cleaning. Pumps of the macerator type impeller with a cutting ring whereby stringy rags and other fibrous material can get cut, are preferable.

When the specific speed of the pump would be low, the non-clog impellers are designed with fewer number of blades than in impellers for handling clear liquids. In pumps of high specific speed, the mixed flow impeller would generally have wide passages. The centrifugal pumps with non-clogging impellers have less efficiency than those of normal design, handling clear liquids. The rating for the drive-motor has to be selected keeping this in mind.

The specific speed of the pump also affects the suction-lift capability of the pump. This can be overcome by selecting a vertical centrifugal pump to be so installed that the impeller would be adequately submerged.

18.3.2 Air-Lift Pumps

These are used in small extended aeration plants to return the sludge and scum to the aeration tank. Small air bubbles are formed in the liquid, which makes the air-water mixing less dense to get lifted to the discharge point. A compressor or blower supplies the air.

Air-lift pumps and ejectors are pumping systems, which are inherently inefficient. However, there being no moving parts in the path of the movement of the sludge, their operation is fairly trouble-free.

18.3.3 Screw Pumps

Sludge enters the screw pump by a screw conveyor', which moves solids to an open impeller, which lifts them to the point of discharge. The submerged lower bearing is of the enclosed and sealed type, the upper bearing is usually grease-lubricated, anti-friction bearing.

A variation of the screw pump is a progressive cavity pump. It has a rubber stator or lining inside a cast iron body. The pumping element is a helical rotor of steel. Although the pump has self-priming capability, the rotor must never run dry against the rubber startor. The pump can pump up or down depending upon the direction of rotation.

18.3.4 Reciprocating Plunger or Diaphragm Pumps

a) The Plunger type pumps have a plunger reciprocating in a cylinder. A pump can have one or more plungers connnected to common crankshaft, thereby obtaining arangements called simplex, duplex, triplex, etc. Reciprocating pumps may be with capacities of the order of 150 to 250 lpm per plunger. The pump-speeds should be between 40 to 50 rpm. Reciprocating pumps are self-priming and can usually work with suction-lifts upto 3 m. The suction-lift capability depends upon the design of the pump, especially of the suction valve.

The pumps can develop high heads and are hence suitable where accumulation of grease in piping can cause progressive increase in head. However if the piping is likely to get completely choked, the pumps would develop very high pressures against choking and this can cause bursting. A relief valve is provided to protect the pump in case of a clogged delivery line. After each use, the pump should be flushed, so that no solids settle in the cylinder and would damage the pump during the next starting.

The suction and delivery valves are the main source of trouble. The valves should be easily accessible for quick cleaning, in case the valves fail to seat properly.

b) The diaphragm pumps have a flexible diaphragm, usually of rubber and actuated by a reciprocating movement. The diaphrgam is fastened peripherally to the casing, which also houses the suction and delivery valves. The interesting feature of the diaphragm pumps is that the components of the reciprocating mechanism, which are the most wear-prone, are isolated from the path of the sludge. Pneumatic or hydraulic drives can also be employed for the reciprocating movement.

18.4 OPERATIONAL PROBLEMS

a) Gas often gets liberated, when the sludge, particularly the digested sludge is subjected to suction. This hampers the proper operation of the pump. The pumps should be installed, as far as possible, with positive suction.

b) If the suction arrangements are improperly designed, a vortex-cone or hole developing in the sludge blanket will cause the watery sludge or supernatant to be pumped instead of the sludge. The suction pipe should not be too long, nor should the pumping be too long or too fast. It is better to pump more often than at reduced speed. With a pump equipped with variable speed drive, the pump can be started at a relatively high speed and the speed can then be reduced.

c) Sludge from two settling tanks should not be connected to the suction of one pump. The settling tank with the thinner sludge will get pumped and the thickned sludge in the other tank will not get pumped. Similar problem will happen, if the suction lines from the two tanks will have differential frictional losses. The tank with higher frictional loss in its suction piping, which may be because of more length or because of choking, will not get pumped.

The capacity of sludge pumps is required to be regulated according to the sewage load. Further, variable speed drives are more appropriate for regulating, because having delivery valves in the sludge-pumping system makes an inefficient and trouble-prone system.

18.5 REQUIREMENT OF STANDBY UNITS

The number of pumping units required including the standbyes is determined by several factors like the particular function involved, the size of the plant and the arrangement of the units, especially having combination of more than one function. A minimum stand bye capacity of 50% is recommended.

Since primary and secondary sludge pumping are important functions, standby pumps are provided in actual numbers or by such arrangement that dual duty is possible. Scum is usually mixed with the primary sludge and pumped.

18.6 SLUDGE CONVEYING PIPING

After selecting the type of pump, the next important thing is to design the pipeline to and from the pumps. The design of the piping is to be based on the rate of sludge-handling, the desired velocity of the flow of the sludges, the possible layout and arrangement of the piping etc. Reference may be made to Table 22.2, regarding piping material. The material for piping and valves should be corrosion and abrasion resistant.

Sewage sludge flows like a thin plastic material and hence the formulae for the flow of water are not applicable. The velocity of flow should be in the critical range above the upper limit of the laminar flow and below the lower limit of the turbulent flow, in order to avoid clogging and deposition of grease, so that the application of the hydraulic formulae for flow of water become permissible. In general velocities between 1.5 to 2.5 m/s are satisfactory. The frictional head losses in the sludge pipe can be estimated by applying the Hazen-William's formula, adopting the `C' value between 40 to 50 depending upon the material to used; the lower value being adopted for high solid content of the sludge.

Pipes less than NS 200 should not be used for gravity withdrawal or for the suction lines to pumps. In order to take care of thin sludge to flow by gravity for short distances within the treatment plant, a 3% or greater slope should be adopted.

Suction and discharge should be arranged in such a way that their lengths are as short as possible, straight and with minimum bends. Adequate provision should be made to facilitate cleaning. Large radius elbows and sweep tees are usually adopted for change in direction. High points should be avoided, as far as possible, to prevent gas pockets. Suitable recess and sleeves are usually provided for all pipes passing through masonry. Double-flanged pipes are usually adopted for sludge-lines, providing valves at selected locations to clean the lines.

18.7 PUMP APPURTENANCES

The performance of the sludge pumps can be more efficient and its assessment and control can be better, if various appurtenances, such as air chambers, sampling devices, measuring devices, valves, gauges are incorporated in the system and facilities such as revolution counters, gland seals, time clocks, etc., are kept available at the plant.

18.7.1 Air Chamber

Air chamber of adequate size is necessary for all plunger type sludge pumps on the discharge side of the pump. It may also be provided on the suction side of the pumps, particularly where positive suction head exists. Such chambers absorb the shock of plunger pump pulsations.

18.7.2 Revolution Counter

Plunger-type sludge pumps should be equipped with revolution counters or intergrating recorders to help the operator to determine the quantity of sludge pumped. In duplicate pump installations these aid in equalising the service and wear of each pump.

18.7.3 Gland Seals

In the case of centrifugal pumps, external sealing is provided in the stuffing box, to ensure against the ingress of air into the pump. The external sealing may be a grease seal or water seal. The water seals are preferable, as it also helps the grit and dirt to be washed away. The water to the water-seal has to be potable water. However, the connection of potable water sould not be taken directly from the supply lines.

18.7.4 Valves

When a dry pit pump has positive suction head in the wet well, there should be a isolating valve, usually a gate-valve, on the suction line, to facilitate isolating the pump for maintenance.

On the delivery side of centrifugal pumps, a non-return valve is necessary, so that the pump would not experience the back-pressure from the delivery head, when the pump is to be shut off. To minimise the pressure-drop across the valve, during the normal running of the pump, the non-return valve should be of the swing-check type or of the ball-check type. To avoid water-hammer, which is likely to be caused by the closure of the valve, the valve may be provided with an anti-slam device, either of the lever and dead-weight type or of the spring-loading type or of the dash pot type. Dual check valves are sometimes used, which gives more consistent operation and facilitates the use of the pump as metering device. All the valves may be provided with drain plugs.

In larger size plants, where pumps may be run in parallel operation with different permutation of the standbyes, isolation valves would be needed ot isolate those pumps, which are to be idle. Mostly the isolating valves are gate valves. All gate valves should perferably be of the rising stem type, since they offer the advantage of visual indication of the valve-position. For exterior underground locations, gate valves are generally used. Underground sludge valves should be avoided as far as possible, by taking advantages of the hydrostatic pressure for withdrawal of sludge through a slant pipe and valve arrangement.

18.7.5 Gauges

Pressure gauges shall be provided on both the suction and delivery sides. For pumps having suction lift, the gauge on the suction side should be a composite vaccum-cum-pressure gauge. The gauges should be with a cast iron bowl and an oil-resistant rubber diaphragm, which would keep the sludge away from the finer working parts of the gauges.

18.7.6 Sampling Devices

All sludge pumps are provided with sampling cocks, either within themselves or in the piping adjacent to the pump. These are usually plug valves, normally of size NS 40. Plug valves are simple and easy to operate for taking the samples.

18.7.7 Washouts and Drains

Washout or flushing arrangements are provided for sludge pumps to facilitate easy and rapid cleansing. The drains on the pump body should be of ample size to ensure release of pressure and drainage of the liquid. The outlet of the drain should be connected to an adjacent floor drain to keep the floor clean.

18.7.8 Time clocks

Time clocks, wired across the magnetic starters or motor leads of sludge pumps can be valuable help to the operators. They help to keep an accurate record of the hours of run of the pump for observing the preventive maintenance schedules in respect of attending to the lubrication, equalisation of wear and tear, etc.

18.7.9 Measuring Devices

While time clocks and counters are adequate for small plants, supplementary flow-metering arrangements, such as flow tubes with flushing provisions are used in large plants for measuring and recording the quantities of sludge handled. Magnetic meters are more suitable for sludge metering.

18.8 PUMP DRIVE EQUIPMENT

The prime movers for the pumps are usually the electric motors, which are discussed in detail in 9.8. It is desirable to use flame proof motors.

I.C. Engines may be used for standbye services in the case of failure of electric power. Again, the I.C. Engines are better used as prime mover for a standbye generator than as a prime-mover for the pumps, because the standbye generator can then provide the power for lighting and ventilation facilities.

Gas enginees using sludge gas as fuel, would help not only as the standbye power supply facility but also as an effective method of energy-conservation in the operation of the plants.

CHAPTER 19

TERTIARY TREATMENT OF SEWAGE FOR REUSE

19.1 GENERAL

Tertiary treatment is supplementary to primary and secondary treatment for the purpose of removing the residual organic and inorganic substances and in some cases even the refractory and dissolved substances to the degree necessary.

Tertiary Treatment of sewage is increasingly being adopted in India. Some of the purposes for which it can be considered are

- industrial reuse of the reclaimed water in cooling systems, boiler feed, process water etc.
- reuse in agriculture, horticulture, pisciculture, watering of lawns, golf-courses and such purposes.
- Ground water recharge for augmenting ground water resources for downstream users or for preventing saline water intrusion in coastal areas.

As more such applications are likely to be made in the future, this subject has been included in the manual for general guidance.

19.2 BASIC APPROACH

When water is used once by a community, various organic and inorganic substances are added to those already contained in the fresh municipal water supply. The concentration of additional constituents can be estimated from the extent of water supplied in lpcd and the likely contribution of each constituent some of which are given in Table 19.1 in grams/person/day. In this manner, the composition of raw sewage expected from one-time use or water by a community can be computed.

During primary and secondary treatment of sewage many constituents, though not all, under go reduction in concentration. Some dissolved and refractory (non-degradable) substances, are however, not reduced at all.

Tertiary treatment provides only the additional treatment necessary to meet the desired end use. Thus, tertiary treatment is quite use-specific and may involve only one item like simple chlorination of treated sewage or several items as in the case of high pressure boiler feed water.

It is, therefore, very important that clear-cut specifications of the reusable water are first obtained.

Inspite of a high degree of treatment achieved in all cases, water is reclaimed only for non-potable uses. In fact, the actual quality may be comparable to that of drinking water but any attempt to supply potable water directly would only meet with psychological resistance from the public and might even present some problems since the full public health significance of direct reuse over a long period of time is not yet known. Indirect use of reclaimed water for potable uses through ground water recharge is no doubt, feasible as the applied water loses its identity in underground travel and, in fact, benefits from natural purification in downstream flow through soil. Indirect reuse systems based on treated sewage have not yet been implemented in India in any planned manner.

TABLE 19.1
DOMESTIC WASTE WATER CHARACTERISTICS

Item	Range of Values contributed in wastes (gpcd)
BOD_5	45 - 54
COD (dichromate)	1.6 to 1.9 x BOD_5
Total Organic Carbon	0.5 to 1.0 BOD_5 (Soluble)
Total Solids	170 - 220
Suspended Solids	70 - 145
Grit (inorganic 0.2 mm and above)	5 - 15
Alkalinity, as $CaCO_3$	20 - 30
Chlorides	4 - 8
Nitrogen, total, as N	6 - 12
Organic Nitrogen	0.4 x Total N
Free Ammonia	0.6 to Total N
Nitrate Nitrogen	absent
Nitrite Nitrogen	absent
Phosphorus, total, as P	0.8 - 4.0
Organic phosphorus	0.3 x Total P
Inorganic (ortho and Polyphosphates)	0.7 x Total P
Potassium, as K_2O	2.0 - 6.0

19.3 TERTIARY TREATMENT METHODS

Tertiary treatment methods are mostly physico-chemical in nature, some examples of which are given below:

Disinfection

Oxidation

Chemical dosing for water quality correction

Chemically aided settling

Filtration

Softening

Activated carbon treatment

Anion/Cation exchange (demineralization)

Reverse Osmosis.

A tertiary treatment plant, therefore, generally, looks like a sewage treatment plant followed by a typical industrial water treatment plant.

Table 19.2. gives the range of removal of impurities that can be expected in sewage treatment using different combinations of different processess.

TABLE 19.2
PROGRESSIVE REMOVAL OF IMPURITIES IN SEWAGE TREATMENT

Sl. No.	Process	% Removal based on raw waste concentration						
		B.O.D.	Phosphates	Nitrogen	ABS*	Suspended Solids	T.D.S	Colifomrs
1.	Conventional Sewage Treatment	90	40-50	40-50	50	90	5	95 - 99
2	Conventional Sewage treatment + lime - alum coagulation, settling filtration	93-95	95	50	50 - 55	99	10	99 - 99.9
3.	2 above + absorption on activated carbon	99	95	50- 55	95	99	15	99 - 99.9
4.	3 above + demineralization or Reverse Osmosis	99	97	75	98	99	80 Further removed by deminerli -zation	99.9 - 100

* ABS = Alkyl Benzene Sulphonate.

19.4 DESIGN CRITERIA

In designing a tertiary treatment system for any purpose the crux of the problem lies in determining what specific treatment units will be required, and in what sequence to achieve the desired end-use quality. The capability of each individual treatment unit is generally known from experience. The range of efficiency a unit can achieve in practice as well as the conditions (e.g. concentration, fluctuation, temperature, etc.) under which it can function best are fairly well known, and the required flow sheet can thus be synthesized to give the overall degree of treatment required.

Once the flow sheet is determined, the actual design criteria to be used for each individual treatment step in the flowsheet are the same as those already given in the other chapters of this Manual and the Manual on water supply and treatment. As stated earlier, the critical aspect is to determine the tolerable level of impurities in the final water depending on the reuse planned.

Some important considerations in selecting tertiary treatment methods for various industrial and agricultural purposes are discussed below.

19.5 REUSE FOR INDUSTRIAL PURPOSES

Reuse for industrial purposes generally includes

- make up water required for cooling towers
- boiler feed water for raising steam or hot water
- water for selected unit processes and unit operations in the industry.

The wastewater to be reclaimed for industrial reuse may come from one or more of the following sources :

- sewage from toilet blocks and washing places within factory campus and from housing colony areas
- municipal sewage from public sewers serving the city area i.e. sewage from off-site sources
- wastewaters from certain selected processes and operations within the factory.

In choosing the source of wastewater it is important to select wastewater which are readily treatable (e.g. sewage from domestic sources) and which do not contain difficult industrial wastes in them especially the difficult-to-remove dyes, heavy metals, refractory chemicals, etc. Treatment as such is possible even if the wastewaters are polluted by such substances, but the costs on quality control instrumentation may prove discouraging.

A few industrial reuse examples are give below.

19.5.1. As Cooling Water

Reuse as cooling water is one of the most common industrial applications of reclaimed sewage water. Typical guidelines for cooling water quality are given in Table 19.3 and may be used where specific requirements are not given.

To determine the quality and quantity of water required for reuse in a cooling system, where an open recirculating system is adopted for air conditioning cooling water, the amount of water to be kept recirculating in the system is approximately 11 lpm for every ton of refrigeration capacity when the temperature drop is 5 degrees C, in the cooling tower. For such a situation, the water lost in evaporation (E) is about 1% of the recirculating water.

Windage loss (W) is of the order of 0.1 to 0.3% of the recirculating water when mechanical draft towers are used, but increases to 0.3 to 1.0% for atmospheric towers. Blowdown requirement (B) is estimated from the following equation if the maximum permissible cycles of concentration (C) are known

$$B = \frac{E + W(1 - C)}{C - 1}$$

Where B, E and W are all in lpm.

For trouble free operation and minimum use of water quality- control chemicals in the recirculating water, the cycles of concentration are generally kept at 2.0 to 3.0 and, in no case, more than 4.0 in cooling towers where reclaimed water is used (Table 19.3). Hence, for a 100-ton air-conditioning plant recirculating 1100 liters/min of water with a temperature drop of, say 10 degrees C through a mechanical draft tower where cycles of concentration are to be restricted to 2.0

$$E = 2\% \times 1100 = 22 \text{ lpm.}$$
$$W = 0.2\% \times 1100 = 2.2 \text{ lpm.}$$

$$B = \frac{22 + 2.2(1 - 2)}{(2 - 1)} = 20 \text{ lpm (approx.)}$$

The total make-up water requirement thus equals 44.2 lpm (= 22 + 2.2 + 20) or 63.4 cum/day for 24 hr. working of a 100-ton plant.

TABLE 19.3
COOLING WATER QUALITY GUIDELINES

	PARAMETER / CONDITION	RECOMMENDED VALUE
(A)	In make-up water	
1.	pH	6.8 - 7.0 (Variation less than 0.6 units in 8 hours)
2.	Average TDS value (with variation ± 25% permisible on 8 hour average)	Cycles of concentration in reciculating water :
	3000 mg/l	2.0
	1000 mg/l	3.5
	500 mg/l	6.0
3.	Oil & Grease	Absent
4.	BOD (5 day, 20 degrees C)	Less than 5.0 mg/l
5.	Chlorides (Cl)	Less than 175 mg/l.
6.	Ammonia	No appreciable amount
7.	Caustic Alkalinity	Absent
8.	Methyl Orange Alkalinity (as $CaCO_3$)	Less than 200 mg/l
B)	In Recirculating Water	
9.	Silica (as SiO_2)	Less than 150 mg/l.
10.	Phosphates, Sulphates	Not to exceed solubility limit in recirculating water
11.	Alkyl Benzene Sulponate (ABS)	Foam not to persist more than 1 min. after 10 secs. of vigorous shaking or recirculating water
12.	Langeller Index at Skin temperature of heat exchange surface	0.5 ± 0.1
13.	Ryzner Stability Index	6.0 to 7.0

Similarly, if 3.0 cycles of concentration are permissible, the total requirement of make-up water reduces to 47.7 Cum/day for a 100 ton plant.

When cycles of concentration equal 3.0, the various stable constituents (e.g. chlorides) in make-up water are theoretically increased by a factor of 3.0 in the recirculating water. If the concentration of various constituents in the make-up water lie within the range of values given in column (F) of Table 19.4 the corresponding concentration in the recirculating water can be readily estimated. For example, if Cl are 60 mg/l in the make-up water, they will increase to 180 mg/l in the recirculating water. However, the pH of the recirculating water cannot be estimated in this manner. The assumption is frequently made that in the absence of phenolphthalein alkalinity, the pH of the water leaving the cooling tower will be between 8.0 and 8.3 due to elimination of free carbon dioxide in the tower. Sometimes, for other reasons, a lower or higher pH may be observed. Thus knowing the pH, the concentrations of calcium, alkalinity and total dissolved solids in the recirculating water, and the temperature in the hottest part of the system, one can determine the Langerlier Index and Ryzner Stability Index and not the tendency of the water to scale or corrode. Assuming that the recirculating water shows the tendency for deposition of scale, reduction in hardness and in alkalinity is the usual means of control. Since nothing can be done to reduce temperature, and reduction in total solids would not have much effect on the Index.

For this reason, partial zeolite softening (by blending the softened water with by-passed hard water), plus acid feeding if required for reduction or alkalinity provide a relatively simple and flexible means of preventing excessive scaling in this type of installation. The blending ensures a certain amount of hardness in the water which is useful to protect against corrosion of ferrous heat exchanger surfaces. The acid treatment (using H_2SO_4) depends for its functioning on the fact that calcium and magnesium sulfates are much more soluble than the carbonates, with the usually adopted dosages and the cycles of concentration obtaining in the system, calcium sulfate concentrations obtaining in the system. Calcuim sulfate concentrations are well below the solubility limit. Similarly, calcium phosphate is also kept within the solubility limit.

Automatic dosing and control equipment is normally not provided in plants in India. The clear water storage tanks helps to maintian uniformity of quality of water pumped to the cooling towers. Storage ensures that pH, total dissolved solids, etc., do not vary much from hour to hour, and the wide variations in inflow quantities are balanced out.

Prechlorination is done as the water enters the coagulation tanks, while postchlorination is mainly in the form of periodic "shock" doses to control lime and algal growths. The latter are likely to form owing of the presence of nitrates and phosphates in the treated water and the warm and sunny climate of India.

A typical flowsheet for making sewage water fit for reuse as cooling water is given in Fig 19.1. Table 19.4 gives an illustrative example of the change in water quality as fresh municipal water becomes wastewater and is gradually renovated for reuse as cooling and process water.

Where nitrates and phosphates in the make-up water are necessary to be reduced, the biological treatment given to wastewater at the secondary stage can itself be modified to include nitrification - denitrifiction and the addition of lime done in the final settling tank to precipitate phosphates.

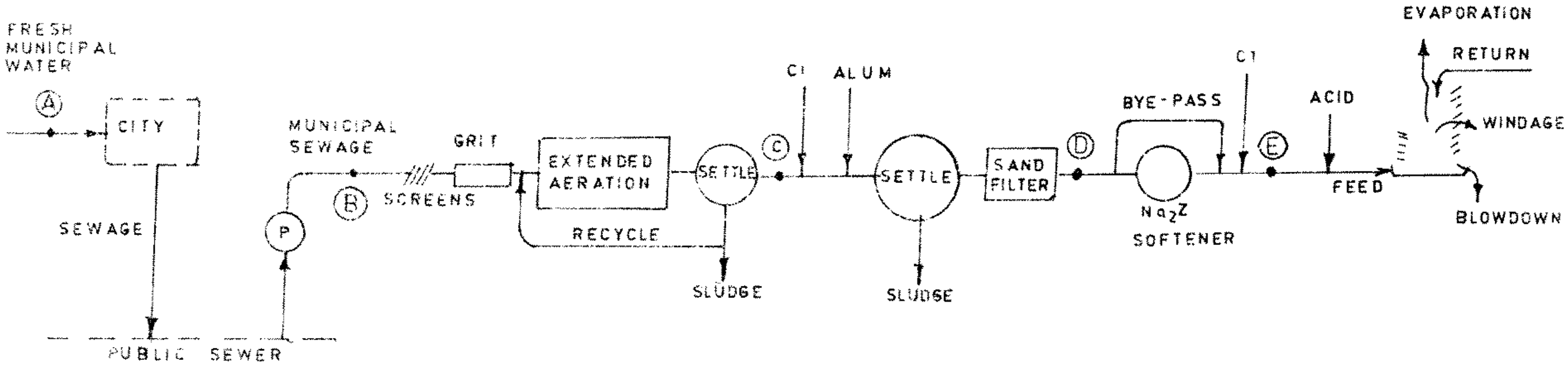

FIG. 19.1: FLOWSHEET FOR TREATMENT OF MUNICIPAL WASTE WATER FOR REUSE AS COOLING TOWER MAKE-UP WATER

TABLE 19.4
THE RANGE OF CHANGE IN WATER QUALITY AS FRESH WATER BECOMES WASTEWATER AND IS GRADUALLY RENOVATED FOR REUSE
(ILLUSTRATIVE EXAMPLE)

			Water quality at different treatment steps			
Item	Fresh Municipal Water	Raw Domestic Sewage from the area	After extended aeration and settling	After coagulation and filtration	After softening and chlorination	After demineralization
	(A)	(B)	(C)	(D)	(E)	(F)
pH	7.6-7.8	7.15-7.65	7.2-7.8	7.1-7.3	7.1-7.2	8.75
Total Hardness (mg/l as CaCO3)	35 - 40	120 - 160	120 - 160	120 - 170	40 (a)	Nil
M.O. Alkalinity (mg/l as CaCO3)	40 - 45	125 - 200	125 - 200	110 - 180 (b)	110 - 180	5.0
Chlorides mg/liter as Cl	15 - 20	60 - 130	60 - 120	60 - 130	60 - 130	Nil.
Sulfates mg/l as SO_4	1.5 - 2.5	10 - 20	10 - 15	15 - 25	15 - 25	Nil.
Phosphates mg/l as PO_4	Traces - 0.1	6 - 16	3 - 5	0.2 - 0.5	0.2 - 0.5	Nil.
Nitrates mg/l as NO_3	1.0 - 2.0	1.0 - 3.0	13 - 19	13 - 19	13 - 19	Nil.
Silica mg/l as SiO_2	8 - 24	10 - 24	10 - 24	10 - 20	10 - 20	Nil.
Total solids mg/l	80 - 90	500 - 800	300 - 500	300 - 450	320 - 480	5.0
Suspended solids mg/l	5 - 10	150 - 250	15 - 30	Nil.	Nil.	Nil.
Turbidity, SiO_2 Units	5 - 10	Turbid	10 - 20	2.0 - 3.0	2.0 - 3.0	0.2
BOD_5 days 20 deg C mg/l	0.1 - 1.5	200 - 250	6 - 10	1.0 - 2.0	1.0 - 1.5	Nil.
COD, mg/l	1.0 - 2.0	250 - 350	16 - 40	4 - 6	3.5 - 5.0	Nil
Bacteriological quality (as per coliform standards)	Safe	UnSafe	Unsafe	Safe	Safe	-
Specific conductance	-	-	-	-	-	10 Microbes

a) Softened water is blended with unsoftened water to give a final hardness of 40 mg/l as in fresh municipal water.

b) Alkalinity is reduced by acid treatment just prior to use in cooling towers. This increases sulfate content some what since H_2SO_4 is used.

19.5.2 As Boiler Feed Water

Reuse as boiler feed water may require additional treatment over that required for cooling purposes. As boiler feed, the quality of water depends on the boiler pressures at which steam is to be raised. The higher the boiler pressure, the purer the water required.

Table 19.5 gives an indication of the water quality required for low and medium pressure boilers. For low pressure boilers, the quality of water required is more or less similar to that for reuse in cooling purposes. For high pressure systems, the treatment required can be quite substantial as can be seen from the water requirements given in Table 19.6. A typical flowsheet given in fig 19.2 includes tertiary treatment in the form of chlorination, chemically aided sedimentation, sand filtration, sodium zeolite softening followed by cation exchange on hydrogen cycle, degassification and weak base anion exchange to give practically complete demineralization.

TABLE 19.5
CHEMICAL REQUIREMENTS OF FEED WATER AND BOILER WATER FOR LOW AND MEDIUM PRESSURE BOILERS

Sl No.	Characteristic	Requirement for Boiler Pressure			Method of Test (ref to CL No of)	
		Upto 2.0 Nm/sq.m	2.1 to 3.9 Nm/sq.m	4.0 to 5.9 Nm/sq.m	IS 3550 1965 (a)	IS : 3025 1964 (b)
1.	Feed Water					
	a) Total hardness (as $CaCO_3$) mg/l Max.	10	1.0	0.5	-	16.1
	b) pH Value	8.5 to 9.5	8.5 to 9.5	8.5 to 9.5	-	8
	c) Dissolved Oxygen mg/l, Max	0.1	0.02	0.01	25	-
	d) Silica (as SiO_2) mg/l, Max.		5	0.5	16	-
2.	Boiler Water					
	a) Total hardness (of filtered sample) (as $CaCO_3$) mg/l, max.	NOT DETECTABLE				16.1
	b) Total alkalinity (as $CaCO_3$), mg/l Max.	700	500	300		13
	c) Caustic alkalinity (as $CaCO_3$) mg/l Max.	350	200	60	-	15
	d) pH value	11.0 to 12.0	1.0 to 12.0	10.5 to 11.0	-	8
	e) Residual sodium sulphite (as Na_2SO_3) mg/l	30 to 50	20 to 30	-	-	21
	f) Residual Hydra zine (as N_2H_4) mg/l	0.1 to 1 (if added)	0.1 to 0.5 (if added)	0.5 to 0.3	26	
	g) Ratio Na_2SO_3 cautic alkalinity (as NaOH)		above	2.5		20.2 and 15
	or					
	Ratio NaNo3 total alkalinity (as NaOH)		above	0.4		48 and 13

a) Methods of Test for routine control for water used in Industry

b) Methods of sampling and test (Physical and Chemical) for water used in Industry.

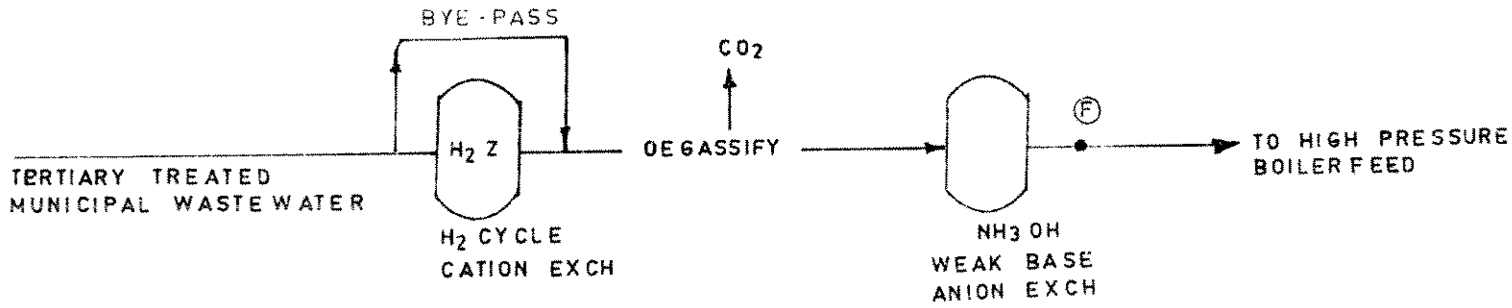

FIG. 19.2: FLOW SHEET FOR REUSE OF WASTE WATER AS HIGH PRESSURE BOILER FEED

TABLE 19.6

REQUIREMENTS FOR FEED WATER, BOILER WATER AND CONDENSATE FOR WATER -TUBE BOILERS (DRUM TYPE)

Sl. No.	Characteristic	Requirements for Boiler Pressure mn/Cu M (in the drum)				Method of test to Cl. No. of		See also Cl. No
		6.0 - 7.8	7.9 - 9.8	9.9 - 11.8	above 11.8	IS 3550 1965 (a)	IS 3025 1964 (b)	
1.	Total Hardness (as $CaCo_3$) mg/l. Max	Nil	Nil	Nil	Nil		16.1	
2.	pH value (see also Note 1)	8.5 - 9.5	8.5 - 9.5	8.5 - 9.5	8.5 - 9.5		6	2.1.1(a)
3.	Oxygen (as O_2) mg/l. Max.	0.01	0.005	0.005	0.005	25		2.1.1(b)
4.	Iron + Copper mg/l. Max	0.02	0.01	0.01	0.01	(See A-1 and A-2 for methods of test)		2.1.1(c)
5.	Silica (SiO_2) Max	0.05	0.02	0.02	0.02	(See A-3 for method of test)		2.1.1(d)
6.	Oil mg/l. Max	Nil	Nil	Nil	Nil		58	
7.	Residual hydrazine (as N_2H_4) mg/l max	0.05	0.05	0.05	0.05	26		
8.	Conductivity after passing through cation exchange column at 25 deg C microsiemens/cm. Max	0.5	0.3	0.3	0.3	7		
9.	Oxygen consumed in 4 hours. mg/l Max. (see also Note 2)	Nil	Nil	Nil	Nil		51	

a) Methods of test for routine control for water used in Industry.

b) Methods of sampling and test (physical and chemical) for water used in Industry.

19.5.3 As Process Water

In order to keep treament to a minimum for reuse as process water, one benefits from identifying those processes which must have fresh waters of high quality and those processes which can do with reclaimed water of low quality (e.g. similar in quality to that used for cooling or for low pressure boilers). This is done by having a multiple quality water supply system within the industry (Fig 19.3).

Indian standards for quality tolerances for a few industrial uses are noted below :

IS 201 : 1964 Quality tolerances for water for textile industry.
IS 2724 : 1964 Quality tolerances for water for pulp and paper industry.
IS 3957 : 1966 Quality tolerances for water for ice manufacture.
IS 4251 : 1967 Quality tolerances for water for processed food industry.
IS 4700 : 1968 Quality tolerances for water for Fermentation industry.

It may be noted that generally all the processes in an industry do not require water of the relatively high quality given in the above noted Indian Standards. There are always several unit processes and operations where water of lesser quality can be tolerated.

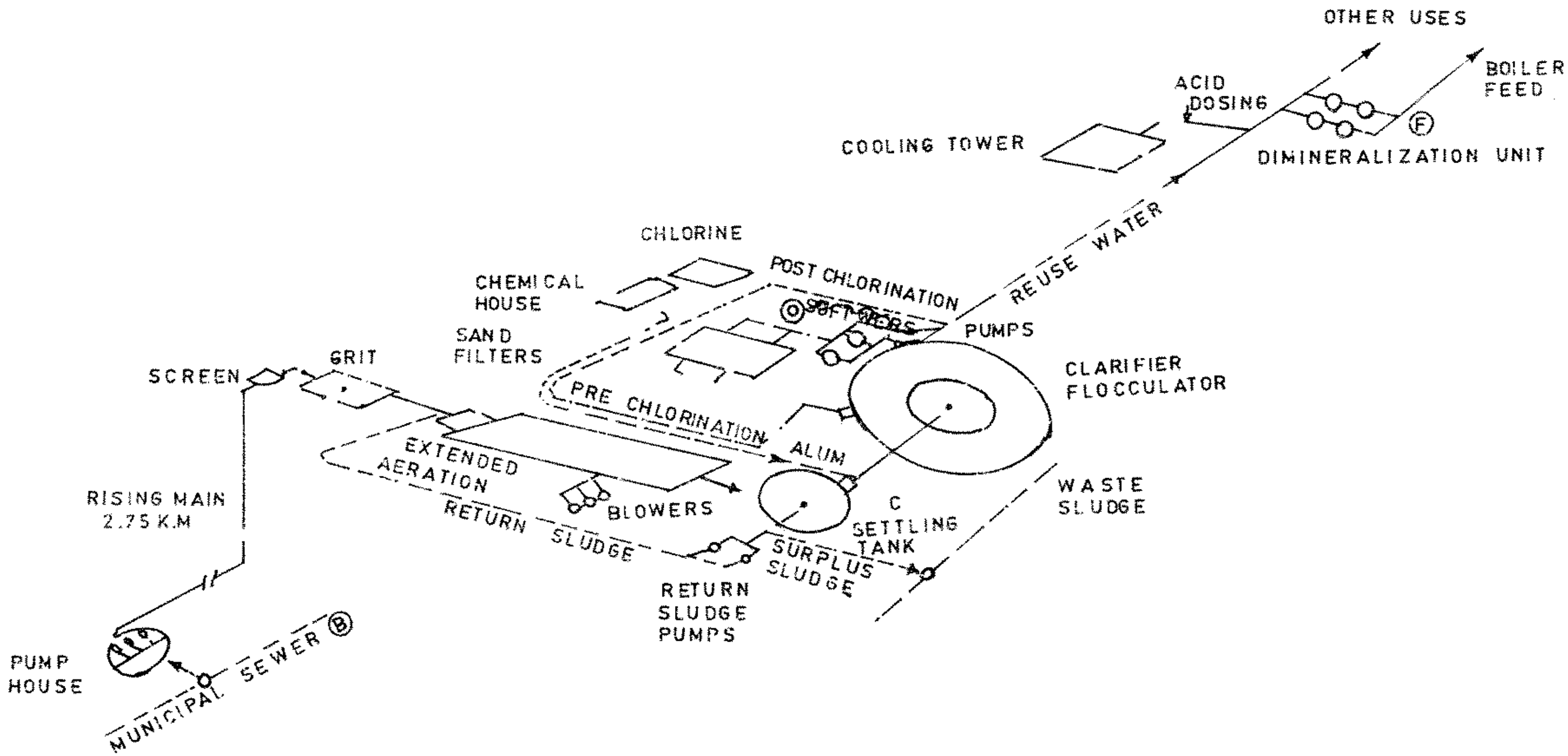

FIG.19.3: ILLUSTRATIVE FLOWSHEET FOR TREATMENT OF MUNICIPAL WASTE WATER FOR REUSE IN COOLING BOILER FEED AND OTHER USES

19.6 REUSE FOR AGRICULTURAL PURPOSES

For general agricultural uses of reclaimed water, the quality guidelines may be useful though it is always advisable to associate an experienced agronomist in deciding on actual water quality requirements, especially in case of large farms. If the water quality after secondary treatment does not meet agricultural use requirements, additional treatment would have to be provided.

Tertiary treatment is mainly needed for meeting coliform and helminth standards which are not met by conventional treatment processes. While coliforms are readily removable by chlorination, helminths are not. Helminth removal can be economically done in the case of relatively large farms by provision of 3-celled oxidation ponds (maturation ponds) of short detention time of 6-7 days only after the regular primary and seondary treatment units (Fig 19.4a). The land requirement of such ponds can generally be found within the relatively large irrigation command area.

For small orchards and farms and for lawns and gardens, helminth removal can be achieved in small land space by using pressure filters or open sand filters rather than oxidation ponds (Fig 19.4b). Chlorination is done for coliform removal. Filteration is also useful where drip irrigation systems are proposed to be used.

19.7 REUSE BY GROUND WATER RECHARGE

A certain amount of unintentional (incidental) ground water recharge occurs during regular land irrigation with fresh water or treated sewage. But intentional recharge at faster precolation rates in soils of required porosity and geological terrain has been limited in India by fresh waters only though treated sewage effluents can also be used.

The availibility of suitable sandy, loamy, or gravelly soils with good infiltrtion characteristics is essential. A number of shallow recharge basins are provided in parallel. Each basin may be a long rectangle, a few hundred meters long dosed with wastewater (pre-treated as necessary) to a depth of about 20-30 cms once or more per day, and operated on an intermittent schedule of a few days wet followed by a few days dry.

Direct recharge systems in permeable soils used in some countries are of the high-rate type and application rates of 1000-3000 cu.m/ha/day have been used with pretreated sewage compared to regular land irrigation rates of only 100-300 cu.m/ha/day. Ground water recharges systems must be differentiated from "deep well" injection systems in which the aim is wastewater disposal to a deep aquifer of poor quality (e.g. brackish aquifer) with no possibility for consumptive use.

The physical, chemical and biological quality of the wastewater has to be kept compatible with the characteristics of the soil and the aquifer into which recharge occurs. Suspended solids, algae, precipitated substances, can affect infiltration rates over a period of time, and the quality of the reclaimed water Hence some pre-treatment of wastewater before recharge is generally required.

The pollution of ground water by nitrates contained in sewage can be controlled by intermittent operation of the recharge basins. Experiments in USA have shown that a sequence of long inundation periods (14 days wet, 7 days dry) yielded about 90% removal of nitrogen whereas with short sequences (2 days wet, 3 days dry) the nitrogen in sewage was converted to nitrates in the percolated water. Longer wet periods with consequent anaerobicity encouraged denitrification. During dry periods, the soil gets aerated and aerobic degradation of organic matter held in the upper layers of the soil occurs.

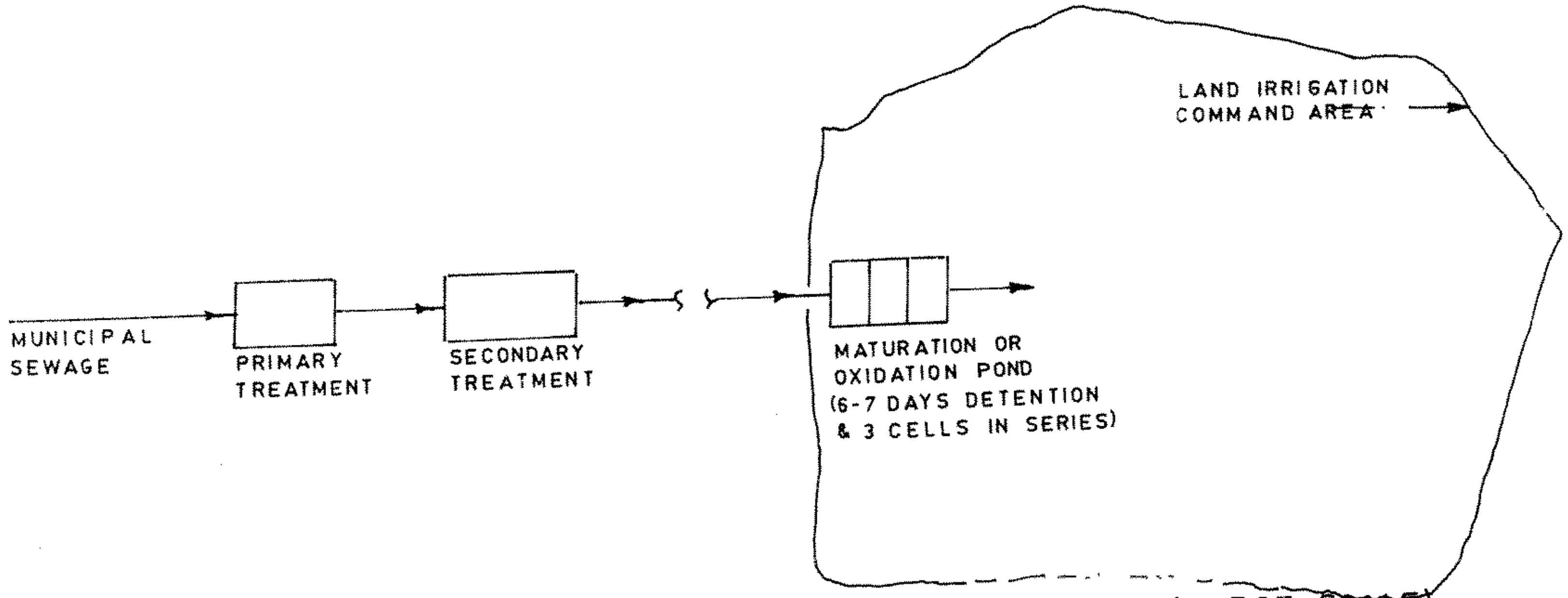

FIG. 19.4 a: TERTIARY TREATMENT FOR LAND IRRIGATION (LARGE SCALE)

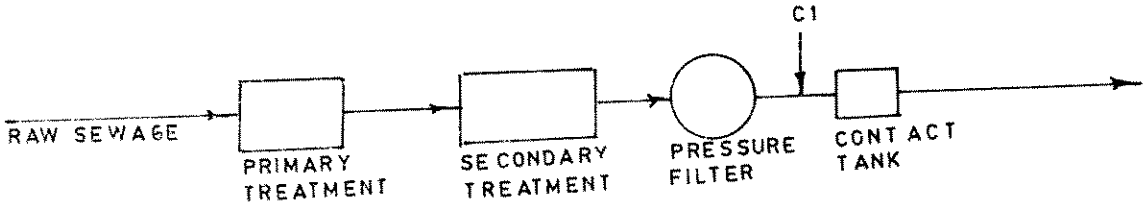

FIG. 19.4 b: TERTIARY TREATMENT FOR SMALL IRRIGATION SYSTEMS
SERVING LAWNS, GARDENS, ORCHARDS, ETC.