Most soils are capable of efficiently removing phosphorus and micro-organisms from the applied wastewater. Heavy metals are also removed well especially in alkaline soils.

Table 19.7 gives the observed efficiency of Rapid Infiltration ponds. A remarkably high degree of removal of most consitituents is achieved.

TABLE 19.7
EFFECTIVENESS OF LAND DISPOSAL TECHNIQUES

Item	Approximate Efficiency of Removal (%)
	Rapid Infiltration Ponds
BOD	99
Suspended Solids	99
N	80
P	90
Heavy Metals	95
Organic compounds	90
Viruses	99+
Bacteria	99+
Total Cations	0 - 75
Total Anions	0 - 50

Data on pre-treated sewage application rates on different types of soils, as well as the optimum wet period - dry period schedules based on Indian experience are not available.

The choice of ground water recharge system must take into account the fact that the treated wastewater so used reduces its availability downstream as a surface water resource. This also occurs when land irrigation is done, but irrigational use helps produce food crops whereas ground water recharge is of no special benefit unless someone downstream abstracts the ground water for reuse, or ground water recharge helps prevent saline water intrusion or recharge helps lift up the general ground water level in the downstream area. Thus, a scheme has to be drawn up on a macro-scale to be benefical.

On a limited scale, wastewater can be treated and recharged into the ground through a basin or well, and abstracted from another well located just 50-100 m downstream so as to use the intervening soil matrix for further treatment of the wastewater to make it fit for reuse in certain industrial purposes.

CHAPTER 20

EFFLUENT DISPOSAL AND UTILISATION

20.1 GENERAL

The effluent from sewage treatment plants may be discharged in receiving waters such as lakes, streams, rivers, estuaries, oceans or on land. The nature and degree of treatment given to the sewage is dependent upon the requirements imposed by the regulatory authorities. It is the large water portion along with small residual organics after treatment that has to be disposed of while the major portion of the organics is handled within the treatment plant itself. The water content of the sewage effluent along with the fertility value of the nutrients serves to make it useful for irrigation and pisciculture; the effluent is also put to low-grade industrial uses where water of high quality is not important or for artificial recharging of aquifers in areas of rapid depletion or underground water sources. Competing land uses, public health impact, energy requirement, aesthetics and biological effects decide the mode of disposal whether on land or in water. The problems encountered in the selection process are complex and demand a multidisciplinary approach.

20.2 DISPOSAL INTO WATER BODIES

Treated effluent conforming to prescribed standards may be disposed into a stream course or into sea or a stagnant body of water. The quality, quantity and use of the receiving water body into which the effluent is discharged decide the degree of treatment required for the sewage. Since the treated waste water may still have a high coliform density, disinfection or any other treatment methods may be considered for reducing the coliform density before disposal of water into the water body.

20.2.1 Disposal into River

Disposal of wastewater in a river causes organic, chemical and microbial pollution. Organic pollution not only depletes the oxygen content in the river resulting in fish kill but also leads to heavy algal growth downstream. The waste assimilating capacity of the river depends on its self-purification properties, the estimation of which is very important to protect and promote the various beneficial uses to which the river water is put to. The wastewater discharge into the river is to be regulated in such a manner that it does not exceed its waste assimilating capacity and the options in this respect include wastwater treatment, wastewater reduction, alternate waste disposal points and methods and increase of the quantity of the available dilution water, where possible.

20.2.2 Disposal into Estuaries

Estuaries behave quite differently with respect to pollution dispersion and they generally have less assimilative capacity when compared to rivers or streams. As in the case of the rivers DO is the most important parameter that governs the presence of fish and other aquatic forms of life in the estuary. The fate and distribution of pollution discharges to an estuary depend on the nature of the pollutant, the type of estuary, well mixed or stratified, location of discharge point, the relative volumes of fresh, saline and wastewater and the mixing characteristics.

20.2.3 Disposal into Ocean

The capacity of the sea to absorb wastewater is less compared to freshwater systems because of its low oxygen and high dissolved solids content, even though the water availability for dilution is high. Since the specific gravity of sea water is greater and temperature lower than that of wastewater, the lighter and warmer wastewater will rise io the surface when discharged into the sea resulting in the spreading of the wastewater as a thin film or sleek. In view of the special characteristics of the marine echo system, the outfall should be carefully located taking into account sea currents, wind direction, wind velocity, tidal cycles etc. To prevent backing up and spreading of wastewater on the sea shore, it is desireable to dispose of wastewater only during low tides. To ensure effective mixing, the wastewater should be taken to a distance of about 11/2 Km into the sea from the shoreline and discharged in deep sea at a point 3 to 5 m below water level. It should be properly supported by piers placed on firm rocky foundation to protect it from external forces, including corrosion and erosion and must be provided with flap gates to prevent tidal waters entering the outfall causing backflow.

20.2.4 Basic Information

The Basic information to be collected for planning effluent outfall works should consist of

i) Studies on the quantity and the characteristics of the treated effluent including its toxicity

ii) hydrographic surveys and examination of available hydraulic and hydrographic records including :

   a) run off records and characteristics of flow both at and below the point of disposal during the lean flow periods in the case of streams

   b) observations on currents and effects of winds and temperature stratification upon the dispersion of the sewage, in the case of lakes, and

   c) tides, the effect of winds, salinity and temperature stratification upon the movement of the sewage, in the case of tidal estuaries.

iii) Studies of possible locations for and forms of sewer outfall in its relation to hydrographic conditions particularly in the case of lakes and ocean outfall, and

iv) Studies of the various uses of the water receiving the sewage effluent, giving due consideration to the protection of water supplies, safeguarding of the bathing and other recreational facilities, conservation and protection of useful aquatic life, the avoidance of unsightly or offensive conditions created by the sewage solids on or in the waters or along the shores, the prevention of sludge bank formation and of the resulting encroachment on water ways and prevention of pollution of water bodies.

When points of effluent discharge are well arranged and effluent quantities are limited, there is no serious threat to ground water quality. However, in many unsewered residential areas, particularly suburban developments, domestic wastes are disposed of through closely spaced individual sewage disposal units sometimes interspersed with water wells. Adequate precautions should be taken to ensure that the water sources are not contaminated by the improper location of cesspools, septic tanks and subsurface dispersion systems. Some of the synthetic detergents are not usually removed by passage through the soil mantle.

20.3 RECLAMATION OF TREATED EFFLUENT

Complete reclamation of sewage effluent is not generally adopted, this being only supplementary to other methods of disposal. Reclamation is restricted to meet the needs depending upon the availablility and cost of fresh water, transportation and treatment costs and the water quality standards and its end uses like watering of lawns and grass lands, cooling, boiler-feed and process water; forming artificial lakes;

wetting of refuse for compaction and composting and raising agricultural crops. Some of these uses may need tertiary treatment as discussed in Chapter 19.

20.4 PISCICULTURE

If local conditions are suitable, partially purified sewage effluent may be used for fish cultrue without further dilution. Raw sewage cannot directly be used for fish cultrue as it does not contain sufficient dissolved oxygen for the survival and growth of fish. The waste stabilisation pond effluent and the percolated effluent from sewage farms have been successfully used in fish culture.

20.5 ARTIFICIAL RECHARGE OF AQUIFERS

Artificial recharge of ground water aquifers is one of the methods for combining effluent disposal with water reuse. Replenishment of ground water sources has been done on a practical scale. Treated effluent has been used to arrest salt water intrusion which may take place due to the lowering of ground water table by excessive pumping to meet large water demands. In the present day when conservation, reclamation and reuse of water are receiving increasing emphasis, sewage effluent constitutes a valuable source for recharging ground water.

20.6 DISPOSAL ON LAND

20.6.1 Sewage Farming

The nutrients in sewage like nitrogen, phosphorus and potassium along with the micronutrients as well as organic matter present in it cound be advantageously employed for sewage farming to add to the fertility and improve the drainage characteristics of the soil, along with the irrigation potential of the water content. However, use of raw sewage or night soil or sullage is fraught with public health dangers. Even application of treated effluent to land has to be carried out with certain precautions as it is not completely free from this risk. A good sewage farm should be run on scientific lines with efficient supervision with the primary objective of disposal of sewage combined with its utilisation to the possible extent in a sanitary manner without polluting the soil, open water courses or artesian waters or contaminating crops raised on the sewage farm, or impairing the productivity of the soil. It should also provide for hygienic safety of the staff to protect them against the infection by pathogenic organisms and helminths.

Though sewage after primary treatment can be applied to the farms, the temptation of providing only primary treatment and eliminating secondary treatment merely on cost considerations should be resisted. Effluent from properly designed waste stabilisation ponds is also suitable for application on land. Under no conditions, application of raw sewage on sewage farms should be permitted.

A moderately permeable soil capable of infiltrating approximately 5 cm/day or more on an intermittent basis is perferable. In general most soils are suitable for farming, provided proper management practices are followed.

20.7 WATER QUALITY CONSIDERATIONS FOR IRRIGATION WATERS

The quality of water for irrigation is determined by the effects of its constituents both on the crop and the soil. The deleterious effects of the constituents of the irrigant on plant growth can result from (i) direct osmotic effects of salts in preventing water uptake by plants, (ii) direct chemical effects upon the metabolic reactions in the plants (toxic effect) and (iii) any indirect effect through changes in soil structure permeability and aeration.

The suitability of an irrigant is judged on the basis of soil properties, quality of irrigation water and salt tolerance behaviour of the crop grown in a particular climate. The water quality ratings along with the specific soil conditions recommended for the country are shown in Table 20.1.

These limits apply to the situations where the ground water table at no time of the year is within 1.5 m from the surface. The values have to be reduced by half if the water table comes up to the root zone. If the soils have impeded internal drainage either on account of presence of hard stratum, unusually high amounts of clay or other morphologic reasons, advisedly the limit of water quality should again be reduced to half. In cases where canal irrigation exists during the lean period, treated wastewater of higher electrical conductivity could be used.

20.7.1 Osmotic Effects

When water is applied for cultivation on land, some of it may run off as surface flow or be lost by direct surface evaporation, while the remainder infiltrates into the soil.

TABLE 20.1
WATER QUALITY RATINGS

Nature of Soil	Crop to be grown	Permissible limit of Electrical Conductivity of Water for safe irrigation (micro-mhos/cm)
Deep black soils and alluvial soils having a clay content more than 30%.	Semi-Tolerant	1500
Fairly to moderately well drained soils	Tolerant	2000
Heavy textured soils having a clay content of 20 - 30%	Semi-Tolerant	2000
Soils well drained internally and having good surface drainage system	Tolerant	4000
Medium textured soils having a clay content of 10 - 20%	Semi-Tolerant	4000
Soils very well drained internally and having good surface drainage system	Tolerant	6000
Light textured soils having a clay content of less than 10%	Semi-Tolerant	6000
Soils having excellent internal and surface drainage	Tolerant	8000

Of the infiltration water, a part be used consumptively, and part is held by the soil for subsequent evapotranspiration and the remaining surplus percolates or moves internally through the soil. The water retained in the soil is known as the `soil solution' and tends to become more concentrated with dissolved constituents as plants take relatively purer water. An excessive concentration of salts in the soil solution prevents water uptake by plants. Table 20.1 shows permissible levels of electrical conductivity (EC) and hence total salts in water for safe irrigation in the four types of soils. It may be pointed out that good drainage of the soils may be a more important factor for crop growth than the EC of the irrigant as leaching of soils results in maintaining a low level of salt in soil solution in the root zone.

20.7.2 Toxic Effects

Individual ions in irrigation water may have toxic effects on plant growth. Table 20.2 lists some of the known toxic elements and their permissible concentration in irrigation waters when continuously applied on all soils and also when used on fine texture soils for short terms. Many of these are also essential for plant growth.

The suggested values for major inorganic constituents in water applied to land are presented in Table 20.3.

Table 20.4 presents the suggested limits for salinity in irrigation waters.

TABLE 20.2
MAXIMUM PERMISSIBLE CONCENTRATION OF TOXIC ELEMENTS IN IRRIGATION WATERS

Element		Maximum Permissible concentration (mg/l)	
		For water used continuously on all soils	For short term use of fine texture soils
Aluminium	Al	1.0	20.0
Arsenic	As	1.0	10.0
Beryllium	Be	0.50	1.0
Boron	B	0.75	2.0
Cadmium	Cd	0.005	0.05
Chromium	Cr	5.0	20.0
Cobalt	Co	0.2	10.0
Copper	Cu	0.2	5.0
Flourine	F	-	10.0
Lead	Pb	5.0	20.0
Lithium	Li	5.0	5.0
Manganese	Mn	2.0	20.0
Molybdenum	Mo	0.005	0.05
Nickel	Ni	0.5	2.0
Selenium	Se	0.05	2.0
Vanadium	V	10.0	10.0
Zinc	Zn	5.0	10.0

TABLE 20.3
SUGGESTED VALUES FOR MAJOR INORGANIC CONSTITUENTS IN WATER APPLIED TO THE LAND

Problem and Related Constituent	Impact on the land *		
	No problem	Increasing Problem	Severe
Salinity			
Conductivity of Irrigation water millimhos/cm	< 0.75	0.75 - 3.00	> 3.00
Permeability			
Conductivity of Irrigation water millimhos/cm	< 0.50	< 0.50	< 0.20
SAR	< 6.00	6.00 - 9.00	> 9.00
Specific Ion Toxicity			
from root absorption			
Sodium (evaluated by SAR) me/l	< 3.00	3.00 - 9.00	> 9.00
Chloride, me/l	< 4.00	4.00 - 10.00	> 10.00
Chloride, mg/l	<142.00	142.00 - 355.00	> 355.00
Boron, mg/l	< 0.50	0.50 - 2.00	2.00 - 10.00
From foliar absorption (sprinklers)			
Sodium, me/l	< 3.00	> 3.00	-
Sodium, mg/l	< 69.00	> 69.00	-
Chloride, me/l	< 3.00	> 3.00	-
Chloride, mg/l	< 106.00	> 106.00	-
Miscellaneous			
NO_3 - N, NH_4 - N mg/l for sensitive crops	< 5.00	5.00 - 30.00	> 30.00
HCO_3, mg/l (only with overhead sprinklers)	< 1.50	1.50 - 8.50	> 8.50
HCO_3, mg/l	< 90.00	90.00 - 520.00	> 520.00
pH	Normal range 6.5 - 8.4		

* : Interpretations are based on possible effects of constituents on crops and/or soils. Suggested values are flexible and should be modified when warranted by local experience or special conditions of crop, soil and method of irrigation.

SAR : Sodium Absorption Ratio.

TABLE 20.4
SUGGESTED LIMITS FOR SALINITY IN IRRIGATION WATERS

Crop Response	Total dissolved solids mg/l	Electrical conductivity mhos/cm
No detrimental effects will usually be noticed.	500	0.75
Can have detrimental effects on sensitive crops.	500 - 1000	0.75 - 1.50
May have adverse effects on many crops.	1000 - 2000	1.50 - 3.00
Can be used for salt tolerant plants on permeable soils with careful management practices.	2000 - 5000	3.00 - 7.50

20.7.3 Impairment of Soil Quality

20.7.3.1 SODIUM HAZARD

In most normal soils, calcium and magnesium are the principal cations held by the soil in replaceable or exchangeable form. Sodium tends to replace calcium and magnesium when continuously applied through irrigation waters. An increase of exchangeable sodium in the soil causes deflocculation of soil particles and promotes compaction, thereby impairing soil porosity and the water and air relations of plants. The sodium hazard of irrigation water is commonly expressed either in terms of percent soluble sodium (PSS) or sodium absorption ratio (SAR) where

$$PSS = \frac{100 \times Na^{+}}{Na^{+} + Ca^{++} + Mg^{++} + K^{+}}$$

or

$$\frac{100 \times Na^{+}}{(Total\ Cations)} \qquad (21.1)$$

and

$$SAR = \frac{Na^{+}}{\left(\frac{Ca^{++} + Mg^{++}}{2}\right)^{\frac{1}{2}}} \qquad (21.2)$$

and the cations are expressed as meq/l. Generally the sodium hazard of soil increases with the increase of PSS or SAR of irrigation water and exchangeable sodium percentage of the soil. The maximum permissible value of PSS in irrigation water is 60. Where waters with higher PSS values are used, gypsum should be added to the soil occasionally for soil amendment. SAR values greater than 9 may adversely affect the permeability of soils.

Hazardous effect of sodium is also increased if the water contains bicarbonate and carbonate ions in excess of the calcium and magnesium and there is a tendency for calcium and magnesium to precipitate as carbonates from the soil solution and thereby increasing the relative proportion of exchangeable sodium. Values of residual sodium carbonate (RSC)* less than 1.25 mg/l are considered safe and above 2.5 mg/l as unsuitable.

* $RSC = (CO_2^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$

where all ion concentrations are expressed as meq/litre.

The effect of potassium on soil is similar to that of sodium but since the concentration of potassium is generally quite small in irrigation waters, it is often omitted from consideration.

20.7.3.2 ORGANIC SOLIDS

While stable organic matter improves porosity of soil, thereby facilitating aeration, an excessive application of unstable organic matter would lead to oxygen depletion in the soil. Depositing of sediments especially when they consist primarily of clays or colloidal material may cause crust formations which impede emergence of seedlings. In additon, these crusts reduce infiltration with the consequent reduction of irrigation efficiency and less leaching of saline soils.

20.7.4 Other Considerations

Soils are usually well buffered systems. The pH is not significantly affected by application of irrigation water. However, extreme values below 5.5 and above 9.0 will cause soil deterioration. Development of low pH values in soils promotes dissolution of elements such as iron, aluminium or manganese in concentrations large enough to be toxic to plant growth. Similarly, water having high pH values may contain high concentration of sodium, carbonates and bicarbonates, the effect of which have been discussed earlier.

Chlorides and sulphates are toxic to most crops in high concentrations. Ordinarily, the detrimental effects of salinity on crop growth become perceptible first.

Excessively high or low temperature in irrigation water may affect crop growth and yields. A desirable range of water temperature is from 12 to 30°C.

20.8 DESIGN AND MANAGEMENT OF SEWAGE FARMS

Optimum utilisation of sewage in agriculture means the complete and judicious use of its three main components, viz., water, plant nutrients and organic matter on the farms in such a way that (a) the pathogenic infection is neither spread among the farm workers nor among the consumer of sewage farm products, (b) the ground water is not contaminated, (c) there is maximum outturn per unit volume of sewage (d) there is no deterioration of the soil properties and (e) none of the three components is wasted.

20.8.1 Management of Water in Sewage Farming

The principle to be borne in mind in irrigation management is to irrigate only when it is required and only to the extent it is required by the crop. The water requirement depends on the soil type, the crop and the climate. The water requirement (cm) of main soil types to be wetted to a depth of 30 cms required by most of the crops is given in Table 20.5.

TABLE 20.5
WATER REQUIREMENTS (cm) TO WET DIFFERENT SOILS TO A DEPTH OF 30 CM.

Type of Soil	Requirement (cm)
Sand	1.25
Sandy Loam	2.50
Loam	5.00
Clay Loam	6.25
Clay	7.50

Water requirement of crops vary with the duration of their growing season and the amount of growth in unit time. Details for some of the Indian crops which can be grown on sewage farms are given in Table 20.6.

TABLE 20.6
WATER REQUIREMENTS OF CROPS

	Crops	Growing Period (days)	Total Water requirements (cm)	Optimum pH range
1.	Soyabean	110 - 120	37.50	6.0 - 8.5
2	Mustard	120 - 140	37.50 - 55.00	6.0 - 9.5
3.	Sunflower (kharif)	100 - 110	37.50	6.0 - 8.5
4.	Sunflower (rabi)	110 - 120	87.50	6.0 - 8.5
5.	Barley	88	35.25	6.5 - 8.5
6.	Cotton	202	105.50	5.0 - 6.0
7.	Jowar	124	64.25	5.5 - 7.5
8.	Maize	100	44.50	5.5 - 7.5
9.	Linseed	88	31.75	5.0 - 6.5
10.	Rice	98	104.25	5.0 - 6.0
11	Milling varieties of Sugarcane	365	237.50	6.0 - 8.0
12.	Wheat	88	37.00	5.5 - 7.5

20.8.1.1 HYDRAULIC LOADING

The elements to be considered in determining hydraulic loading are the quantity of effluent to be applied, precipitation, evapotranspiration, percolation and run off. For irrigation systems, the amount of effluent applied plus precipitation should equal the evapotranspiraton plus a amount of percolation. In most cases, surface runoff from fields irrigated with sewage effluent is not allowed or must be controlled. The water balance then will be

Precipitation + Wastewater application = Evapotranspiration + percolation

Seasonal variations in each of these values should be taken into account by evaluating the water balance for each month as well as the annual balance.

The irrigation requirement of any crop is not uniform throughout its growing period. It varies with the stage of growth. For example grain crops require maximum irrigation during the time of ear-head and grain formation. Sugarcane requires more frequent irrigation from about the sixth or the seventh month onwards. In case of fruit trees the irrigation has to be stopped during their resting period. If the irrigation is not given at critical growth stages of the crop, it results in lower yields.

Water requirement of crop at different stages of growth can be determined either directly (gravimetrically) or indirectly by use of Tensiometers or Irrometers or Gypsum blocks. Normally, when there is about 50% depletion of available moisture in the soil, irrigation is recommended. The crop plants themselves show signs of moisture stress. One has to be always on the look out for such first symptoms to determine the need for irrigation. Some plants like sunflower also serve as good indicators of stress symptoms. Sunken screen pan evaporimeter could also be used for estimating use of water by crop plant and scheduling irrigation.

The extent of irrigation depends on the depth of irrigation to be given and volume of water required to wet the soil to the required depth. If tensiometers or Gypsum blocks are embedded at the required depths, they would indicate the stage when the soil at that depth is saturated. Nearly about 70 to 80% roots of most crops are found in the first 30 cm. of the soil. Some may go deeper to the next 30 cm. Normally, in irrigating medium type of soil it is wetted to about 30 cm. depth or a little more.

If the figures for water requirements for crop as mentioned in Table 20.6 are to be satisfied, much higher hydraulic loadings have to be applied since a portion of sewage after its passage through the soil is carried away by the sub-soil underdrainage system. The extent of desirable percolation rate depends upon the salinity of the irrigant. The applicable hydraulic loadings of settled sewage are therefore dependent upon the type of soil and the recommended rates are given in Table 20.7.

Sewage conforming to the norms should be applied to the soil by strip, basin or furrow irrigation. Wild flooding should not be adopted. Sprinkler irrigation could be used for adequately treated sewage.

The distribution channels should be properly graded to avoid ponding and silting. It is advisable that the main distributary is lined.

TABLE 20.7
RECOMMENDED HYDRAULIC LOADINGS

	Type of Soil	Hydraulic Loading (Cu.M/hectare/day)
i)	Sandy	200 - 250
ii)	Sandy Loam	150 - 200
iii)	Loam	100 - 150
iv)	Clay Loam	50 - 100
v)	Clayey	30 - 50

20.8.1.2 ORGANIC LOADING

11.0 to 28.0 Kg/ha/day of organic loading in terms of BOD_5 is needed to maintain a static organic matter content in the soil that helps to conditions the soil by microorganisms without soild clogging. Higher loading rates can be managed depending on the type of system and the resting period. When primary effluent is used organic loading rates may eceed 22.0 Kg/ha/day without causing problems.

20.8.1.3 IRRIGATION INTERVAL

Resting periods for surface irrigation can be as long as 6 weeks but is ussually between one and two weeks during which the soil bacteria break down organic matter and the water is allowed to drain from the top few centimeters, thus restoring aerobic condition in the soil. It depends upon the crops, the number of individual plots in the rotation cycle and management consideration.

20.8.2 Management of Soil

A well-planned program of crop growth and harvesting can help to maintain a soil receptive to effluent application. Crop uptake of nutrients followed by removal of the crop from the field increases the capacity of the land for removal of nutrients from the next effluent application.

It is necessary that the soil is given rest for about 3 to 4 months every alternate or third year preferably in summer months. This can be achieved if the farm is designed on the basis of water requirement in the winter season. After the harvest of the crop, the soil may be opened up by deep ploughing and cultivated appropriately to make it as porous and permeable as possible before the next crop is raised.

Maintenance of soil oxygen level is very important as it is required for root respiration and a number of biological processes in the soil. Refilling of oxygen in the pores in the surface layers of soil depends upon the reestablishment of contact of the soil with the atmosphere. This process can be accelerated by suitable cultural practices and by providing sufficient irrigation intervals. It is, therefore desirable that an intercultural operation is followed as soon as the soil condition allows working after every irrigation. It should always be seen that the soils of sewage farm should have a surplus of oxygen than that normally required in the ordinary farm because the soil oxygen has to perform an additional job of satisfying the BOD of sewage. The intercultural operation following every one or two irrigations is all the more necessary in the case of clayey soil. In the areas where rainfall is low, it is desirable to flood the soils with irrigant at least once a year to leach down the salts accumulated in the soil. If the soil salinity and alkalinity pose a serious problem, amendment of soil with the required quantity of gypsum should be carried out. Subsoil drainage is very important. Poor drainage should be improved by installing underground drains.

Sewage farm fields must be laid out in accordance with the natural slope of the terrain to eliminate the irregularities of distribution.

On sewage farms, no sewage should be allowed to flow beyond the farm boundaries. With this in view, protection banks are arranged along the lowest lying boundaries of each crop rotation field.

20.8.3 Utilisation of Plant Nutrients

Sewage contains 26-70 mg/l of nitrogen (N), 9-30 mg/l of Phosphate (P_2O_5) and 12-40 mg/l or even more of potash (K_2O). The recommended dosages for N, P and K for majority of field crops are in the ratio of 5:3:2 or 3 respectively. The figures for N, P, and K contents of sewage on the other hand show that sewage is relatively poor in phosphates. Excess potash is not of significance but a relative excess of nitrogen affects crop growth and development. Crops receiving excessive dosage of nitrogen show superfluous vegetative growth and decrease in grain or fruit yield. The phosphate deficit of sewage, therefore, should be made good by supplementing with phosphate fertilisers, the extent of phosphate fortification depending upon the nature of crop and its phosphate requirements. As the availability of phosphate is low in the irrigant it would be desirable to apply the required quantity of phosphatic fertiliser at the time or even (about a fortnight) before the sowing or planting of the crop.

Even when sewage nutrients are balanced by fortification, irrigation with such sewage may supply excessive amount of nutrients resulting in waste or unbalanced growth of plants with adverse effects on yields. It may therefore be necessary to dilute the sewage. Dilution also helps in reducing the concentration of dissolved salts and decomposable organic matter in the sewage thus decreasing hazards to the fertility of the soil. It is desirable to limit the BOD and total suspended solids of sewage to be disposed on land for irrigation, as per relevant standards.

20.8.4 Land requirements

The field-area requirement for farming based on the liquid loading rate is calculated by

$$A = [3.65 Q / L]$$

Where

A = Field-area in hectares

Q = Flow rate in Cu.m./day

L = Annual liquid loading, cm/year

For loading of constituents such as Nitrogen

$$A = [0.365 CQ / L_c]$$

Where

C = Concentration of the constituents, mg/l.

L_c = Loading rate of the constituent, kg/ha/year.

20.9 ALTERNATIVE ARRANGEMENTS DURING NON-IRRIGATING PERIODS

During rainy and non-irrigating seasons, sewage farm may not need any water for irrigation. Even during irrigating season, the water requirement fluctuates significantly. Hence satisfactory alternative arrangements have to be made for the disposal of sewage on such occasions either by storing the excess wastewater or discharging it elsewhere without creating environmental hazards. The following alternatives are generally considered :

1. Provision of holding lagoons for off-season storage. They enable irrigation of a fixed area of land to varying rates of crop demand. They may also serve as treatment units such as aerated or stabilisation lagoons, provided the minimum volume required for treatment is provided beyond the flow-balancing requirement

2. Provision of additional land where wastewater is not required on the main plot of land

3. Discharge of surplus wastewater to river or into sea with or without additional treatment. Combining surface discharge facilities with irrigation system is quite common and often quite compatible

4. Resorting to artifical recharge in combination with an irrigation system where feasible.

20.10 PROTECTION AGAINST HEALTH HAZARDS

Sewage farms should not normally be located within 1 Km of sources of centralised water supply, or mineral springs; in the vicinity where waterbearing layers prevail; or on areas with ground water levels less than 2 m below the surface. Measures should be taken to prevent pollution of artesian water. Sewage farms must be separated from residential areas by at least 300 m.

The Public Health aspects of sewage farming should be considered from the view points of exposure of farm workers to sewage and that of the consumers to the farm products.

Evidence is on the increase to show that labourers working on the sewage farms suffer from a number of ailments directly attributed to handling of sewage. In view of this it is desirable to disinfect sewage and where feasible mechanise sewage farm operation.

Sewage or wastewater of individual enterprises engaged in the processing of raw material of animal origin or hospitals, biofactories and slaughter houses should in addition be disinfected before they are taken to the sewage farms.

Agricultural utilisation of sewage containing radio active substances are carried out in accordance with special instructions.

The staff of sewage farms must be well educated in the sanitary rules on the utilisation of sewage for irrigation as well as with personal hygiene.

All persons working in sewage farms must undergo preventive vaccination against enteric infections and annual medical examination for helimnthoses and provided treatment if necessary.

Sewage farms should be provided with adequate space for canteens with proper sanitation, wash-stands and lockers for irrigation implements and protective clothing; besides, safe drinking water must be provided for the farm workers and for population residing within the effective range of the sewage farms.

All the farm worker should be provided with gum boots and rubber gloves which must compulsorily be worn while at work. They should be forced to observe personal hygiene such as washing after work as well as washing before taking food. The use of antiseptics in the water used for washing should be emphasized. The farm worker should be examined medically at regular intervals and necessary curative measures enforced.

Cultivation of crops which are eaten raw should be banned. Cultivation of paddy in bunded fields is likely to give rise to sanitation problems and hence is undesirable. Growing of nonedible commercial crops like cotton, jute, fodder, milling varieties of sugarcane and tobacco would be suitable. Cultivation of grasses and fooder legumes, medicinal and essential oil yielding plants like menthal and citronella may be allowed. Cultivation of cereals, pulses, potatoes and other crops which are cooked before consumption may be permitted, if sewage is treated and care is taken in handling the harvests to ensure that they are not contaminated. Cultivation of crop exclusively under seed multiplication programmes would be advantageous as these are not consumed. As an additional safeguard, sewage irrigation should be discontinued at least two months in advance of harvesting for fruits and berries, one month for all kinds of vegetables and a fortnight for all other crops. Direct grazing on sewage farms should be prohibited.

20.11 STANDARDS

It is necessary to adhere to the standards laid down by the Pollution Control Boards/Environmental Protection Act with regard to the quality of the sewage to be discharged into a body of water, inland or marine, or on land for farming purposes or into underground for purposes of recharge. Wherever, these provisions do not exist, the standards laid down by the Bureau of Indian Standards may be adhered to.

CHAPTER 21

ON-SITE SANITATION

21.1 BACKGROUND

The conventional off-site excreta disposal method - water borne sewarage system followed by a sewage treatment and disposal plant, is an expensive option and not affordable by low income communities and by small comunities in rural areas. This resulted in the development of several alternative low cost on- site disposal methods, with almost the same health benefits. However, over a period of time most of these options have been discarded, mostly due to various operational reasons and only two options - Septic tanks and Twin pit Pour Flush latrines are being widely used. Therefore in this chapter, while the septic tank and twin pit pour flush latrines are discussed in detail, only an overview of other options is given.

21.2 SEPTIC TANK

A septic tank is a combined sedimentation and digestion tank where the sewage is held for one to two days. During this period, the suspended solids settle down to the bottom. This is accompanied by anearobic digestion of settled solids (sludge) and liquid, resulting in reasonable reduction in the volume of sludge, reduction in biodegradable organic matter and release of gases like carbon dioxide, methane and hydrogen sulphide. The effluent although clarified to a large extent, will still contain appreciable amount of dissolved and suspended putrescible organic solids and pathogens. Therefore the septic tank effluent disposal merits careful consideration. Because of the unsatisfactory quality of the effluent and also the difficulty in providing a proper effluent disposal system, septic tanks are recommended only for individual homes and small communities and institutions whose contributory population does not exceed 300. For larger communities, septic tanks may be adopted with appropriate effluent treatment and disposal facilities.

21.2.1 Design

Several experiments and performance evaluation studies, have established that only about 30% of the settled solids are anaerobically digested in a septic tank. In case of frequent desludging, which is necessary for satisfactory effluent quality, still lower digestion rates have been reported. All these studies have proved that when the septic tank is not desludged for a longer period i.e., more than the design period, substantial portion of solids escape with the effluent. Therefore for the septic tank to be an efficient suspended solids remover, it should be of sufficient capacity with proper inlet and outlet arrangements. It should be designed in such a way that the sludge can settle at the bottom and scum accumulates at the surface, while enough space is left in between, for the sewage to flow through without dislocating either the scum or the settled sludge. Normally sufficient capacity is provided to the extent that the accumulated sludge and scum occupy only half or maximum two- thirds the tank capacity, at the end of the design storage period.

Experience has shown that in order to provide sufficiently quiescent conditions for effective sedimentation of the suspended solids, the minimum liquid retention time should be 24 hours. Therefore, considering the volume required for sludge and scum accumulation, the septic tank may be designed for 1 to 2 days of wastewater retention.

The septic tanks are normally rectangular in shape and can either be a single tank or a double tank. In case of double tank, the effluent solids concentration is considerably lower and the first compartment is usually twice the size of the second. The liquid depth is 1-2 m and the length to breadth ratio is 2-3 to 1. Recommended sizes of septic tanks for individual households (upto 20 users) and for housing colonies (upto 300 users) are given below in tables 21.1. and 21.2 respectively :

TABLE 21.1
RECOMMENDED SIZES OF SEPTIC TANK UPTO 20 USERS

No. of Users	Length (m)	Breadth (m)	Liquid depth ((cleaning interval of)	
			2 years	3 years
5	1.5	0.75	1.0	1.05
10	2.0	0.90	1.0	1.40
15	2.0	0.90	1.3	2.00
20	2.3	1.10	1.3	1.80

Note 1 : The capacities are recommended on the assumption that discharge from only WC will be treated in the septic tank.

Note 2 : A provision of 300 mm should be made for free broad.

Note 3 : The sizes of septic tank are based on certain assumption on peak discharges, as estimated in IS : 2470 (part 1) - 1985 and while choosing the size of septic tank exact calculations shall be made.

TABLE 21.2
RECOMMENDED SIZES OF SEPTIC TANK FOR RESIDENTIAL COLONIES

No.of Users	Length (m)	Breadth (m)	Liquid depth ((cleaning interval of)	
			2 years	3 years
50	5.0	2.00	1.0	1.24
100	7.5	2.65	1.0	1.24
150	10.0	3.00	1.0	1.24
200	12.0	3.30	1.0	1.24
300	15.0	4.00	1.0	1.24

Note 1 : A provision of 300 mm should be made for free board.

Note 2 : The sizes of septic tank are based on certain assumptions on peak discharges, as estimated in IS : 2470 (Part 1)-1985 and while choosing the size of septic tank exact calculations shall be made.

Note 3 : For population over 100, the tank may be divided into independent parallel chambers ofmaintenance and cleaning.

21.2.2 Construction Details

The inlet and outlet should not be located at such levels where the sludge or scum is formed as otherwise, the force of water entering or leaving the tank will unduly disturb the sludge or scum. Further, to avoid short circulting, the inlet and outlet should be located as far away as possible from each other and at different levels. Baffles are generally provided at both inlet and outlet and should dip 25 to 30 cm into and project 15 cm above the liquid. The baffles should be placed at a distance of one fifth of the tank length from the mouth of the straight inlet pipe. The invert of the outlet pipe should be placed at a level 5 to 7 cm below the invert level of inlet pipe. Baffled inlet will distribute the flow more evenly along the width of the tank and similarly a baffled outlet pipe will serve better than a tee-pipe.

For larger capacities, a two-compartment tank constructed with the partition wall at a distance of about two-thirds the length from the inlet gives a better performance than a single compartment tank. The two compartments should be interconnected about the sludge storage level by means of pipes or square openings of dia or side length respectively of not less than 75 mm.

Every septic tank should be provided with ventilation pipes, the top being covered with a suitable mosquito proof wire mesh. The height of the pipe should extend at least 2 m above the top of the highest building within a radius of 20 m.

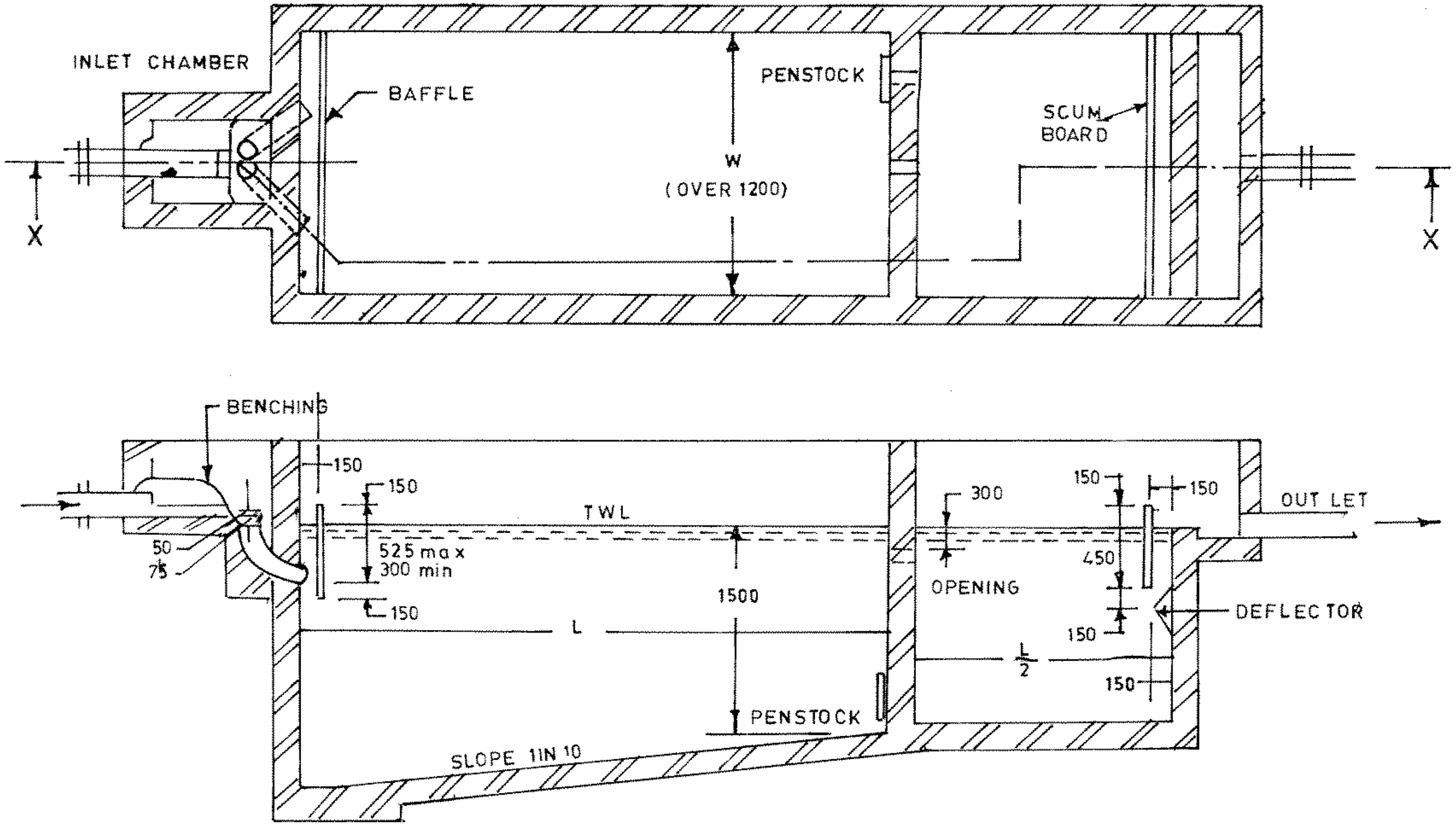
Septic tanks may either be constructed in brick work, stone masonry or concrete cast in situ or pre-cast materials. Pre-cast household tank made of materials such as asbestos cement could also be used, provided they are watertight and possess adequate strength in handling and installing and bear the static earth and superimposed loads.

All septic tanks shall be provided with watertight covers of adequate strength. Access manholes of adequate size shall also be provided for purposes of inspection and desludging of tanks.

The floor of the tank should be of cement concrete and sloped towards the sludge outlet. Both the floor and side wall shall be plastered with cement mortar to render the surfaces smooth and to make them water tight. A typical two compartment septic tank is shown in Figure 21.1.

21.2.3 Sludge withdrawal and Disposal

When sludge is drawn off from the bottom of the tank, at first the small quantity of sludge in the immediate vicinity of the outlet or suction pipe is withdrawn. This is followed by drawing off sewage, because the sludge, being only slightly heavier but much more viscous than the sewage, lies away from the point of outlet and the scum remains floating on the surface. With continued draw-off more sewage is removed, until finally only sludge and scum remain in the tank. These come off last, and then only if there is sufficient slope on the floor of the tank, force them to gravitate to the outlet. This is the reason for the slow bleeding-off of sludge from steep bottomed pyramidal sedimentation tanks and for desludging the septic by complete emptying. If septic tanks are desludged by partial removal only of the contents, they become more and more filled with sludge and scum, and the quality of the effluent deteriorates soon. For some reasons, desludging of septic tanks under hydrostatic head by means of a sludge pipe -collecting of sludge from the lowest point in the tank and discharging at a higher level, -should be discouraged. As far as particable manual handling of sludge should be avoided. If possible particularly in case of densely populated large cities, mechanical vaccum tankers should be used by the municipal authorities to empty the septic tanks. Alternately, where space is not a constraint, a sludge pipe -with a delivery valve to draw the sludge as and when required, -be installed at the bottom of the tank to empty its contents into a sump, for subsequent disposal on land or sent for further treatment. Spreading of sludge on the ground in the vicinity should not be allowed. Portable pumps may also be used for desludging in which case there will be no need for sludge pipe or sludge sump.



SECTION XX

ALL DIMENSIONS IN mm

FIG.21.1: TYPICAL SKETCH OF TWO COMPARTMENT SEPTIC TANK FOR POPULATIONS OVER 50 (IS : 2470 (PART 1)-1985)