ENVIRONMENTAL ENGINEERING
(23HPC0119)

LECTURER NOTES

III-B.TECH & II-SEM

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CIVIL ENGINEERING					
III B.Tech – II Semester					
Course Code	**ENVIRONMENTAL ENGINEERING**	**L**	**T**	**P**	**C**
23HPC0119		3	0	0	3

Course Objectives:

The objectives of this course are to make the student to:

1. **Understand** the sources, demand estimation, and quality parameters of water.
2. **Apply** water treatment processes for purification and supply.
3. **Analyze** storage, distribution, and operation of water supply systems.
4. **Design** sewerage systems, stormwater drainage, and plumbing networks.
5. **Evaluate** sewage treatment, sludge management, and water reuse methods.

Course Outcomes:

Upon successful completion of this course, students will be able to:

1. **Explain** water sources, quality standards, and waterborne diseases.
2. **Design** unit processes of water treatment plants.
3. **Analyze** water distribution networks and pumping stations.
4. **Design** sewerage systems, including stormwater and sanitary sewers.
5. **Assess** sewage treatment methods and advanced wastewater management techniques.

CO – PO Articulation Matrix:-

Course Outcomes	**PO 1**	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PSO1**	**PSO2**
CO -1	3	2	2	1	-	3	3	1	-	1	-	2	3	3
CO -2	3	3	3	2	2	2	2	1	-	-	-	1	3	3
CO -3	3	3	3	2	2	2	3	1	-	-	-	1	3	3
CO -4	3	3	3	2	2	2	3	1	-	-	-	1	3	3
CO -5	2	2	2	1	3	3	3	1	-	1	1	2	2	2

UNIT – I

WATER SUPPLY

Estimation of Surface and Subsurface Water Resources - Predicting Demand for Water- Impurities of Water and Their Significance – Physical Chemical and Bacteriological Analysis - Waterborne Diseases - Standards for Potable Water. Intake of Water: Pumping and Gravity Schemes

UNIT – II

WATER TREATMENT

Objectives - Unit Operations and Processes - Principles, Functions, and Design of Water Treatment Plant Units, Aerators of Flash Mixers, Coagulation and Flocculation – Clarifloccuator- Plate and Tube Settlers - PulsatorClarifier - Sand Filters - Disinfection - Softening, Removal of Iron and Manganese - Defluoridation- Softening - Desalination Process - Residue Management - Construction, Operation and Maintenance Aspects

UNIT – III

WATER STORAGE and DISTRIBUTION

Storage and Balancing Reservoirs - Types, Location and Capacity. Distribution System: Layout, Hydraulics of Pipe Lines, Pipe Fittings, Valves Including Check and Pressure Reducing Valves, Meters, Analysis of Distribution Systems, Leak Detection, Maintenance of Distribution Systems, Pumping Stations and Their Operations - House Service Connections.

UNIT – IV

PLANNING and DESIGN of THE SEWERAGE SYSTEM

Characteristics and Composition of Sewage - Population Equivalent - Sanitary Sewage Flow Estimation - Sewer Materials - Hydraulics of Flow in Sanitary Sewers - Sewer Design - Storm Drainage-Storm Runoff Estimation - Sewer Appurtenances - Corrosion in Sewers - Prevention and Control – Sewage Pumping-Drainage in Buildings - Plumbing Systems for Drainage

UNIT – V

SEWAGE TREATMENT and DISPOSAL

Objectives - Selection of Treatment Methods - Principles, Functions, - Activated Sludge Process and Extended Aeration Systems - Trickling Filters - Sequencing Batch Reactor(SBR) - UASB - Waste Stabilization Ponds - Other Treatment Methods - Reclamation and Reuse of Sewage - Recent Advances in Sewage Treatment - Construction, Operation and Maintenance Aspects. - Discharge Standards-Sludge Treatment -Disposal of Sludge

TEXT BOOKS:

1. Environmental Engineering by H. S Peavy, D. R. Rowe, G. Tchobanoglous, McGraw Hill Education (India) Pvt Ltd, 2014
2. Environmental Engineering, I and II by BC Punmia, Std. Publications.

REFRENCE BOOKS:

1. Environmental Engineering, I and II by SK Garg, Khanna Publications.
2. Environmental Pollution and Control Engineering CS Rao,Wiley Publications
3. Waste water engineering by Metcalf and Eddy, McGraw Hill, 2015.
4. Environmental Engineering by D. P. Sincero and G.A Sincero, Pearson 2015.
5. Water and Waste Water Technology by Mark J Hammar and Mark J. Hammar Jr. Wiley, 2007.

Online Learning Resources:

https://nptel.ac.in/courses/103107084

UNIT – I WATER SUPPLY Estimation of Surface and Subsurface Water Resources - Predicting Demand for Water- Impurities of Water and Their Significance - Physical, Chemical and Bacteriological Analysis - Waterborne Diseases - Standards for Potable Water. Intake of Water: Pumping and Gravity Schemes.

INTRODUCTION

SOURCES OFWATER:

i) Surfacewater
- Pondsandlakes
- Streamsandrivers
- Storagereservoirs
- Oceans

ii) Sub- surfacewater (or)undergroundsources
- Springs
- Infiltrationgalleries
- Infiltrationwellsand
- OpenWellsandtube-wells.

Surfacewater:
Waterthat getscollected onthesurfaceoftheground ortoplayer ofabodyofwater iscalled surface water.

PondsandLakes:
Anaturallargesizeddepressionformedwithinthe surfaceoftheearth, whengetsfilled with water is known as pond or lake.Thedifferencebetweenthepondandlakeisonlysize. If size is small, its termed as pond, large size lake Flow of water in lake is like flow in stream channel Quality of water in lake is good. Qualityofwater availableinlakeissmall. Qualitydependsuponthecatchment areaofthe lakebasin, annualrainfalland geological formation. Duetosmallerquantityofwateravailable forthem, lakesarenotconsideredasprincipal sources of water supplies.

Streamsand Rivers:
Smallstreamchannels feedtheirwaterstothe lakeorriverswhichisnot usedforwater Supply.Larger andperennialstreamsareuseda sourceofwater byprovidingstoragereservoirs, barrages etc.Rivers are most important sources ofwater for public supply. Qualityofwaterobtained fromrivers isgenerallynotreliable.

StorageReservoirs:
Barrier inthe formofdam, maybeconstructedacrosstheriver so astoformapoolof water on the upstream side of the barrier.Thispoolor artificial lake formed ontheupstreamsideofthedamisknownastorage reservoir.Watercanstoreinreservoircanbeusednotonlyforwatersupplybut also forother purposes.
Variouskindsofdamsare
- Earthdams+madeofsoil

- Rockfilldams+madeoflooserocks
- Solidmasonrygravitydams–madeofstone masonry.

Oceans:
Not usedaswatersupplysource normally.

Sub-surfacewater(or)undergroundsources:
Springs:
Naturaloutflow ofgroundwateratthe earth'ssurfaceformsa spring
Apervious layer sandwichedbetweentwoimperviouslayers forma spring.
Capableofsupplyingverysmallamount ofwater,notrecommended forwatersupplies. Good developed springs can sometimes use for water supply source for small towns, especially in hilly areas.

Thetwo typesofspringsare
a) Gravitysprings–whenthegroundwater raiseshighandwateroverflowsthroughthe sides of a natural; valley or depression.
b) Surface springs – sometimes an impervious obstruction (or) stratumsupporting the undergroundstoragesbecome inclinedcausingwatertabletogo upandget exposedto the ground surfaces.
c) Artesiansprings–whenwatercomesoutofpressure it'scalledartesiansprings. Since water comes out of pressure; theyare able to provide higher yields and may be considered as source of water supply.

InfiltrationGalleries:
Horizontaltunnelsconstructedat shallowdepth(3-5m) alongthebanksofriversthrough the water bearing strata.
Alsocalledashorizontalwells.
Constructedofmasonrywallswithroofslabsandextractwaterfromtheaquifer by various porous lateral drain pipes located at suitable intervals in the gallery.
Dischargefromgallerycan becomputedusing Darcy'slaw,Q=KiA

Infiltration Wells:
Shallowwells constructedinseriesalongthebanksofariver inordertocollecttheriver water seeping through their bottoms
Constructedofbrickmasonrywithopenjoints.
Various infiltrationwellsare connected byporouspipesto a sumwell,calledjackwell.

Open wells:
Openmasonrywellshavingbiggerdiameterandsuitable forlow discharge(18 cumecs/hr). Dischargeislimitedto3to 6l/s.Diametersvaryfrom2to 9mand lessthan20min depth. Yield is limited. Canput8to10cmdiameterborehole inthecenterofthewell, toextract additional water.

Tubewells:

Deepas70to 300mandtapmorethanoneaquifer Yield as high as 200 to 220 l/s.

Types:

a) deeptube well

b) shallowtubewell

c) cavitytypetubewell –drawswaterfromthebottomofwell

d) screentypetubewell–drawnfromthesides

1. Strainertubewell

2. Slottedpipegravelpacktubewell

OBJECTIVESOFPUBLICWATERSUPPLY:

- Tosupplysafeand wholesomewaterto theconsumers.
- To supplywaterinadequate quantity.
- Tomakewater availablewithineasyreachoftheconsumersso asto encouragethe general cleanliness.
- A water distribution systemconsists ofa networkofpipelines ofvarious sizes with controlvalvesforcarryingwatertoallstreetsandsupplyingwaterto theconsumers through the service connections to the properties.
- Waterdistributionsystemmaybeeither continuousorintermittent.

REQUIREMENTSOFWATERSUPPLY:

- Waterqualityshouldnotgetdeterioratedinthedistributionpipes.
- Itshould becapableofsupplyingwaterat allthe intendedplaceswithsufficient pressure head.
- Itshouldbecapableofsupplyingtherequisiteamountofwater duringfirefighting.
- Thelayout shouldbesuchthat noconsumerwouldbewithoutwatersupply,during the repair of any section of the system.
- Allthedistributionpipesshould bepreferablylaid one meterawayorabovethesewer lines.
- Itshouldbefairlywater-tightastokeeplossesduetoleakagetotheminimum.

NEEDOFPROTECTEDWATER SUPPLY:

- Thesource
- Quantityofwater
- Check calculation
- Distanceanddifference inelevation
- Qualityofwater
- Methodsofpurification
- Servicereservoir
- Distributionsystem

PLANNINGFACTORSFORPUBLICWATER SUPPLY:

- PopulationForecast
- AssessmentofWater Demand
- RecordofIndustry
- RecordofPublicPlaces

REQUIREMENTSOFWATERFORVARIOUS USES:

- Drinking&Cooking
- Bathing
- Washingofclothesand utensils
- Gardening
- Swimmingpools,Fountains, etc.
- FireFighting and
- Trades &Industries

TYPESOFWATERDEMAND:

- DomesticDemand
- Commercial&InstitutionalDemand
- IndustrialDemand
- PublicDemand
- FireDemand
- CompensateLosses

DomesticDemand

- Waterrequiredfordrinking,bathing,cooking,washing etc.
- Waterdemand dependsonhabits,socialstatus,climateandcustomofpeople.
- In India, the average domestic consumption under normal condition is 135 litres/capita/day.
- For developedcountries, theaveragedomesticconsumptionunder normalconditionis 350 litres/capita/day.
- The increase in water consumption in developed countries is mainly due to use of air coolers, air conditioners, maintenance of lawns, automatic household appliances such as home laundries, disc washers etc.
- Thetotaldomestic waterconsumption is50to60%oftotalwaterconsumption.
- Total domestic water demand = Total Design Population x Per capita domestic consumption.

Use	Consumption in litres /day/ person
(a) Drinking	5
(b) Cooking	5
(c) Bathing	55
(d) Washing of clothes	20
(e) Washing of utensils	10
(f) Washing and cleaning of houses and residences	10
(g) Flushing of Latrines etc.	30
Total	135

CommercialDemand

- Thewaterdemandforoffice,hotels, restaurants,theatres etc.
- CommercialDemandis25litres/capita/dayto40litres/capita/day.

IndustrialDemand

- Industrialwaterdemand isfocusedoncooling,processingandmanufacturing operations, power generation etc.

- IndustrialDemandis 20%to25%oftotalwaterdemandofthecity.

PublicDemand

- Thewaterdemandsforvariouspublicuseslikepublictoilets,publicparks,gardening, washing and sprinkling on roads, use in public fountains, swimming pool etc.
- Anominalamount not exceeding5%ofthetotalconsumptionmaybeaddedtomeet this demand.

FireDemand

- Duringthefire breakdownlargequantityofwaterisrequired forthrowing it over the fire to extinguish it.
- Therefore, provisionismade inthewaterworktosupplysufficient quantity of water or keep as reserve in the water mains for this purpose.
- FireDemand isthe functionofpopulationbut withaminimumlimit, becausegreater the population, greater the number of buildings and greater the risk of fire.

CompensateLosses

- Defectivepipe joints,crackinpipe,
- Faultinvalvefittings,
- Publictaps damaged,
- Wastingwaterkeeping thetapsinopencondition,
- Unauthorizedconnection.
- 15%oftotalwaterrequirement.

SystemofwaterSupply

CONTINUOUSWATERSUPPLY	**INTERMITTENTWATER SUPPLY**
lesserdiameterpipesarerequired	Biggerdiameterpipesarerequired
water isavailablefor 24hours	water is supplied atregular intervals throughout the day

Asthesupply iscontinuous,so thereismoreconsumption of water and less chances of contamination.	Asitisnotcontinuoussupplyso the consumption is less.
negativepressurecannotoccurandasaresultthequalityof water is better.	Due to negative pressure, the quality of water is not so good compared to the case ofcontinuous supply.

WATERSUPPLYSYSTEMS:

- TheMunicipalwater systemsconsistofthe following units
  - ✓ Collectionworks
  - ✓ Conveyanceworks
  - ✓ Treatmentworksand
  - ✓ Distributionworks.

PERCAPITADEMAND:

- Theaveragedailywaterrequiredperpersonperdaybasedontheannualaverage demand.
- IfQ isthetotalquantityofwater requiredbyatownper year inlitresandthe population of the town is P, then,

  PercapitaDemand=Q/(Px365)litres/capita/day

- The per capita demand ofthe towndepends onvarious factors and willbe according tothe livingstandardofthepublicandthetypeofthecommercialplaces inthetown etc.
- ForanaverageIndiantown,therequirement ofwaterin varioususesisgivenbelow.

  DomesticUse–135lpcd

  IndustrialUse–40lpcd

  CommercialUse–25lpcd

  PublicUse –15lpcd

Loss&Waste –55lpcd

Total=270lpcd.

- Totalquantityofwaterrequiredbythetown/day=270lpcdxpopulation.

FACTORSAFFECTINGPERCAPITADEMAND:

- ClimaticConditions
- CostofWater
- DistributionPressure
- Habits ofPopulation
- Industrial&CommercialActivities
- Policyofmeteringandmethod ofcharging
- Qualityofwater
- ExistingSewerageFacilities
- Size ofthecity
- Systemofsupply

FLUCTUATIONORVARIATIONSINWATER DEMAND:

Seasonallyor Monthly Fluctuation

- Waterdemand variesfromseasontoseason.
- Summerwaterdemandis maximum.
- Thisdemandgoesonreducingandinwinteritbecomesminimum.
- Thevariationmaybeupto15%totheaveragedemandofthe year. Daily

Fluctuation

- Variationdependsonthegeneralhabitsofpeople, climaticconditionsand character of city.
- MorewaterdemandwillbeonSundaysandhoildays.

Hourly Fluctuation

- Peakhourflowwillbefrom6 to10 A.Mand4P.Mto8P.M.
- Minimumflowmaybebetween12P.Mto4P.M.

POPULATIONDATA

- ThePopulationdataisdetermined bytheCensusDepartment.
- Officialsurveysarecarriedoutbythegovernment at intervalsofabout 10yearsto estimate the future population.

POPULATIONDENSITY

- Itindicatesthenumberofpersonsper unitarea.
- Thedistributionofpopulationisstudiedbydeterminingthepopulationdensitiesof various parts of the city.

POPULATIONFORECAST

- Estimatingthefuturepopulationisknownaspopulationforecast.Thepopulation change can occur in following three ways.
- Bybirth(gain inpopulation)
- Bydeath(lossinpopulation)
- Bymigrations(lossorgain inpopulation)

USESOFPOPULATION FORECAST:

- Toassist thegovernment agenciesforthepreparationofeconomic,employment and social programmes.
- Tocollect informationforlocationofanindustry, itsfutureexpansion, availabilityof labored marketing and distribution of the product etc.
- To designwatersupplysystemand sewerage system.
- Toprovidedatatotransportation industry.
- Toworkoutrequirementsforotherpublicutilitiessuchastelephones,electric power etc.

METHODSOFPOPULATIONFORECAST:

- ArithmeticalIncreaseMethod
- GeometricalIncreaseMethod
- IncrementalIncreaseMethod
- Decreasingrateofgrowthmethod
- Graphical method
- ✓ (a)Simple
- ✓ (b)Comparative
- MasterPlanMethod(or)ZoningMethod
- LogisticCurveMethod
- Ratio Method

ArithmeticalIncreaseMethod:

This method is basedontheassumptionthatthepopulationincreasesat aconstant rateorthe rate of change of population with time is constant.

$$P_n=P+n.C$$

Where,

P_n=ForecastedPopulationafterndecades P =

Population at present

n=Numberofdecadesbetweenpresent and futureC=Averagearithmetic increaseof population.

GeometricalIncrease Method:

Inthis method, it isassumedthatthepercentageincrease inpopulationfromdecadeto decaderemainsconstant.This method isalso knownasuniformincrease method.The increase is compounded over the existing population in every decade.

$$P_n=P+(1+(I_G/100))^n$$

Where,

P_n=ForecastedPopulationafterndecades P =

Population at present

n=Numberofdecadesbetweenpresentandfuture

$I_{G=}$Averagepercentagegrowthat theend ofthedecade.

IncrementalIncreaseMethod:

This method is an improved method of other two methods. The average increase in the populationisdetermined bythearithmetic methodandtothis isaddedtheaverageofthenet incremental increase once for each future decade.

$$P_n=P+ n(Ia+Ic)$$

Where,

P_n=ForecastedPopulationafterndecades P =

Population at present

n=Numberofdecadesbetweenpresent and future Ia

= Average Arithmetical Increase

Ic= AverageIncrementalIncrease.

Decreasing rateofgrowth method:

Inthismethod,theaveragedecrease inthepercentage increase isworkedout and isthen subtracted from the latest percentage increase for each successive decade.

Problems:

1. Thefollowingdatahave beennotedfromthecensusdepartment.Calculatetheprobable population in the year 1980,1990 and 2000 by Arithmetical Increase method.

YEAR	POPULATION
1940	8,000
1950	12,000
1960	17,000
1970	22,500

YEAR	POPULATION		INCREASEIN POPULATION
1940	8,000		-
1950	12,000		4000(12000–8000)
1960	17,000		5000(17000–12000)
1970	22,500		5500(22500–17000)
	TOTAL	=	14500
	AVERAGE	=	4833

YEAR	POPULATION
1980	22,500+1X4833=27,333
1990	27,333+1X4833= 32,166
2000	32,166+1X4833=36,999

2. Thefollowingdatahavebeennotedfromthecensusdepartment.Calculatetheprobable population in the year 1980,1990 and 2000 by Geometrical Increase method.

YEAR	POPULATION
1940	8,000
1950	12,000
1960	17,000
1970	22,500

$P_n= P+(1+ (I_G/100))^n$

YEAR	POPULATION	INCREASEINPOPULATION	% INCREASE IN POPULATION
1940	8,000	-	-
1950	12,000	4000(12000– 8000)	4000/8000X 100=50.0%
1960	17,000	5000(17000– 12000)	5000/12000X 100=41.7%
1970	22,500	5500(22500– 17000)	5500/17000X 100=32.4%
	TOTAL	14500	124.1%

	AVERAGE	4833	41.37%

YEAR	POPULATION
1980	22,500+ (41.37/100X22,500)=31,808
1990	31,808+(41.37/100X31,808)=44,967
2000	44,967+(41.37/100X44,697)=63,570

3. Thefollowingdatahavebeennotedfromthecensusdepartment.Calculatetheprobable population in the year 1980,1990 and 2000 by Incremental Increase method.

YEAR	POPULATION
1940	8,000
1950	12,000
1960	17,000
1970	22,500

YEAR	POPULATION	INCREASEIN POPULATION	INCREMENTAL INCREASE IN POPULATION
1940	8,000	-	-
1950	12,000	4000(12000– 8000)	-
1960	17,000	5000(17000– 12000)	+1000(5000– 4000)
1970	22,500	5500(22500– 17000)	+500(5500– 5000)
	TOTAL	14,500	+1500
	AVERAGE	4,833(14,500/3)	+750(1500/2)

P_n= P+ n(Ia+Ic)

Pin1980=22,500+1X(4833+ 750)

=28,083

Pin1990=28,083+1X(4833+750)

=33,666

Pin2000=33,666+1X(4833+750)

=39,249

4. Thefollowingdatahavebeennotedfromthecensusdepartment.Calculatetheprobable population in the year 1980,1990 and 2000 by Decrease rate of growth method.

YEAR	POPULATION
1940	8,000
1950	12,000
1960	17,000
1970	22,500

YEAR	POPULATION	INCREASEIN POPULATION	%INCREASEIN POPULATION	DECREASE IN THE % INCREASE
1940	8,000	-	-	-
1950	12,000	4000(12000– 8000)	4000/8000X100= 50.0%	-
1960	17,000	5000(17000–12000)	5000/12000X100= 41.7%	+8.3% (50 –41.7)
1970	22,500	5500(22500–17000)	5500/17000X100= 32.4%	+9.3% (41.7–32.4)
	TOTAL	14,500		17.6
	AVERAGE	4,833		8.8

YEAR	NET%INCREASEINPOPULATION	PROBABLE POPULATION
1980	32.4–8.8=23.6	22,500+(23.6/100X 22,500)=27,810
1990	23.6–8.8=14.8	27,810+(14.8/100X 27,810)=31,926
2000	14.8–8.8=6.0	31,926+(6.0/100X 31,926)=33,842

DESIGNPERIOD:

- Thenumberofyears forwhichthedesignsofthewaterworkshavebeendone is known as design period.
- Mostlywater worksaredesigned for designperiodsof20 –30yearswhichisafairly good period.

INTRODUCTION

INTAKE:

- The main function of the intakes structure is to collect the water from the surface source and then to discharge this water by means of pumps or directly to the water treatment plants.
- Itessentiallyconsistsof opening, gratingorstrainerthroughwhichtherawwaterfrom river, canal or reservoir and is carried to a sump well by means of conduits.
- Waterfromthesumpwellispumpedthroughtherisingmainstothetreatmentplants. Intake

consists of

- ✓ Conduitwithprotectiveworks
- ✓ Screensatopenends
- ✓ GatesandValvestoregulateflow

Factors GoverningLocationof Intake:

- Asfaras possible,thesiteshould benearthetreatment plant so that thecost of conveying water to the city is less.
- The intake must be located in the purer zone of the source to draw best quality water from the source, thereby reducing load on the treatment plant.
- The intake must never be located at the downstream or in the vicinity of the point of disposal of wastewater.
- The site should be such as to permit greater withdrawal of water, if required at a future date.
- The intake must be located at a place from where it can draw water evenduring the driest period of the year.
- The intake site should remain easily accessible during floods and should not get flooded. Moreover, the flood waters should not be concentrated in the vicinity of the intake.

TYPESOFINTAKES:

- Dependinguponsource of water,intakesareclassified as,
- ✓ Reservoirintakes.
- ✓ River Intakes
- ✓ Canal Intakes.
- ✓ LakeIntakes
- Dependingupon the position,intakes areclassified as,

- ✓ Wet intake
- ✓ Dry intake

Reservoirintakes:

- Therearelargevariationsindischargeofalltheriversduringmonsoonandwinter.
- Thedischargeofsomeriversinsummerremainssufficienttomeetup thedemand,but some rivers dry up partly or fully and cannot meet the hot weather demand.
- In such cases reservoirs are constructed by constructing weirs or dams across the rivers.
- Reservoirintakesis mostlyused todrawthewaterfrom earthendam reservoir.
- It essentially consists of an intake tower constructed on the slope of the dam at such place from where intake can draw sufficient quantity of water even in the driestperiod.
- Intake pipes are fixed at different levels, so as to draw water near the surface in all variations of water level.
- Theseallinlet pipesareconnectedto oneverticalpipeinsidetheintake well.
- Screens areprovided at themouth ofall intakes to prevent theentranceof floatingand suspended matter in them.
- Thewaterwhich enters theverticalpipeistakentotheothersideofthedambymeans of an outlet pipe.
- Atthe top ofthe intaketower, sluicevalves areprovided to control theflow ofwater.
- The valve tower is connected to the top of the dam by means of a foot bridge gang - way for reaching it.

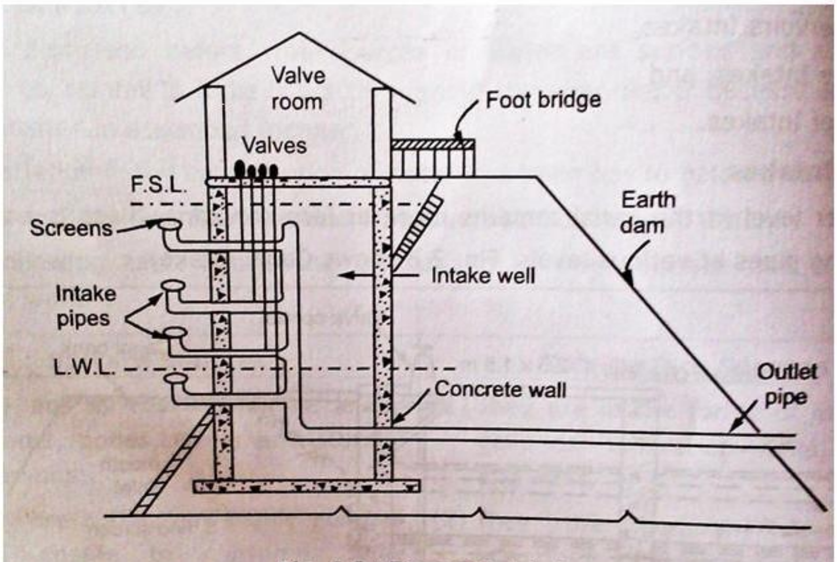


Fig. 2.9 : Reservoir intake

River Intake:

- Water from the rivers is always drawn from the upstream side, because it is free from the contamination caused by the disposal of sewage or industrial waste water disposal in it.
- It is circular masonry tower of 4 to 7 m in diameter constructed along the bank of the river at such place from where required quantity of water can be obtained even in the dry period.
- The water enters in the lower portion of the intake known as sump-well from penstocks.
- The penstocks are fitted with screens to check the entry of floating solids and are placed on the downstream side so that water free from most of the suspended solids may only enter the jack well.
- Number of penstock openings are provided in the intake tower to admit water at different levels.
- The opening and closing of penstock valves is done with the help of wheels provided at the pump house floor.

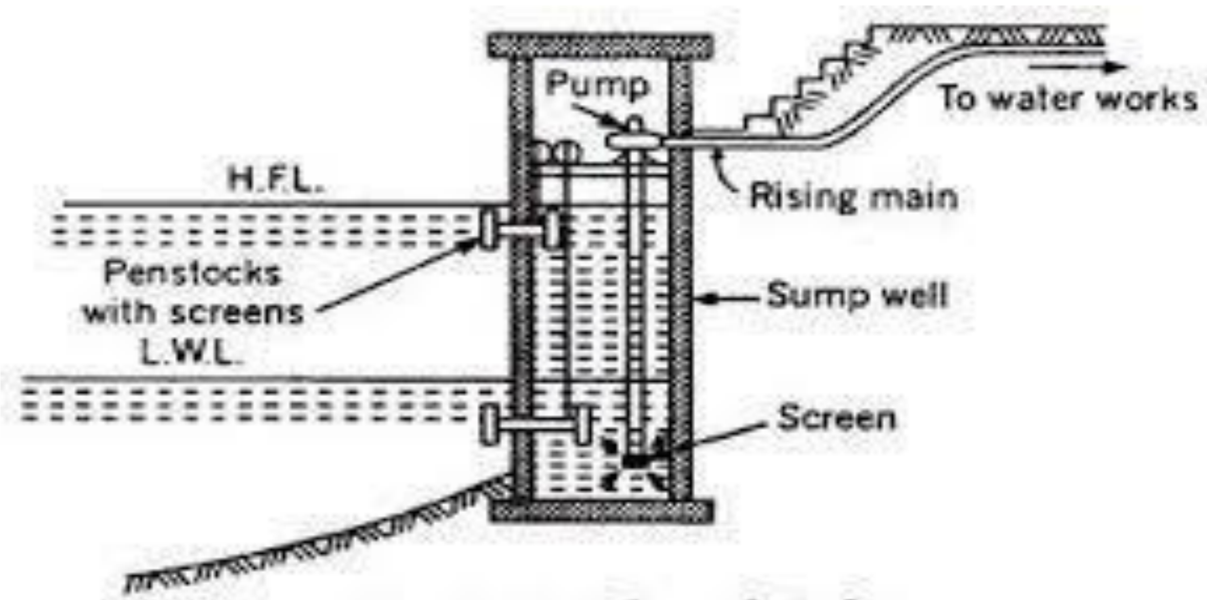
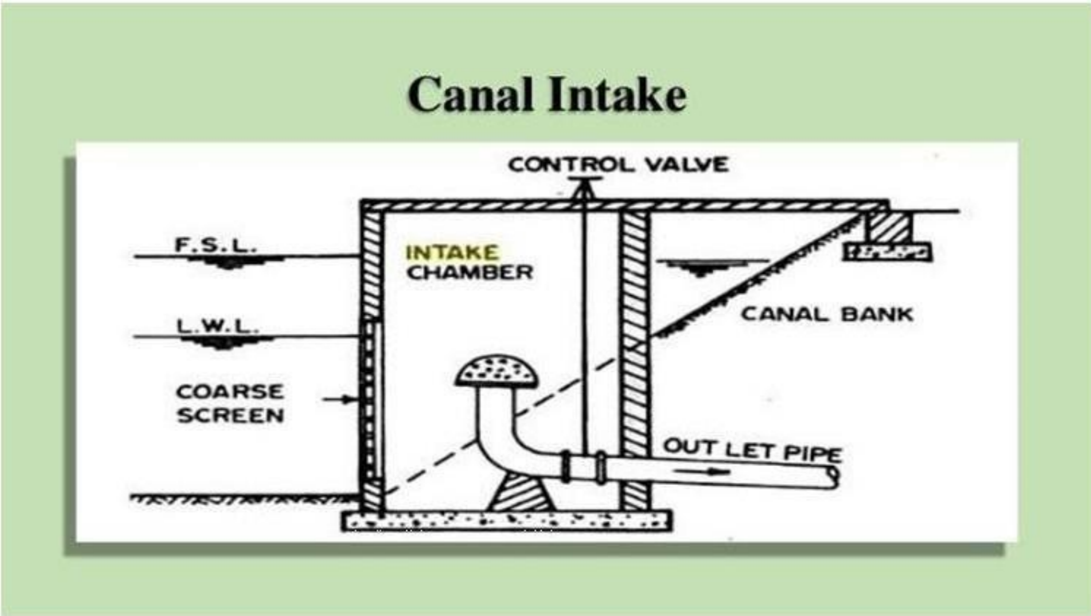


Fig. 7.3. River intake.

Canal intake:

- Canalintakeis a verysimplestructureconstructed onthe bank.
- It essentially consists of a pipe placed in a brick masonry chamber constructed partly in the canal bank.
- Ononesideofthechamber,anopeningisprovidedwithcoarsescreenfortheentrance of water.

- The end of the pipe in side chamber is provided with the bell mouth fitted with a hemispherical fine screen.
- The outlet pipe carries the water to the other side of the canal bank from where it is taken to the treatment plants.
- Onesluicevalvewhich is operatedbyawheel from thetop ofthemasonrychamberis provided to control the flow of water in the pipe.



Lakeintake:

- Forobtainingwaterfromlakesmostlysubmersibleintakes areused.
- Theseintakes areconstructedinthebed ofthelakebelowtheslowwaterlevelsoasto draw water in dry season also.
- Itessentiallyconsists ofapipe laidin the bedof theriver.
- One end which is in the middle of the lake is fitted with bell mouth opening covered with a mesh and protected by timber or concrete crib.
- The water enters in the pipe through the bell mouth opening and flows under gravityto the bank where it is collected in a sump-well and then pumped to the treatment plants for necessary treatment.
- If one pipe is not sufficient two or more pipes may be laid to get the required quantity of water.
- Advantagesoflake intake:

- Noobstruction tothenavigation.

- Nodangerfromfloatingbodies
- Notrouble dueto ice.

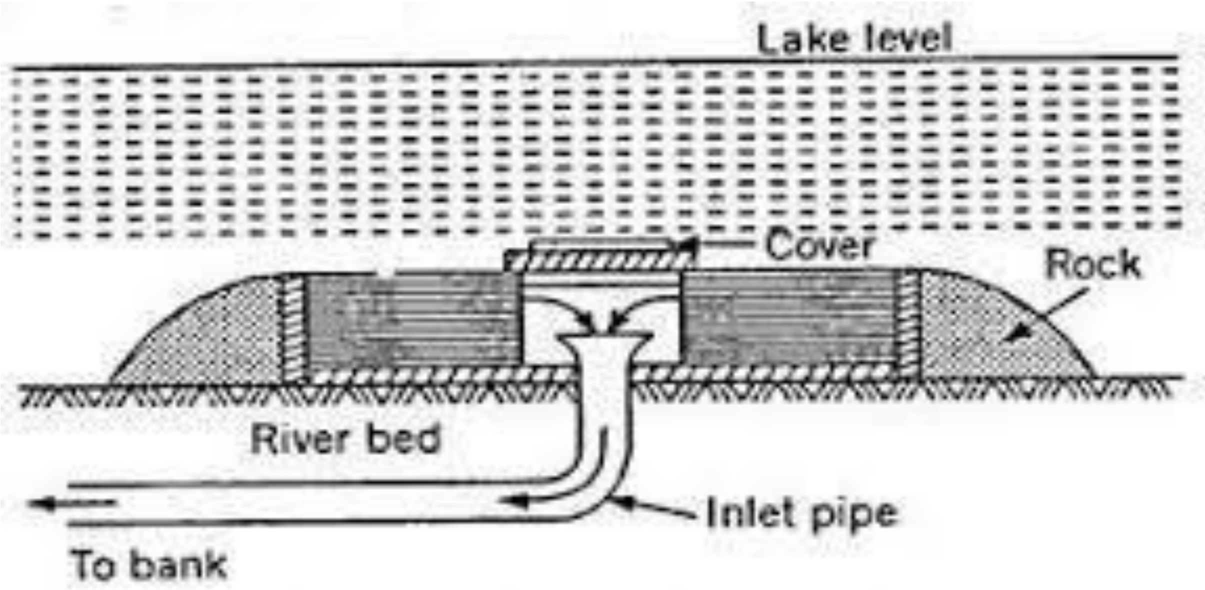


Fig. 7.1. Lake Intake.

Channelsandpipesforconveying water:

- Conduitsarethechannels forconveyingwater.
- Dependingupon conditionsand characteristicsof flow,conduits areclassified as
  - ✓ Gravityconduits
  - ✓ Pressureconduits

GRAVITYCONDUITS:

Channels:

Theseareoccasionallyused to conveywaterfrom the sourceto treatmentplant.

Thesecanbeeasilyandcheaplyconstructedbycuttinginhighgroundsandbankinglow grounds.

The channels should be lined properly to prevent the seepage and contamination of water.

Aswaterflowsonlyduetogravitationalforcealongitudinaluniformslopeshouldbegiven.

The velocityof water in channels should not exceed the permissible limit, otherwise scouring will start in the bed and water will get dirty.

Inchannelsthereisalwayslossofwaterbyseepage andevaporation.

Aqueducts:

It’s theclosed conduit constructedwith masonryand used forconveyingwaterfrom source to treatment plant.

Itmaybeconstructed with bricks,stones or R.C.C.

In older days, rectangular aqueducts were used, but now-a-days horse-shoe or circularsections are used.

Thevelocityshouldbe1m/sec.

Tunnels:

Thisisalsoagravityconduit,inwhichwaterflowsunder gravitational force.

But sometimes, water flows under pressure and in such cases, these are called pressure tunnels.

In pressure tunnels, the depth of water in general such that the weight of the overlying material will be sufficient to check the bursting pressure.

Tunnelsshould bewater-tightand thereshouldbenoloss of water.

Flumes:

Theseareopenchannelssupportedabovethe groundovertrestlesetc.

It’s used for conveying water across valleys and minor low-lying areas or over drains and other obstructions coming in water

ItmaybeconstructedwithaR.C.C,woodormetal

Thecommon sections arerectangular and circular.

PRESSURE CONDUITS:

Thesearecircularconduitsinwhichthewaterflowsunderpressure. Now

a day’s pressure pipes are used in every place

In distribution system, pipes of various diameters having many connections and branches are used.

Thecost of pipelinedepends on theinternal pressureandthe length of pipeline.

To prevent theburstingofpipesdueto waterhammer,surgetanksorstandpipesareprovided at the end of the pipes.

The pipe material which will give the smallest annual cost or capitalized cost will be selected because it will be more economical.

PIPEMATERIALS:

- ➢ Theselection ofmaterialforthepipe is doneon thefollowingpoints,
- ✓ Carryingcapacityof the pipe

- ✓ Durabilityand lifeof pipe
- ✓ Typeofwatertobeconveyedanditscorrosiveeffect
- ✓ Availabilityof funds
- ✓ Maintenance,cost,repairetc.

TypesofPipeMaterials:

- ➢ Castiron pipes
- ➢ Wroughtironpipes
- ➢ Steel pipes
- ➢ Concretepipes
- ➢ Cementlinedcastironpipes
- ➢ Asbestoscement pipes
- ➢ Copperandleadpipes
- ➢ Wooden pipes
- ➢ Vitrifiedclaypipes
- ➢ Plastic pipes
- ➢ Galvanizedironpipes

CastIron Pipes:

- ✓ These pipes were earlier cast vertically but, thus type has been largely superseded by spun iron pipes which are manufactured by spinning and centrifugal action.
- ✓ These spun iron pipes are lighter in weight, longer in length and have improved metal qualities.

Wroughtironandsteelpipes:

- ✓ These pipes are stronger than cast iron pipes can withstand higher pressure but are of lighter section are easier to transport.
- ✓ They are less durable, more liable to corrosion and is also difficulty of availability of pipes specials viz, joints, bends etc.

ConcretePipes:

- ✓ Thesepipesaredurable, heavier andcan behad insizes 1800mm.
- ✓ Transportationcostsaremuchreducedifpipesarecastinsitu.Concretepipeshave low
- ✓ maintenanceisresistanttocorrosionandparticularlysuitabletosoftandacidic waters.
- ✓ Theyhowever can withstand highpressureuntil reinforced.

HumeSteel Pipes:

- ✓ These pipes are made from a then mild steel shell lined and out coated with cement concrete or cement mortar through a centrifugal process.
- ✓ They are available up to 1350mm and are used for trunk and distribution mains. They are heavy and difficult to handle and concrete coating gets damaged while fixing branch connection.

AsbestosCement Pipe:

- ✓ ThesepipesarecomposedofasbestosfibreandPortlandcementcombinedunder pressure into dense homogenous structure.
- ✓ Availableinlargevariationfrom50to 600mm.

Wood Pipe:

- ✓ Thesepipes arebuiltof staves ofwood heldtogether bysteel bands.
- ✓ Woodislessdurableforpipematerialandpipemustbeconstantlyfullofwaterto prevent crackdown due to alternate wet and dry conditions.

PIPEJOINTS:

- ➢ Requirementsofajointingmaterial.
- ✓ Imperviousness
- ✓ Elasticity
- ✓ Strength
- ✓ Durability
- ✓ Adhesiveness
- ✓ Availability
- ✓ Workability
- ✓ Economy

TYPESOFJOINTS:

- ➢ SpigotandsocketJoint
- ➢ Expansion Joint
- ➢ FlangedJoint
- ➢ MechanicalJoint
- ➢ Flexible Joint
- ➢ ScrewedJoint
- ➢ CollarJoint
- ➢ A.C.pipe Joint

SpigotandSocket Joint:

- ✓ Jointis commonlyused incaseofcast iron pipe.
- ✓ Spigotofonepipeiscenteredintosocketofprecedingpipe,taredgasketorhempyarn is then wrapped around spigot leaving unfilled required depth of socket for lead.
- ✓ Thegasketor hempyarn iscaulked tightlyhomewitha yarningtool.
- ✓ Ajointingringorkneededclayusingisthenplacedaroundbarrelandagainst faceof socket molten pig lead is powered into remainder of socket.

FlangedJoint:

- ✓ Agasketofrubbercanvasorleadisintroducedh/wtwoflangesofcastironpipes which are tightened with bolt and nuts.
- ✓ Flanged joints are strong and rigid are easy to disjoint as such used where pipe joints are occasionally opened for repair pipe.

MechanicalJoint:

- ✓ Whentwoendsofcastiron,steelorwroughtironpipesareplain,amechanical coupling is required to make a water tight joint.

SpecialJoints:

- ✓ Usedforspecialpipesincaseof castiron pipes.
- ✓ Examplesareexpansion jointsandflexiblejoints.
- ✓ Expansionjointsareusedonpipesexposedtoconsiderabledifferencesof temperature allowing free expansion or contraction without any thermal stresses.
- ✓ Flexiblejointsusedinpipes tobelaidsubmergedunder water.

LAYINGOF PIPES:

Preparingdetailedmap:

Preparingdetailedmapofroadsandstreetsshowingpositionofrocks,otherunderground water pipes, gas pipes, telephone cables.

Locatingproposedalignmenton ground:

Bench line is marked by driving centrallystakes 30 m apart on straight trenches and 7.5 – 1.5 m apart on cover.

Excavatingtrenches:

With width sufficient to allow pipes to be properly laid and jointed and with depth sufficient to give adequate protection to pipes against impact of traffic and other factors.

Dewateringof Trenches:

Dewateringinvolvescontrollinggroundwaterbypumping,tolocallylowergroundwaterlevels in the vicinity of the excavation.

Thesimplest form ofdewateringis sump pumping, where groundwateris allowed to enter the excavation where it is then collected in a sump and pumped away by robust solids handling pumps.

TimberingofTrenches:

When the depth of trench is large, or when the sub-soil is loose, the sides of the trench may cave in.

Theproblem can besolved byadoptingasuitablemethod oftimbering.

Timbering of trenches, sometimes also known as shoring consists of providing timber planks or boards and struts to give temporary support to the sides of the trench.

Timberingofdeeptrenchescanbedonewiththehelpofthefollowingmethods:

1. Staybracing.
2. Boxsheeting
3. Verticalsheeting
4. Runnersystem
5. Sheet piling.

Bottomingupof trenches:

Bottoming of trench should be carefully prepared so that barrel of pipe can be bedded true to line and gradient for its entire length on firm surface.

Loweringof pipes:

Aftertransportingtosite,pipesarestacked on eithersideof trench.

Theseshouldbegentlylowered intotrenchso asnotto damagetheirouterprotectivecoating.

Layingof pipes:

Pipes are seldom laid with a flat slope parallel to hydraulic gradient thus it avoids any lock troubles.

Thepipesshallbeloweredintothetrenchbymeansofsuitablepulleyblocks,sheerlegs chains, ropes etc. In no case the pipes shall be rolled and dropped into the trench.

Oneendofeach ropemaybetiedto awoodenorsteelpegdrivenintothegroundandthe other end held by men which when slowly release, will lower the pipe.

Afterlowering,thepipesshallbearrangedsothatthespigotofonepipeiscarefullycentered into the socket of the next pipe, and pushed to the full distance, that it can go.

Thepipe line shall belaid to thelevel required.

Specialsshallalso belaidin theirproperposition asstated above.

Ifsodirected,thepipesandspecialsmaybelaidonmasonryorconcretepillars. All the

pipes shall rest continuously on the bottom of the trench.

Thepipes shall not rest on lumps of earth oron thejoints.

Someclayeysoilslikeblackcottonsoilaredrasticallyaffectedbyextremesofsaturationand dryness.

Whilechangingfromsaturationtodrycondition,thesesoilsaresubjectedtoextraordinary shrinkage which is usually seen in the form of wide and deep cracks and maydamage the underground structures.

Atsuchplacesanenvelopeof10cmminimumoftampedsandshallbemadearoundthepipe line.

Atslopybedofpipelineshavingmorethan30°slope,itisnecessaryto anchorfewpipes against sliding downward.

Jointingof pipes:

Theconnectionat theends of pipesthat ensurestight sealingand strength.

The most common types used for general-purpose metalpipesare welded, flanged, threaded, and bell-and-spigot joints.

Weldedjointsaremadebetweenstraightsectionsof pipeofthesamediameterbybutt-welding the pipe ends.

Anchoring ofpipes:

Atallbends,tees,valvesandotherbranchconnectionsitwouldbenecessarytoprovidethrust blocks of concrete to transmit hydraulic thrust and distribute to wider area.

Anchorblocksofconcretewouldberequiredtobeprovidedatregularintervalsandpipes would be firmly secured to them with steel straps.

Backfilling:

Refillingoftrenchwithexcavatedmaterial.Thematerialaroundpipeshouldbesoft,free from lumps or rock or large stone and laid preferably in layer of 15 cm or 30 cm.

TESTINGOF PIPES:

- Testingfor Straightness.
- Testingfor Obstruction.

Testing forStraightness:

Thestraightnessofthesewerpipecanbetestedbyplacingamirroratoneendofthesewer line and a lamp at the other end.

Ifthepipe lineisstraight, thefull circleoflight willbe observed.

However,ifthepipelineisnon-straight,thiswouldbeapparentandthemirrorwillalso indicate any obstruction in the pipe barrel.

Testing forObstruction:

Any obstruction present in the pipe can also be tested by inserting at the upper end of the sewerasmoothinsertingattheupperendofthesewerasmoothballofdiameter13mmless than internal diameter of the sewer pipe.

Intheabsenceofanyobstruction,suchas yarnormortarprojectingthroughthejointsetc.the ball shall roll down the invert of the sewer pipe and emerge at the lower end.

PUMPS:

- Thefunctionofthepumpistolift thewaterathigherelevation orhigher pressure.
- Inwater workspumpsarerequiredunderthefollowingcircumstances,
- ✓ Tolift theraw waterfrom rivers,streams, wellsand topump itto thetreatment works.
- ✓ Forpumpingthechemicalsolutionsattreatmentplant.
- ✓ Toincreasethe pressurein thepipelines byboostingup thepressure.
- ✓ Forfillingtheelevateddistributionreservoirsoroverheadtanks.
- ✓ Forthebackwashingof filtersand increasetheirefficiency.

Classificationsof Pumps:

- Basedontheirprinciple of operation:
- ✓ Displacementpumps
- ✓ Centrifugalpumps
- ✓ Air lift pumps
- ✓ Impulsepumps
- Basedonthetypeofpower required:
- ✓ Electricallydriven pumps
- ✓ Gasolineengine pumps
- ✓ Steamengine pumps
- ✓ Dieselengine pumps
- Basedonthetypeof service:

- ✓ Lowliftpumps
- ✓ Highliftpumps
- ✓ Deepwellpumps
- ✓ Boosterpumps
- ✓ Stand-bypumps.

FactorsaffectingtheSelectionofPumps:

- ➢ Inorderto selectproperpumps,the followingfactors shouldbeconsidered,
  - ✓ Capacity– it should becapableofpumpingrequired quantityofwater
  - ✓ Reliability–itshouldbereliableandshouldnotfailsuddenlyandcause troubles
  - ✓ Cost– it should becheap in initial cost
  - ✓ Power–thepowerwhichisusedforrunningpumpsshouldbeavailableeasily at low cost
  - ✓ Maintenance–themaintenancecostofrunningpumpsshouldbeassmallas possible
  - ✓ Efficiency– pump should havehigherefficiency
  - ✓ Depreciation– it should havelonglifeand depreciation cost should besmall
  - ✓ Costof labour – it should below
  - ✓ Numberofpumping– moreunitsrequired
  - ✓ Totalliftofwater required.
  - ✓ Qualityofwaterto bepumped
  - ✓ Quantityofwaterto bepumped
  - ✓ Importanceof water supplyscheme
  - ✓ Spacerequirements forlocatingthepump
  - ✓ Lifeofpump
  - ✓ Variationsinpumpingheadandpumpingrate
  - ✓ Dischargeandsuctioncondition
  - ✓ Positionofpump (horizontalor vertical)
  - ✓ Typeofpoweravailable
  - ✓ Typeof supplyservice (continuousorintermittent)
  - ✓ Workingor operatingconditions

✓ Totalheadofliquid.

LOSS OFHEADINPIPES:

Manning'sFormula,

$$H_L = \frac{m^2 V^2 L}{R^{4/3}}$$

Where,m=Manning's Coefficient.

L=Lengthof thepipeline in m.

R=Hydraulicmeandepthofpipeinm. V =

Velocity of flow in m/sec.

2. HazenWilliam'sFormula,

$$V = 0.85\ C_H R^{0.63} S^{0.54}$$

Where,C_H=Coefficient ofhydraulic capacity.

S =Slope ofthe energyline.

R=Hydraulic meandepthofpipein m.

3. Darcy–WeisbachFormula,

$$H_L = \frac{f\ L\ V^2}{2\ gd}$$

Where,H_L=Lossof head in m.

L= Length ofpipein m.

d = diameter of the pipe in m.

V = Velocityof flow in m/sec.

g=accelerationduetogravity. f

= friction factor.

PROBLEMS:

1. Determinethehydraulicgradientina90cmdiameteroldcastironpipecarryingadischarge of 0.75 cu.m/sec by using Manning's formula, Darcy's formula and Hazen William'sformula. Assume suitable data not given.

Solution:

Discharge, Q=0.75cu.m/sec

Areaof thepipe, A= $\frac{\pi d_2}{4}$

$=\frac{\pi X 0.90^2}{4}$

$=0.636\ m^2$.

Velocityof flow, V=Q/A =0.75/0.636

=1.18 m/sec.

Assumingthevalueofm=0.014 R =

d/4 = 0.90/4 = 0.225 m.

UsingManning's formula, $\frac{H_{L}}{L}=\frac{m^2V^2}{R^{4/3}}$

$= \frac{0.014^2 X\ 1.18^2}{0.225^{(4/3)}}$

Thus,thehydraulicgradient=1/502.

Assuming the value of f = 0.015

UsingDarcy-Weisbachformula,

$\frac{H_L}{L} = \frac{f\ V^2}{2gd}$

$H_L = \frac{0.015 X 1.18^2}{0.90\ X\ 2\ X 9.81}$

Thus,thehydraulicgradient=1/845. Assume

C = 120.

UsingHazenWilliamformula, V

$= 0.85\ C_H R^{0.63} S^{0.54}$

$1.18=0.85X120X(0.90/4)^{0.63}XS^{0.54}$ S =

1/672.

Thus,thehydraulicgradient= 1/672.

2. Wateris to besupplied to atown of population of 1.5 lakh. If the water works is situated at alowerelevationof50 mthanthewaterlevelinthesource.Determinethesizeofthegravity

main to convey the water from source to the water work, if the length of the gravity main is 25Kmandthepercapitademandofthetownis150litres/day/capita.Takevalueoff=0.075

Solution:

Quantityofwater required bythe town=150000X 150

$=225 \times 10^5$ litres/dayor

$=22500\ m^3/day$.

Letthepumpwork for12 hours,

then thequantityofwater carried bythepipe,=22500/12 = 22500/12 X 60 X60

=0.52 m /sec.

Now,discharge, $Q = \frac{\pi d^2 X V}{4}$

$$0.52 = \frac{\pi d^2 X\ V}{4}$$

$$V = \frac{0.52\ X\ 4}{\pi d^2} = \frac{0.66}{d^2}$$

ByusingDarcy-Weisbach formula, $H_L = \frac{fLV^2}{2\ gd}$

$$= \frac{0.075\ X\ 25\ X1000X\ (0.66/d^2)^2}{d\ X\ 2\ X9.81}$$

$$50 = \frac{0.075\ X\ 25\ X1000X\ (0.66/d^2)^2}{d\ X\ 2\ X9.81}$$

$d^5 = 0.83$

d =0.9635 m OR 1 m.

d =100 cm.

PIPEAPPURTENANCES:

- Thedifferentdevicesrequiredforcontrollingtheflowofwater,forpreventing leakage and other purposes in water supply system are called “appurtenances”.
- The distributionpipesare provided with various pipe appurtenancesor accessories so as to make the distribution of water easy and effective.
- **VariousPipe Appurtenances:**

✓ Sluice valves

- ✓ CheckValveorReflux Valve
- ✓ Airrelief valves
- ✓ Firehydrants
- ✓ Drainvalves orblowoff valves
- ✓ ScourValves

Sluicevalves:

Thesearealsoknownasgate-valvesorstopvalves.Thesevalvescontroltheflowofwater through pipes.

Thesevalves arecheaper,offersless resistancetotheflowofwaterthanothervalves.

The entire distribution system is divided into blocks by providing these valves at appropriate places.

They are provided in straight pipeline at 150-200 m intervals. When sluice valve is closed, it shuts off water in a pipeline to enable to undertake repairs in that particular block.

Theflowof watercan becontrolledbyraisingor loweringthe handle or wheel.

Checkvalve orReflux valve:

Thesevalves arealsoknownasnon-returnvalves.

Areflux valveisanautomatic devicewhichallowswatertogoinonedirection only.

When the water moves in the direction of arrow, the valve swings or rotates around the pivot and it is kept in open position due to the pressure of water.

Whentheflowofwaterinthisdirectionceases,thewatertriestoflowinabackwarddirection.

Butthisvalvepreventspassageof waterinthereverse direction.

Refluxvalveis invariablyplaced inwater pipe,which obtainwaterdirectlyfrom pump.

Whenpumpfailsorstops,thewaterwillnotrunbacktothepumpandthuspumpingequipment's will be saved from damage.

AirRelief Valves:

Sometimes air is accumulated at the summit of pipelines and blocks the flow of water due to air lock.

Insuchcasestheaccumulatedairhastoberemovedfromthepipelines.Thisisdone automatically by means of air relief valves

This valveconsists ofachamberin which oneortwofloats areplaced and is connectedto the pipe line.

Whenthereisflowunderpressureinthepipelinewateroccupiesthefloat chamberand makes the float to close the outlet.

But where there is accumulation of air in the pipeline, air enters the chamber, makes the float to come down, thus opening the outlet.

Theaccumulatedairisdrivenoutthroughthe outlet.

FireHydrants:

Afirehydrantisaconnectionpointbywhichfirefighterscantapintoawatersupply. It is a

component of active fire protection.

Itispurelyawaterbased firefightingsystemtoextinguishtheblazingfirethathappens during the emergencies.

Firehydrantinstallationconsistsofasystemofpipeworkconnecteddirectlytothewater supplymain to provide water to each and everyhydrant outlet and is intended to provide water for the firemen to fight a fire.

Drain ValvesOr BlowOffValves:

Thesearealsocalledwashoutvalvestheyareprovidedatalldeadendsanddepressionof pipelines to drain out the waste water.

Theseareordinaryvalves operated byhand.

Scour Valves:

Thesearesimilar toblowoff valves.

Theyare ordinaryvalvesoperated byhand.

Theyarelocatedatthedepressionsanddeadendstoremovetheaccumulatedsiltandsand. After the

complete removal of silt, the valve is to be closed.

CORROSION OFPIPES:

- Pipelinecorrosionis a natural deterioration and destruction of pipematerial and essential properties due to electrochemical and other ingredient reactions of pipeline materials with their environment - on the inside as well as outside surfaces.
- Corrosionis adeterioration ofsomethingdueto reactingwith its environment.
- In verysimpleterms,themetalfrom thepipesimplydissolvesbecauseof areactionto the water or to other environmental factors.

PreventionforCorrosionof Pipes:

- Usingcoatingsareoneof theeasiestwaystoprotectyourpipesagainstcorrosion.
- Coatingsandliningscanbeusedonpipesthatare aboveor underground.
- Theyfrequentlyareusedincombination with cathodicprotection.
- Somematerialsthat areusedto adddefensetoyourpipelinesincludeepoxyand zinc.

- **WHOLESOME WATER:**

- ✓ Wholesomewateristhewaterthatissafeandpotentfor drinkingtohumanhealth.
- ✓ Itiscleaned ofharmfulcontaminants,transparent,odourless,harmlessand
- ✓ Wholesomewater is fit to use for drinking, cooking, food preparation or washing without any potential danger to human health by meeting the requirements free from any disease-causing bacteria.
- ✓ Water which is not chemically pure but does not contain anything harmful to human health.

- **Requirementsofwholesomewater:**

- ✓ Itshouldbefreefrombacteriaswhichmaycause disease.
- ✓ Itshouldbecolourlessandsparklingwhichmaybeacceptedbythe public.
- ✓ Itshouldbetasty, odour-freeandcool.
- ✓ Itshouldcorrodepipes.
- ✓ Itshouldbefreefromallobjectionablematter.
- ✓ Itshouldhavedissolvedoxygenandfreecarbonicacidsothatitmayremain fresh.

- **PALATABLEWATER:**

  The water which is tasteful for drinking and aesthetically pure is known as palatablewater.

- **POTABLEWATER:**

  The water which has both the characteristics of wholesome water and palatable water is known as potable water.

- **POLLUTEDWATER:**

  The water which consists of undesirable substances which make it unfit for drinking and domestic use is known as polluted water.

- **CONTAMINATEDWATER:**

- ✓ Thewatercontainingpathogenicorganisms iscalledascontaminated water.
- ✓ The contaminated water is always be polluted but the polluted water may not be contaminated.

IMPURITIESINWATER

Suspendedimpurities:

- ✓ Impurities are dispersion of solid particles that are large enough to be removed by filtration on surface and heavier ones settle down.

- ✓ Suspended impurities which have same specific gravity as that ofwater, are mixed in the water.
- ✓ Suspended impurities include Clay, silt, Algae, protozoa, Fungi, Organic and Inorganic matters and mineral matter etc.,
- ✓ Theseallimpuritiesaremacroscopicandcauseturbidityinthe water.
- ✓ Theconcentrationofsuspendedmatter inwaterismeasuredbyitsturbidity.
- ✓ Thesizeofsuspendedimpuritiesranges from0–10^{-3}mm.

Colloidalimpurities:

- ✓ Itisveryfinelydivided dispersionofparticlesinwater.
- ✓ These particles are so small that these cannot be removed by ordinary filters and are not visible to the naked eye.
- ✓ As a matter of fact, all the colloidal impurities are electrically charged and remain in continuous motion.
- ✓ Theelectricchargeisduetothepresenceofabsorbedionsonthesurfaceofthesolid.
- ✓ These colloidal impurities are generally associated with organic matter containing bacteria's and are the chief source of epidemics.
- ✓ Mostofthe colourofthe waterisdue tocolloidalimpurities.
- ✓ The size of colloidal particles is between (1 = 1 micron = 0.001mm) to 1 = 1 milli micron = 0.000001mm) or (10^{-3}mm to 10^{-6}mm)

Dissolvedimpurities:

- ✓ Someimpuritiesaredissolvedinwaterwhenitmovesovertherocks,soiletc.,
- ✓ Solids,liquidsandgasesaredissolvedinnaturalwaters.
- ✓ These dissolved impurities maycontainorganic compounds, inorganic salts and gases etc.
- ✓ The concentration of total dissolved solids is usually expressed in p.p.m and is obtained byweighing the residue after evaporationofthe water sample froma filtered sample.
- ✓ DissolvedimpuritiesincludeCalciumandmagnesium,Sodium,Metal,Gases.
- ✓ Suspended solids are substances that are not completely soluble in water and are present as particles.
- ✓ These particles usually impart a visible turbidity to the water. Dissolved and suspended solids are present in most surface waters.

CHARACTERISTICSOFWATER

PHYSICAL CHARACTERISTICS

- ✓ Temperature
- ✓ Colour
- ✓ Turbidity
- ✓ Tasteand Odours
- ✓ Specificconductivityofwater

Temperature:

- ✓ Thetemperatureofwaterismeasured bymeansofordinarythermometers.
- ✓ The temperature of surface water is generally same to the atmospheric temperature, while that of ground water may be more or less than atmospheric temperature.
- ✓ Themostdesirabletemperaturefor publicsupplyisbetween4.4°Cto10 °C.
- ✓ Temperatureabove28°Careundesirableandabove35°Careunfit for publicsupply, because it is NOT PALATABLE (NOT ACCECTABLE TO TASTE).

Colour:

- ✓ The colour of water is usually due to presence of organic matter, but sometimes it is also due to mineral and dissolved organic and inorganic impurities.
- ✓ Thecolourofwateris comparedwithstandardcoloursolution.
- ✓ Thepermissiblecolour for domesticwateris20ppmonplatinumcobaltscale.
- ✓ Thecolourinwaterisnotharmfulbutitisobjectionable.

Turbidity:

- ✓ **I**tiscauseddueto presenceofsuspendedandcolloidalmatter inthewater.
- ✓ The character and amount of turbidity depends on the type of soil over which the water has moved ground waters are less turbid than the surface water
- ✓ Turbidityisameasureofresistanceofwaterto thepassageoflightthrough it.
- ✓ Turbidity is expressed as NTU (Nephelometric Turbidity Units) or PPM (parts per million) or Milligrams per litre (mg/l).

Tasteand Odours:

- ✓ Taste and odours in water may be due to the presence of dead or alive micro-organisms, dissolved gases such as hydrogen sulphide, methane, carbon dioxide or oxygen combined with organic matter, mineral substance such as sodium chloride,iron compounds, and carbonate and sulphates of other substances.

- Thetest ofthesearedonebysenseofsmelland tastebecausethese arepresent in such small proportions that it is difficult to detect them by chemical analysis.
- Theodourofwateralsochangeswithtemperature.
- Theodourmaybeclassifiedasfishy,mouldy,sweetish,vegetable,greasyetc.
- Theodourofbothcold and hot watershouldbedetermined.
- The water having bad smell or odour is objectionable and should not be supplied tothe public.
- Theintensitiesoftheodoursaremeasuredintermsofthresholdnumber.

Specificconductivityof water:

- The total amount of dissolved salts present in water can be easily estimated by measuring the specific conductivity of water.
- The specific conductivity of water is determined by means of portable dionic water tester and it expressed in micro-mohs per cm at 25° C (Mho is the unit of conductivity).
- The specific conductivity of water in micro-mhos per cm at 25° C is multiplied by a coefficient (generally 0.65) so as to directly obtain the dissolved salt content in mg/litre or ppm.
- Theexactvalueofthiscoefficientdependsuponthetypeofsaltpresentinwater.

CHEMICALCHARACTERISTICS

- pH-value
- TotalSolids
- Hardness
- Chlorides
- Dissolvedgases
- Nitrogen
- Ironandmanganese
- Leadandarsenic
- Metalsandchemicalsubstance
- Acidity
- Alkalinity
- Sulphates

pH-value:

Depending uponthe natureofdissolved salts and minerals, the water found innaturalsources may be acidic or alkaline.

The acidity or alkalinity is usually measured in p.p.m. of the dissolved salts and is expressed in terms of equivalent weight of calcium carbonate.

Denotes the concentration of hydrogen ions in the water and it is a measure of acidity or alkalinity of a substance.

$pH = -\log_{10}[H^+]$ or $1 / \log_{10}[H^+]$

Dependinguponthenatureofdissolvedsaltsand minerals, thePHvalueranges from0to14. For

pure water, pH value is 7 and 0 to 7 acidic and 7 to 14 alkaline ranges.

For publicwater supplypHvaluemaybe6.5to8.5.

The lower value may cause tuberculation and corrosion, whereas high value may produce incrustation, sediment deposits and other bad effects.

pHvalueofwateris generallydeterminedbypHpapers orbyusingpHmeter.

Its knowledge is also helpful in controlling softening and coagulation processes in water treatment.

Therearetwo methodsofdetermine pH value ofwater:

- ✓ Colourimetricmethod,
- ✓ Electrometricmethod

Totalsolids:

Includesthesolids insuspension, colloidalandindissolvedform.

The quantity of suspended solids is determined by filtering the sample of water through fine filter, drying and weighing.

The quantityof dissolved and colloidal solids is determined by evaporating the filtered water obtained from the suspended solid test and weighing the residue.

Thetotalsolids inawater samplecanbedirectlydetermined byevaporatingthe filteredwater obtained from the suspended solid test and weighing the residue.

The total solids in a water sample can be directly determined by evaporating the water and weighing the residue of the residue of total solids is fused in a muffle furnace the organic solids will decompose whereas only inorganic solids will remain.

Hardness:

It isa propertyofwater,whichpreventsthelathering ofthe soap.

It is caused due to the presence ofcarbonates and sulphates ofcalcium and magnesium in the water.

Sometimesthepresenceofchloridesandnitratesofcalciumandmagnesiumalsocause hardness in the water.

- ✓ Hardnessisoftwotypes.
- ▪ Temporaryhardness:
- ✓ Itiscausedduetothepresenceofcarbonatesandsulphatesofcalciumand magnesium. It is removed by boiling.
- ▪ Permanent hardness:
- ✓ It is caused due tothe presence ofchlorides and nitratesofcalciumand magnesium. It is removed by zeolite method.
- ✓ Hardnessisusuallyexpressedinmg/litreorppm.ofcalciumcarbonateinwater.
- ✓ Hardnessofwaterisdetermined byEDTA method.
- ✓ For potablewaterhardnessrangesfrom5 to 8 degrees.

Chloridecontent:

- ✓ Sodiumchlorideisthemainsubstanceinchloridewater.
- ✓ Thenaturalwater nearthemines and seahavedissolvesodiumchloride.
- ✓ Similarlythepresenceofchloridesmaybeduetothemixingofsalinewaterand sewage in the water.
- ✓ Excessofchlorides isdangerousandunfitfor use.
- ✓ Thechloridescanbereducedbydilutingthewater.
- ✓ Chloridesabove250p.p.m.arenotpermissible inwater.
- ✓ Chloridesareestimatedbytitrationthewaterwithstandardsilvernitratesolution using potassium chromate as indicator.
- ✓ Inthistitrationprocessreddishcolourswill beformedifchloridesarepresent.

Chlorine:

- ✓ Dissolvedfreechlorine isneverfoundinnaturalwaters
- ✓ Itispresentinthetreatedwaterresultingfromdisinfectionwithchlorine.
- ✓ Thechlorineremainsasresidualintreatedwaterforthesakeofsafetyagainst pathogenic bacterias.
- ✓ Residualchlorinedeterminedbythestarchiodide test.
- ✓ The residual chlorine should remain between 0.5 p.p.m. to 0.2 p.p.m. in the water so that it remains safe against pathogenic bacteria.

Nitrogencontent:

- ✓ The presence of nitrogen in the water indicates the presence of organic matters in the water. The nitrogen may be present in the water may be in one or more of the following forms.
  - Nitrites
  - Nitrates
  - Freeammonia
  - Albuminoidnitrogen.
- ✓ Excess presence of nitrogen will cause "MATHEMOGLOBINEMIA" disease to the children.

Nitrites:

- ✓ The presence of nitrites in the water due to partly oxidized organic matters, is very dangerous.
- ✓ Therefore, in no case nitrites should be allowed in the water, their presence must be nil.
- ✓ The nitrites are rapidly and easily converted to nitrates by the full oxidation of the organic matters.
- ✓ Thepresenceofnitratesisnotsoharmful.
- ✓ But in no case its quantity should increase 45 p.p.m., because excess presence of nitrate will cause "mathemoglobinemia" disease to the children.
- ✓ Nitrite in water is either due to oxidation of ammonium compounds or due to reduction of nitrate.
- ✓ Asanintermediatestageinthenitrogencycle,itisunstable.
- ✓ Ausualconcentrationinnaturalwaterisinthe rangeofsome tenthsof mg/L.
- ✓ Higher concentrations are present in industrial wastes, sewage and in biologically purified effluents and in polluted streams.
- ✓ Very high nitrite levels are usually associated with water of unsatisfactory microbiological activity.
- ✓ Thepresenceofnitritesornitratecanbedetermined bycolourmatchingmethods.
- ✓ For determining the presence of nitrites, the colour is obtained by adding sulphonic acid and napthamine.
- ✓ For testing presence of nitrates, the colour is obtained if phenol-di-sulphonic acid and potassium hydroxide are added.
- ✓ The colours so developed are compared with standard colours to ascertain the p.p.m. contents.

Nitrate:

- ✓ Nitrate constitutes the final stage in the oxidation of nitrogen compounds, and normally reaches important concentrations in the final stages of biological oxidation.
- ✓ The nitrate contained in pure well water derived from an extensive catchment is largely the result of biological activity in the surface layers of the soil, enhanced by cultivation and the application of manures.
- ✓ When the nitrate in in the excessive amounts, it contributes to the illness known as infant methemoglobinemia.
- ✓ Nitrate is measured either by reduction to ammonia or by matching the colours produced with phenol-di-sulphonic acid.

Freeammonia:

- ✓ Freeammoniaisobtainedfromthedecompositionoforganicmattersinthe beginning.
- ✓ Therefore, if free ammonia is present in the water, it will indicate that the decomposition of the organic matters has started recently.
- ✓ The presence of nitrates indicates partly decomposition of organic matters. Whereas the presence of nitrates indicates fully oxidized organic matters.
- ✓ The presence of free ammonia in water should not exceed 0.15 p.p.m. the presence of free ammonia can be easily determined by boiling the water and measuring the ammonia gas obtained.
- ✓ Ammonia is produced by the microbiological degradation of organic nitrogenous matter.
- ✓ Itappears,therefore,inmanygroundwatersas wellassurfacewaters.
- ✓ Concentrations of ammonia above a certain level in water polluted either due to sewage or industrial waste is toxic to fish.
- ✓ Theproportionsofthe twoformsofammonia nitrogeninsurface waterdependonpH.
- ✓ For accurate results, it is generally preferable to distill off ammonia from the sample, and absorb in boric acid.
- ✓ Itisthendeterminedeitherbytitrationor colorimetricallyusingNessler reagent.

AlbuminoidNitrogen:

- ✓ Thepresence ofalbuminoidnitrogeninwaterindicatesthe pollutionofwater.
- ✓ Its measurement is done by adding strong alkaline solution of potassiumpermanganate to the already boiled water.
- ✓ Innocasethequantityofalbuminoid nitrogenshould exceed 0.3p.p.m.

Dissolvedgases:

- ✓ Oxygenand carbondi-oxidearethe gasesmostly found inthenaturalwater.
- ✓ The surface water contains large amount of dissolved oxygen because they absorb it from the atmosphere.
- ✓ Algaeand othertinyplantlifeofwateralsogiveoxygentothewater.
- ✓ Thepresenceofoxygen inthewaterindissolvedformkeepsitfreshand sparkling.
- ✓ Butmorequantity of oxygencausescorrosiontothepipesmaterial.Waterabsorbs carbon-dioxide from the atmosphere.
- ✓ If watercomes across calcium andmagnesium salts,carbon-dioxide reacts with the salts and converts them into bicarbonates, causes hardness in the water.
- ✓ The presence of carbon-dioxide is easily determined by adding lime solution to water gives milky white colour.

Iron& Manganese:

- ✓ Thesearegenerallyfoundingroundwater.
- ✓ Ifthesearepresentlessthan0.3p.p.m.,itisnotobjectionable,butifexceeds0.3 p.p.m.thewaterisnotsuitablefordomestic,bleaching,dyeingandlaundering purposes.
- ✓ Thepresenceofironand manganese inwatermakesbrownishredcolourinit, leadsto the growth of microorganism and corrodes the water pipes.
- ✓ Ironandmanganesealsocausetasteandodour inthe water.
- ✓ Thequantityofironandmanganeseisdeterminedbycolorimetricmethods.

Lead&Arsenic:

- ✓ Thesearenotusuallyfoundinnaturalwaters.
- ✓ But sometimes lead is mixedup inwaterfromlead pipesorfromtanks linedwithlead paint when water moves through them.
- ✓ Thesearepoisonousanddangerousto thehealthofthe public.
- ✓ Thepresenceoflead and arsenicisdetected bymeansofchemicaltestsforit.

Metals&otherchemicalsubstances:

- ✓ Water contains various types of minerals or metals such as iron, manganese, copper, lead, barium, cadmium, selenium, fluoride, arsenic etc.
- ✓ Theconcentrationofironandmanganeseshouldnotbeallowedmorethan0.3p.p.m.
- ✓ Otherwisetheywillcausediscolourationofclothesduring washing.
- ✓ Theymayalso cause incrustation inwater mains due to depositionofferric hydroxide and manganese oxide.

- ✓ Asbariumandleaareverytoxic,alowp.p.m.oftheseare allowed.
- ✓ Arsenic,seleniumispoisonousandmaycausefatality,thereforetheymustbe removed totally.
- ✓ Human lungs areaffectedbypresenceofhighqualityofcopperinthewater.
- ✓ Alaxativeeffectiscausedinthehumanbodyduetopresenceofsulphatesinthe water.
- ✓ Fewercavitiesintheteethwillbeformedduetoexcessivepresenceoffluoridein water more than 1 p.p.m.

BIOLOGICALCHARACTERISTICS:

Total count of bacteria

Bacteriacoli(B-coli)test

Total count of bacteria:

- ✓ Bacterialexaminationofwaterisveryimportant,sinceitindicatesthedegreeof pollution.
- ✓ Waterpollutedbysewagecontainoneormorespeciesofdiseaseproducing pathogenic bacteria.
- ✓ Pathogenic organisms cause water borne diseases, and many non-pathogenic bacteria such as E.Coli, a member of coliform group, also live in the intestinal tract of human beings.
- ✓ Coliform itself is not a harmful group but it has more resistance to adverse condition than any other group.
- ✓ So, if it is ensured to minimize the number of coliforms, the harmful species will be very less.
- ✓ So, coliform group serves as indicator of contamination of water with sewage and presence of pathogens.
- ✓ Themethodstoestimatethe bacterialqualityofwaterare:
  - ✓ StandardPlateCountTest
  - ✓ MostProbableNumber
- ✓ MembraneFilter Technique

Bacteriacoli(B-coli)test:

- ✓ Sometimesthis isalsocalledasE–colitest.
- ✓ TherearetwotestsforB-coli,firstispresumptiveandsecond confirmative.

- ✓ In the presumptive test, definite amount of diluted sample of the water in standard fermentation tubes containing lactose broth as culture medium is kept in incubator at 37 C for 24 to 48 hours.
- ✓ Ifsomegasisproduced inthefermentationtube,itindicatesthepresenceofB-coli.
- ✓ Inthe confirmationtest some sample fromthe presumptive tube istakenand placed in another fermentation tube containing "brilliant green lactose bile" as culture medium.
- ✓ It is again kept in incubator at 37 C for 48 hours, if there is formation of gas in the tube, it confirms the presence of B-coli and the water is unsafe for use.
- ✓ Nowadays a new technique of finding out the B-coli is developed which is called 'Membrane Filter Technique".
- ✓ This isaverysimplemethod.
- ✓ Inthis methodthe sample ofwateris filtered througha sterilized membrane of special design due to which all the bacteria are retained on the membrane.
- ✓ The member is then put in contact of culture medium-M-Endo's medium in the incubator for 24 hours at 37 C.
- ✓ The membrane after incubating is taken out and the colonies of bacteria are countedby means of microscope.
- ✓ Thismethodisknownas'membrane filtertechnique".

Membranefiltertechnique:

- ✓ Now adaysanew technique offindingouttheB-coli.
- ✓ AlternativetoMPN.
- ✓ Membranecontainsmicroscopicporeswhicharecapableofretainingbacteria.
- ✓ Water is filtered through the membrane and it is then incubated for a period of 20 hours along with nutrients.
- ✓ Thecoloniesofbacteriacanthen be counted.

MostProbableNumber:

- ✓ It is the number which represents the bacterial density which is most likely to be present.

ColiformIndex:

- ✓ Coliforms are the rod, shaped, non-pathogenic bacteria whose presence or absence in water indicates the presence or absence of fecal pollution.
- ✓ The total coliform group consists of members whose normal habitat is the – (lower portion of intestines) of humans and warm- and cold-blooded animals and soil.
- ✓ Some members whichare not found insoiland vegetationconstitute about 96% ofall the coliforms of human fecal.

- ✓ Suchmembersarecalledfecalcoliformsandrecentlynamedby WHO.
- ✓ The totalcoliformgroup is widely used as a indicatororganismofchoice for drinking water.
- ✓ Escherichiacoli(E-Coli)isthepredominantmemberofthefecalcoliformgroup.
- ✓ Usedtomeasurecoliformbacteriapresentinwatersample.
- ✓ It is defined as the reciprocal of the smallestquantity of sample which would give apositive B-coli test.
- ✓ Shouldbepreferablylessthan3andshouldnotexceed10
- ✓ Butduetothedevelopmentofthe‘MembraneFiltertechnique”theMPNorC.I methods are not used.
- ✓ Forthedrinkablewateritisnecessarythatitmustbefreefrompathogenicbacteria.

WATERBORNEDISEASES:

- ✓ Whenwatercontainscertainharmfulanddiseaseproducingmatter,itmayleadto many diseases on being consumed by healthy persons.
- ✓ Water –bornediseases maycausebyfollowingfactors:
    - Presenceofmicro organisms
    - Presenceofparasiteova
    - Presenceofinorganicmatter
- Presenceoforganicmater

Presenceof Microorganisms:

- ✓ Bacteria(Cholera,typhoid,paratyphoiddysentery,diarrhea)
- ✓ Virusdiseasesofpoliomyelitis (infectivehepatitis (Jaundice)
- ✓ Protozoainfection(amoebicdysentery)

PresenceofParasiteova:

- ✓ Eggordevelopedembryosoftheeggsofroundwormsandtapeworms,mosquito eggs.
- ✓ Malarianematodesflukes,guineawormandhookworminfections.

PresenceofInorganic matter:

- ✓ Fluorides>1.5 mg/lcauses–eruptingteeth.
- ✓ Nitrate– bluebabies.

Presenceoforganicmatter:

- ✓ Excessofvegetablematter

- ✓ Sewageeffluents(diarrheaandgastricdisturbance)

TypesofWaterborne diseases:

CommonColdandFlu:

- ✓ Thediseasethatcatchespeopleacrosstheagelines.
- ✓ Youwillgetwet,constantsneezing,throatandfeverarethesevere symptomsof common cold and flu.
- • Prevention:
- ✓ Avoidgetting inrain.
- ✓ Andifitiscaught,thebesthomemaderemedyishotturmericmilk.

Dengue:

- ✓ Theverycommondiseaseduring rainyseasons.
- ✓ Thevirus isspreadbytheAedesmosquito.
- ✓ The symptoms include high fever, pain in joints & muscles, vomiting, bleeding from nose, gums & even under skin due to hemorrhagic fever.
- • Prevention:
- ✓ Stayaway from mosquitoes & clean your surroundings so that the mosquitoes doesn't multiply.

Chikungunya:

- ✓ Another mosquitotransmitteddisease.
- ✓ Thevirus isspreadbytheAedesAegyptusmosquito.
- ✓ The symptoms include fever, swelling & stiffness of joints, muscular pain, headache, fatigue & nausea.
- • Prevention:
- ✓ Protectyourselffrommosquitobites.

Cholera:

- ✓ Itspreadsthroughcontaminatedfood,water&poorhygienic conditions.
- ✓ Thesymptoms includediarrhea,vomiting,lowbloodpressure,drymouthetc.
- • Prevention:
- ✓ Keepdrinkingboiledwaterandmaintainpersonal hygiene.

Typhoidfever:

- ✓ Thediseasethatspreadsduringthemonsoonseason.

- ✓ Thediseaseisspreadthroughcontaminatedfood&water.
- ✓ Thesymptomsincludeprolongedfever,abdominalpain&headache.
- Prevention:
- ✓ Gettingavaccinationinadvance.Gethighintakeoffluidtopreventdehydration.

Prevention:WaterborneDisease

- ✓ Improvequalityandquantityofdrinkingatsource,atthe tap,orinthe storagevessel.
- ✓ Interruptroutesoftransmissionbyemptyingaccumulatedwatersources.
- ✓ Chlorinate water.
- ✓ Changehygienebehavior,likehandwashing.
- ✓ Properuseof latrines.
- ✓ Carefuldisposalofallwasteproducts.
- ✓ Propermaintenanceofwatersupply,sanitationsystems,pumpsandwells.
- ✓ Goodfoodhygiene-washbeforeeating, protectfromflies.
- ✓ Improvedimmunizationspractices,especiallyrotavirus.
- ✓ Developorenhancepublichealthsurveillancesystem.
- ✓ Fasterresponsestoemergentanddangerouspandemicstrainsofpathogenic infections.
- ✓ Healtheducationprogramsacrossthe country.

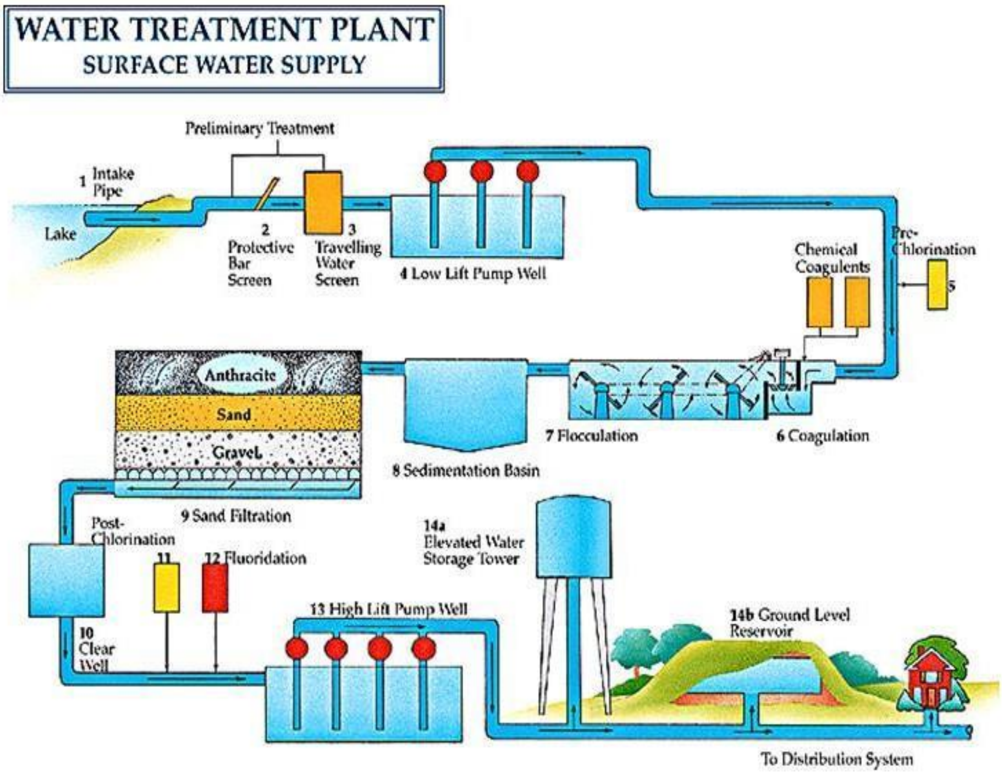
UNIT – II WATER TREATMENT Objectives - Unit Operations and Processes - Principles, Functions, and Design of Water Treatment Plant Units, Aerators of Flash Mixers, Coagulation and Flocculation – Clarifloccuator- Plate and Tube Settlers - PulsatorClarifier - Sand Filters - Disinfection - Softening, Removal of Iron and Manganese - Defluoridation- Softening - Desalination Process - Residue Management - Construction, Operation and Maintenance Aspects

INTRODUCTION

INTRODUCTION

OBJECTIVESOFWATERTREATMENT:

- Ingeneral,Watercontainsmanyimpurities,suchastraceminerals, metals,chemicals etc.
- Thefollowing aretheobjectivesofwater treatment:
- ✓ Toremovethedissolvedgasesandcolourofwater.
- ✓ Toremovetheunpleasantandobjectionabletastesandodoursfromthe water.
- ✓ Tokillallthe pathogenic organismswhichare harmfultothe humanhealth.
- ✓ Tomakewaterfit fordomesticusesuchascooking,washingandvariousindustrial purposes as dyeing, steam generation etc.
- ✓ Toeradicatethecontaminantsthatarecontainedinwaterasfoundinnature.
- ✓ Tocontroltheimpuritiesfromscaleformation.
- ✓ Purewaterqualityisrequired tominimizethecorrosion,radiationlevelsand fouling of heat transfer surfaces in reactor facility systems.
- ✓ Toprovesafepotablewaterto thepublic.
- ✓ Toreducethephysical,chemicalandbiologicalcontaminants inwater.
- ✓ Toeliminatethetuberculating andcorrosivepropertiesofwaterwhichaffectsthe conduits and pipes.
- ✓ Watertreatment isrequiredforsurfacewaters andsomegroundwatersfordrinking purposes.
- ✓ Water treatments involves the removal of pollutants generated from different sources andtoproducewaterthat ispureandsuitable forhumanconsumptionwithout causing any long term or short-term adverse health effects.
- ✓ Toimprovethequalityofwaterforseveralpurposes,watertreatmentis required.
- ✓ Toprovideappropriatetreatment technologytothecontaminatedwater,whichwillbe useful to all population’s groups.



LocationofTreatment Plants:

- Thewatertreatmentplantsshouldbelocatedasneartothetownsaspossible.
- Ifthesourceofwatersupplyistubewellthetreatment plant should be locatedinthe central part of the town, so that purified water may reach the public as early as possible.
- Ifthecityis verylargeto whichwater cannot besupplied fromonetubewell, thecity should bedivided into zonesand aseparatetubewell with necessarytreatment plants should be provided for each zone.
- Ifthesourceofwaterisriverorreservoir,thetreatment plant should be locatedas near the town as possible preferably in the central place.
- Thefollowingpointsshouldbekept inmind while givingthelayout ofanytreatment plant,
- Alltheplantsshould be locatedinorderofsequence, sothat waterfromoneprocess should directly go into next process.
- Ifpossible, alltheplantsshouldbe locatedat suchelevationsthat watershould flow from one plant to next under its force of gravity only.
- Allthetreatment unitsshould bearranged insuchawaythat minimumarea is required, it will also insure economy in its cost.
- Sufficientareashouldbeoccupiedforfutureextensioninthebeginning.

- Staffquartersandofficeshouldalso beprovided nearthetreatment plants,sothat operators can watch the plants easily.
- Thesiteoftreatment plant should be veryneat and giveverygoodaesthetic appearance.

WATERTREATMENTPROCESSES:

- Thewatertreatmentprocessesdirectlydependontheimpuritiespresentinwater.
- Forremovingvarioustypesofimpurities,thefollowingtreatmentprocessesareused.

Screening:

- ✓ Removaloffloatingmattersasleaves,deadanimalsetc.

PlainSedimentation:

- ✓ Removalofsuspendedimpuritiesassilt,clay,sandetc.

Sedimentation with coagulation:

- ✓ Removaloffinesuspendedmatter.

Filtration:

- ✓ Removalofmicro-organismsand colloidalmatters.

Aerationandchemicaltreatment:

- ✓ Toremovethedissolvedgases,tastesand odours.

WaterSoftening:

- ✓ Removalof hardness.

Disinfection:

- ✓ Removalofpathogenicbacteria.

Screening:

- Screening isaunit operationthat separateslargefloating materialsfromwaterand from entering water treatment facilities and mains.
- Ascreener isadevicewithopenings(usuallyuniforminsize) toremovethefloating materials and suspended particles.
- Theprocessofscreeningcanbecarriedoutbypassingwaterthroughdifferenttypes of screeners (with different pore sizes)
- Thescreenersareclassifiedascoarse, mediumorfine, dependingonthesizeofthe openings.
- Thecoarsescreen haslargeropenings(75-150mm).

- Theopenings formediumand finescreensrespectivelyare20-50mmand lessthan20 mm.
- Different typesofscreens-fixed barscreen(coarseormedium)disctype finescreen, drum type fine screen is in use.

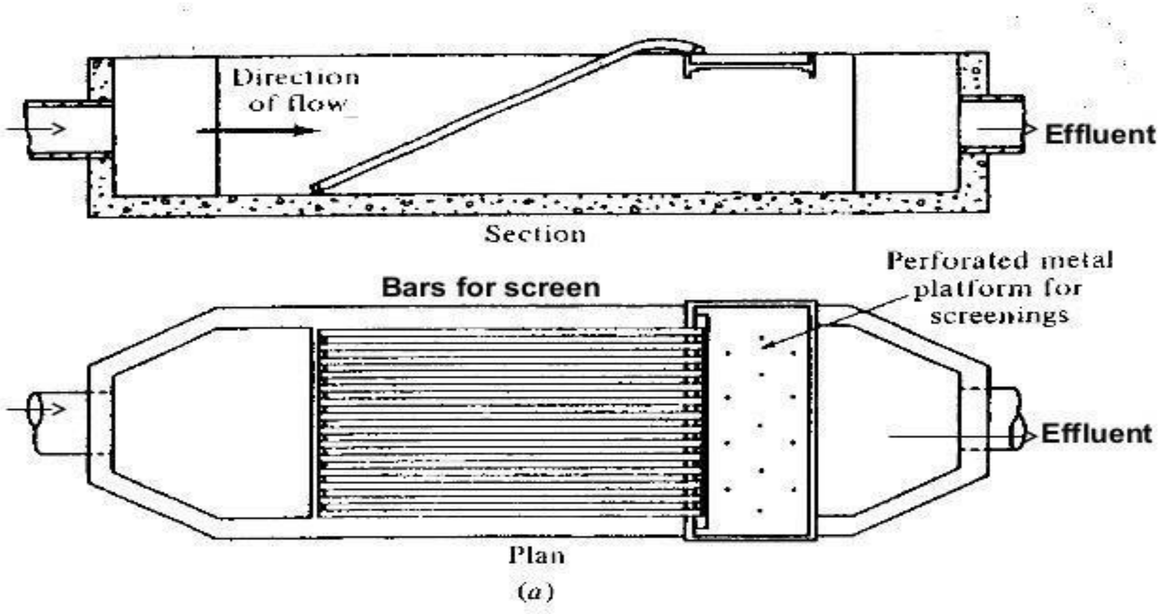


Figure : Fixed Bar-Screen (course or medium)

PlainSedimentation

- Plain sedimentation is the process ofremoving suspended matters fromthe water by keeping it quiescent intanks,sothat suspended mattermaysettledowninthebottom due to force of gravity.
- Sedimentation,orclarification, isthe processesofletting suspended materialsettleby gravity.
- Suspendedmaterialmaybeparticles,suchasclayorsilts.
- Sedimentationisaphysicalwatertreatment processusinggravitytoremove suspended solids from water.
- Solidparticlesentrainedbytheturbulenceofmoving watermayberemoved naturally by sedimentation in the still water of lakes and oceans.
- Sedimentationistheprocessofremovingsuspendedcoarserparticles inwaterby settling down them to the bottom of tank.
- Foraparticletosettledown,theflowvelocitymustbereduced.

- Thisprocess iscarriedoutinastructurecalledsedimentationtankorsettlingtank.
- The mainprinciple involved inthesedimentationtank isto reducetheflowvelocityof water which allows the major number of suspended particles to settle down.
- Thevelocitywithwhichtheparticleissettlingisknownsettlingvelocity.
- The number of suspended particles collected at bottom of the tank is based on different factorslikeshapeandsizeoftank, sizeofparticle, temperatureofwater, flow velocity, detention period etc.

DiscreteParticle:

- ✓ Anyparticlewhichdoesnotalteritssize,shapeandweight whilerisingorsettling in any fluid is called discrete particle.
- ✓ Alltheparticleshaving morespecificgravitythantheliquidwillmove vertically downward due to gravitational force.

SettlingVelocity:

- ✓ Whenanydiscreteparticle isfallingthroughaquiescent fluid, it willaccelerate until the frictionalresistance or dragforce becomes equalto the gravitational force acting upon the particle.
- ✓ Atsuchstage,theparticlewillsettleatuniformvelocity.
- ✓ Thisuniformvelocityiscalled“settling velocity” and isaveryimportantfactor. $V_s = \frac{1}{18} \frac{g(\rho_s - 1)d^2}{\mu}$

Where,

V_s=settlingvelocityincm/sec. g

= 981 cm/sec.

ρ_s=specificgravityoftheparticle.

d=diameterofthesettlingparticleincm. μ =

viscosity of water in centi-stokes.

Detention Time:

Thetime forwhichthewaterisdetained inthesettlingtank iscalleddetentiontime.

$$\text{Detention time} = \frac{\text{Capacity of tank}}{\text{Rateofflow ofwater}}$$

AdvantagesofPlainSedimentation:

- Itlightenstheloadonthesubsequentprocess.

- Theoperationof subsequentpurificationprocesscanbecontrolledinabetterway, because plain sedimentation delivers less variable quality of water.
- Thecostofcleaning the chemicalcoagulationbasinsare reduced.
- Nochemicalislostwithsludgedischargedfromtheplainsettlingbasin.
- Lessquantityofchemicalsisrequiredinthesubsequenttreatmentprocesses.

TypesofSedimentationTanks:

- Dependinguponvarious factorssedimentationtanksareclassifiedasfollows.
- Based on methodsofoperation
- ✓ Fillanddrawtypetank
- ✓ Continuousflowtypetank
- Based onshape
- ✓ Rectangulartanks
- ✓ Circulartanks
- ✓ Hopper bottomtanks
- Based onlocation
- ✓ Primarytank
- ✓ Secondarytank

FillandDrawTypeSedimentation Tank:

- Incaseoffillanddrawtypesedimentationtank, waterfrominlet isstoredforsome time.
- Thetimemaybe24hours.
- Inthattime,thesuspended particlesaresettled atthebottomofthetank.
- After 24hours,thewater isdischargedthroughoutlet.
- Thensettledparticleare removed.
- Thisremovalactionrequires6-12hours.
- So,onecompleteactionofsedimentationrequires30-40hoursincaseoffillanddraw type sedimentation tank.

ContinuousFlowTypeSedimentation Tank:

- Inthiscase,waterisnotallowedtorest.
- Flowalwaystakesplacebutwithaverysmallvelocity.
- Duringthisflow, suspendedparticlesaresettledatthebottomofthe tank.

- ➢ Theflowmaybeeitherinhorizontaldirectionorverticaldirection.

Horizontalflowtypesedimentationtank:

- ✓ Thesetanksgenerallyinrectangularshape. Theyhavemorelengthtwiceitswidth.
- ✓ Becausetheyneedtoflowmoredistancetosettleallsuspended particles.
- ✓ The maximumpermissiblevelocityinthiscaseis0.3m/sec.

Verticalflowtypesedimentation tank:

- ✓ The vertical flow type sedimentations tanks are generally in circular shape and flowtakes place in vertical direction.
- ✓ Hopperbottomisprovidedat thebottomofthetanktodispose thecollectedsludge.

2. Continuous type:

A. Horizontal Flow Type

(a) Rectangular tanks with longitudinal flow

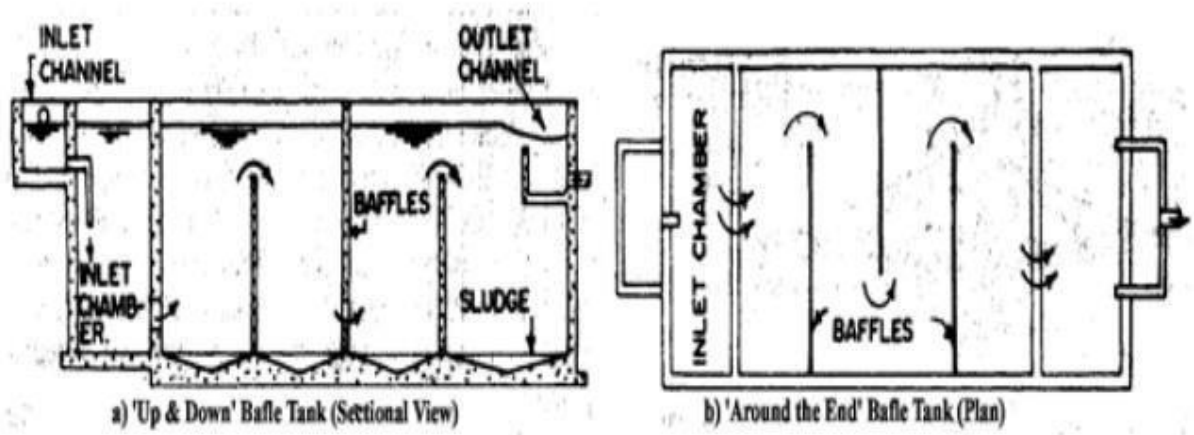


Fig 6.5 Rectangular sedimentation tank (ST) with baffles

(Source: Punmia et al., 2005)

- ➢ Rectangularsedimentationtanksaremostlypreferredsedimentationtanksandare used widely.
- ➢ Theflowtakesplaceinhorizontal direction thatislength wisein rectangulartanks and consists of large number of baffle walls.
- ➢ The functionofbafflewalls isto reducethevelocityofincomingwaterto increasethe effective length of travel of the particle and prevent the short circuiting.
- ➢ Maintenancecostsarelowincaseofrectangular sedimentationtanks.

- Theyarealsosuitableforlargecapacityplants.
- These tanksare generallyprovided withchanneltype inlet and outlet extending onthe full width.
- Thefloorbetweentwobafflesismadelikeahopperslopingtowardscentrewhere sludge pipe is provided.
- The sludge is takenout through sludge outlet under hydrostatic force byoperating the gate valve.

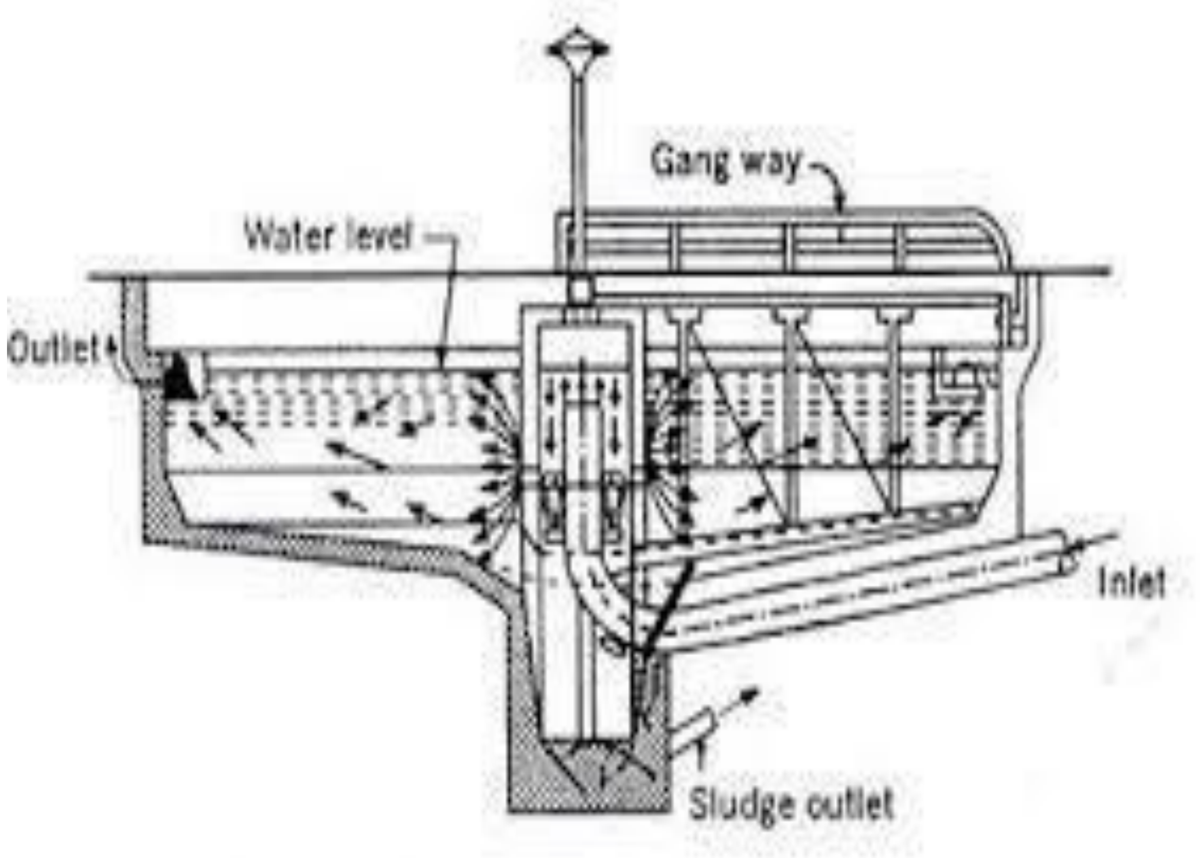


Fig. 11.7. Radial flow circular-tank.

- Thesearegenerallynotusedinplainsedimentation,butaremostlyusedin sedimentation with coagulation.
- Circularsedimentationtanksarepreferredforcontinuousverticalflowtypesedimentation tanks.
- Inthiscaseinfluentissentthroughcentralpipe ofthetankandradialflow takes place.
- Mechanicalsludge scrappersare provided to collect the sludge and collected sludge is carried through sludge pipe provided at the bottom.

- But circular tanks are uneconomical as compared to rectangular tanks but they have high clarification efficiency.
- Itis oftwotypes,
  - ✓ Radialflowcirculartank
  - ✓ Circumferentialflowcirculartank.

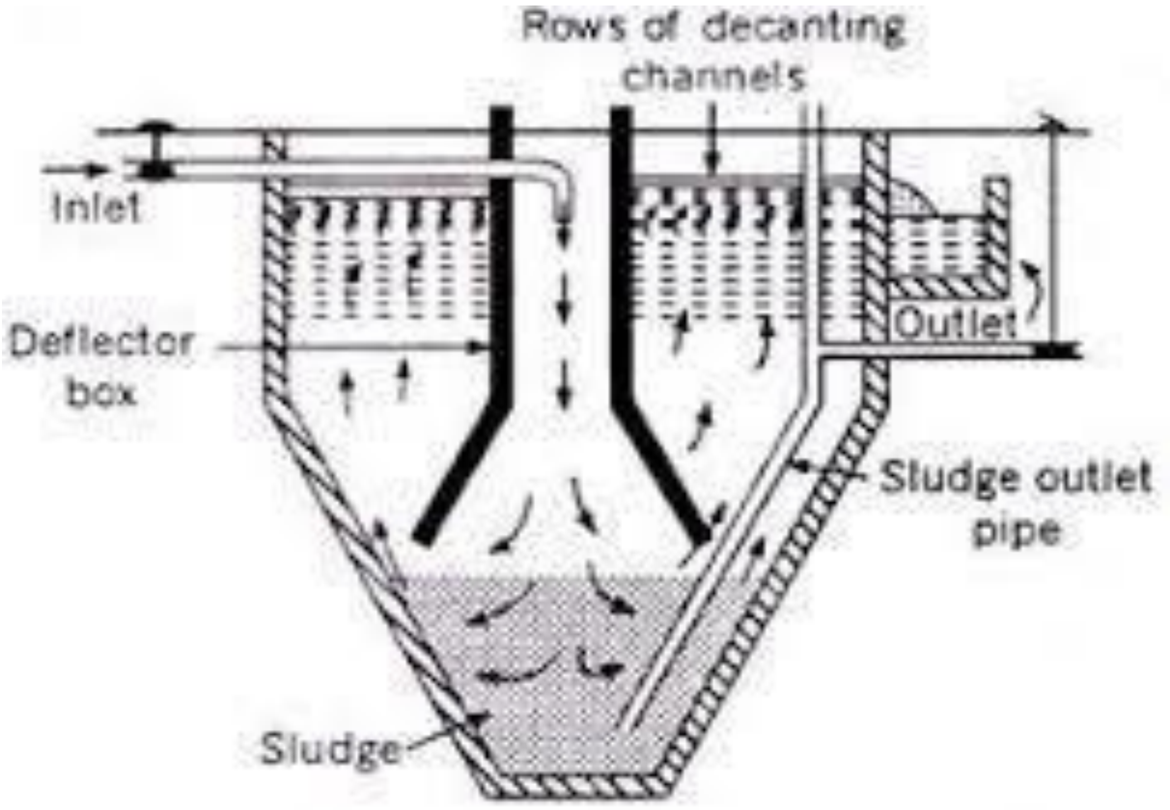


Fig. 11.9. Hopper bottom settling tank.

- These are vertical flow tanks, because water flows upward and downward in these tanks.
- Thewaterentersinthesetanksfromthetop into deflectorbox.
- After flowing downward inside the deflector box, the water reverses its direction and starts flowing upward around the deflector box.
- The suspended particles having specific gravity more than one, cannot follow the water at the time of reversing its direction, and settle in the bottom, from where they are removed through sludge outlet pipe under hydrostatic pressure.
- Sludgeiscollectedatthebottomanditisdisposedthroughsludge pump.
- Rowsofdecanting channelsareprovided atthetoptocollecttheclearwater.

- The water after flowing in the channel is taken out from the outlet channel providedon one side of the tank.
- Thesetanksaremostlyusedinsedimentationwith coagulationprocess.

PrimarySedimentationTank

- ✓ Primary sedimentation tank is a normal sedimentation tank in which water is stored at rest for some time and sludge collected at bottom and oily matter collected at top are removed.
- ✓ After primary sedimentation process the wastewater is discharged into aerobic filter where activated sludge process take place.

SecondarySedimentationTank

- ✓ After activated sludge process the wastewater enters secondary sedimentation tank in which suspended particles contains microbes are removed and are reflected towards aerobic filter to maintain high microbe concentration in aerobic filter.

SedimentationTankDesign Parameters

- TodesignSedimentationtankfollowingelementsarerequiredintheconsideration:
- ✓ Velocityofflow
- ✓ Capacityoftank
- ✓ Detentionperiod
- ✓ Overflowrate
- ✓ DimensionsorShape ofthe tank
- ✓ FreeBoard
- ✓ Sludgecapacityandsludge removal.

PROBLEMS

1. A water has to purify the water for a town whose daily demand is 9 X 10^6 litres/day. Design the suitable sedimentation tank of the water works fitted with mechanical sludge remover. Assume the velocity of flow in the sedimentation tank as 22 cm/minute and the detention period as 8 hours.

Solution:

Quantityofwaterto be treated bythe sedimentationtank during detentionperiod of8 hours= $\frac{9 \text{ X } 10^6 \text{ X } 8}{24}$ = 3 X 10^6 litres = 3 X 10^3 m^3.

Capacityofthesedimentationtankrequired= 3000m^3.

Velocityofflow insidethetank isgivenas22cm/minute=0.22m/minute. Length of

the tank = Velocity of flow X Detention period

= 0.22X(8X 60)=106m.

Thecross-sectionalarea oftankrequired=$\frac{\text{Capacityofthetank}}{\text{Lengthofthetank}}$=$\frac{3000}{106}$= 28.3m^2

Assume the depth of the water as 3.5 m.

Requiredwidthofthetank=$\frac{28.3}{3.5}$ = 8.10m.

Providingafreeboardof0.5 m,

Overalldepthofthetank=0.5+3.5=4.0m.

Dimensionofthe tank= 106X 8.10X 4.0m.

2. Design a sedimentation tank for a water works, which supplies 1.4 X 10^6 litre/day water to the town. The sedimentation period is 5 hours, the velocityof flow is 12 cm/minute, depthof water in the tank is 4.0 m. Assuming an allowance for sludge is to be made as 80 cm.

Solution:

Quantityofwatertobetreatedbythesedimentationtankduringdetentionperiodof5hours= $\frac{1.4 \text{ X}10^6\text{X5 litres}}{24}$ =292m^3

Thevelocityofflowhasbeengivenas 12cm/min. =0.12m/min.

Required length of the tank = Flow velocity X Detention time

=0.12X(5X60)=36.0m.

Crosssectionalarea ofthe tank=$\frac{\text{Tankcapacity}}{\text{Tank length}}$= $\frac{292}{36}$ =8.12m^2

Depthofthewaterinthetank=4.0m Depth of

sludge = 0.8 m

Netwaterdepth= 4.0–0.8= 3.2m

Widthofthe tank= $\frac{\text{Crosssectionalarea}}{\text{Depthof water}}$ =$\frac{8.12}{3.20}$=2.54msay 2.60m.

Providing free boardof0.5m, Overalldepth=4.0+0.5=4.5m. Size of

the tank = 36 X 2.6 X 4.5 m.

SEDIMENTATIONWITHCOAGULATION:

- Groundwaterandsurfacewatercontainbothdissolvedandsuspendedparticles.
- Veryfinesuspendedclayparticlesarenotremovedbyplain sedimentation.

- Silt particle of 0.06 mm size requires 10 hours to settle in 3 m deep plain sedimentation tank and 0.02 mm particle will require about 4 days for settling.
- Thissettling is impracticable.
- Inadditionto fine suspended matter, water also contains electricallycharged colloidal matter which are continuously in motion and never settle down due to gravitational force.
- When water contains such fine clay particles and colloidal impurities, it becomes necessary to apply such process which can easily remove them from the water.
- After long experience it has been found that such impurities can be removed by sedimentation with coagulation.
- It has been found that when certain chemicals are added to water an insoluble, gelatinous, flocculent precipitation is formed.
- This gelatinous precipitate during its formation and descent through the water absorb and entangle very fine suspended matter and colloidal impurities.
- The gelatinous precipitate has the property of removing fine and colloidal particles quickly and completely than by plain sedimentation.
- These coagulants have the advantages of removing colour, odour and taste from the water.
- Thesecoagulantsifproperlyappliedareharmlesstothe public.
- First the coagulants are mixed in the water to produce the required precipitate, thenthe water is sent in sedimentation basins where sedimentation of fine and colloidal articles takes place through the precipitate.
- Coagulation and flocculation are used to separate the suspended solids portion from the water.

ChemicalCoagulants:

- ✓ AluminiumSulphate(Alum)
- ✓ SodiumAluminate
- ✓ FerricCoagulants(FerricChloride&Ferric Sulphate)
- ✓ Chlorinated Copperas
- ✓ FerrousSulphateandlime.

Dosageof Coagulants:

Thedosageofcoagulantswhichshouldbeaddedinthewaterdependsonthe following factors,

- ✓ Kindofcoagulant
- ✓ Turbidityofwater

- ✓ Colourofwater
- ✓ pHofwater
- ✓ Temperatureof water
- ✓ MixingandFlocculationtime.

DeterminationofOptimumDosageof Coagulant:

- ➢ Alaboratoryprocedurethat simulatescoagulation/flocculationwithdiffering chemical doses.
- ➢ Theoptimumdosage ofcoagulantsisdetermined byJarTestApparatus.
- ➢ The purpose of the procedure is to estimate the minimum coagulant dose required to achieve certain water quality goals.
- ➢ Samplesofwatertobetreatedareplacedinsixjars.
- ➢ Stirring paddles ofnon-corrosive metalare placed in each jar, which can be rotated at any desired speed by gear and spindle system.
- ➢ First ofall,thesamplesofwaterinrealamountsistakeninevery jar.
- ➢ Thencoagulantisaddedinjarinvaryingamounts.
- ➢ Thequantityofcoagulantaddedineachjarisnoted.
- ➢ Thenwiththehelpofelectricmotorallthepaddlesarerotatedataspeedof30-40 R.P.Mforabout 10 minutes.
- ➢ Afterthisspeedisreduced andpaddlesarerotatedforabout20-30minutes.
- ➢ Therotationofpaddlesisstoppedandtheflocformedineachjarisnotedandis allowed to settle.
- ➢ Thedosageofcoagulantwhichgivesthebestflocistheoptimumdoseofcoagulants.

FILTRATION:

- Sedimentationprocessremoveslargepercentageofsuspendedimpurities,organic material and small percentage of bacteria.
- Ifsedimentationwithcoagulationisused,thepercentageremovalofcolloidal particles is increased.
- Forremoving bacteria, colour,taste,odoursand producing clear and sparkling water, filters are used.
- The process of passing the water through beds of sand or other granularmaterials isknown as filtration.
- Waterflowsthroughafilterdesignedtoremoveparticles fromwithinit.
- Thefiltersaremadeoflayersofsandandgravel,andinsomecases,crushed anthracite.
- Filtration collects the suspendedimpuritiesin water, enhancing the effectiveness of disinfection.
- Thesefiltersareroutinelycleanedbybackwashing.

Typesof Filters:

- ✓ GravityFilters
- ▪ SlowSandFilter
- ▪ RapidSandFilter
- ✓ PressureFilters
- ▪ HorizontalpressureFilter
- ▪ VerticalpressureFilter

➢ Forsmallplantsandindividualcolonyorindustry,pressurefiltersare employed.

➢ Forwaterworks, pressurefiltersarenotusedduetotheir costlymaintenance.

SandforFiltration:

Thesandusedforfiltersshouldhavethefollowingproperties:

✓ Itshouldbe free fromclay,loam,limeandorganic matteretc.

✓ Itshouldbeobtainedfromhardrockssuchasbasalt, trapandquartz.

✓ Itshouldbeofuniformsizeand nature.

✓ Itshould beresistantand hard.

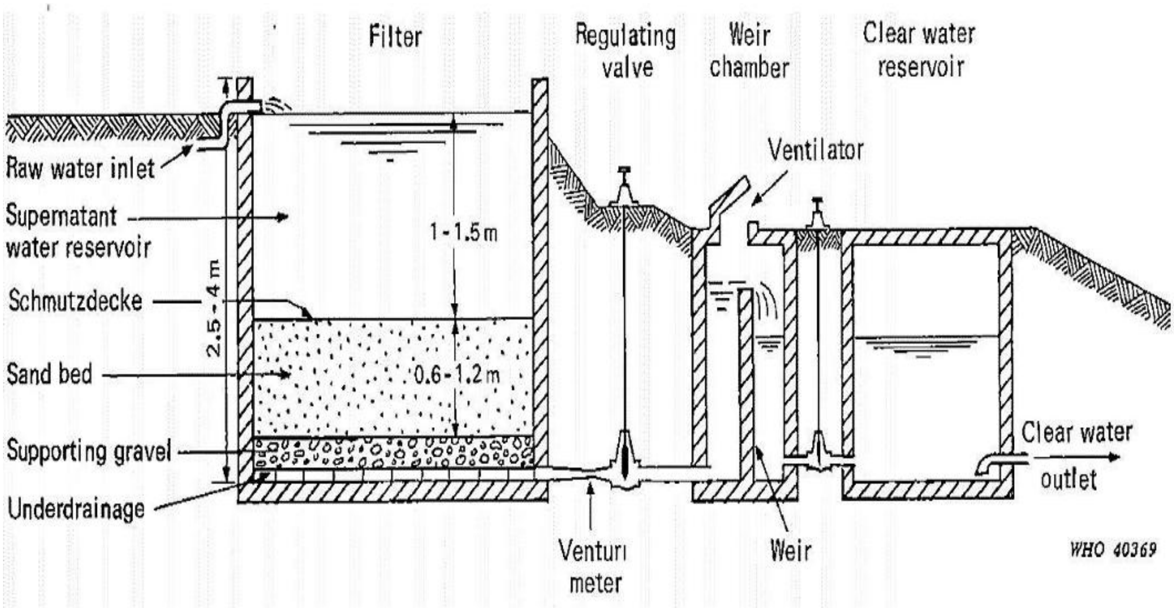
Gravelfor Filtration:

✓ Thegravelusedinfiltrationplantshouldbeclean,hard,durableand rounded.

✓ Itshould befreefromclay,loam,shellsandotherforeign matters.

✓ Itshouldnotcontainflat,thinorlong pieces.

✓ Itshouldhave adensityofabout1600Kg/m^3.



➢ Slowsandfiltersareusedin waterpurification fortreatingraw watertoproducea potable product.

➢ These are watertight shallow tanks about 2.5 m to 4 m deep and having surface area100 m to 2000 m in plan.

➢ These tanks contain 60-90 cm thick bed of sand supported on 30-60 cm thick gravelbed.

➢ Generally,threetofourlayersofgravelhaving thicknessof15-20cmare used.

- The coarsest gravel is placed in the bottom and the smallest size gravel is used in the topmost layer.
- The size ofthe bottomlayer gravel is40-60 mm, the size ofthe intermediate layer 20-40 mm and 6 mm to 20 mm.
- Thesizeofthetopmostgravellayeris3-6 mm.
- The gravel is supported on a bed of concrete sloping towards a central longitudinal drain connected by a system of open jointed under-drains.

ComponentsofSlowSand Filter:

- ✓ Inlet
- ✓ Underdrainagesystem
- ✓ Depth of water
- ✓ Outlet
- ✓ Miscellaneous
- ✓ Appurtenances.
- OperationofFilter:
- ✓ The water from the sedimentation tanks enters the slow sand filter through a submersible inlet.
- ✓ This water is uniformly distributed over the sand bed without causing anydisturbances.
- ✓ Thewaterpassesthroughthefilteringmediaatanaveragerateof100 to 200lit/m/hr.
- ✓ This rate of filtration is continued until the difference between the water level on the filter and inthe outlet, chamber is slightlyless thanthe depthofwaterabove the sand.
- ✓ The difference between the water above the sand bed and in the outlet, chamber is called loss of head.
- ✓ During filtering, the filtering media gets clogged due to impurities which stay in the pores, the resistance to the passage of water and loss of head also continuously increases.
- ✓ When loss of head reaches its permissible limit the working of filter is stopped and about 2-3cmsand fromthetopofbed isscrapped andreplacedwithcleansand before putting back into service to the filter.
- ✓ The scrapped sand is washed withwater, dried and stored for returnto the filter at the time of the next washing.

Advantages:

- ✓ Very effective removal of bacteria, viruses, protozoa, turbidity and heavy metals in contaminated fresh water.

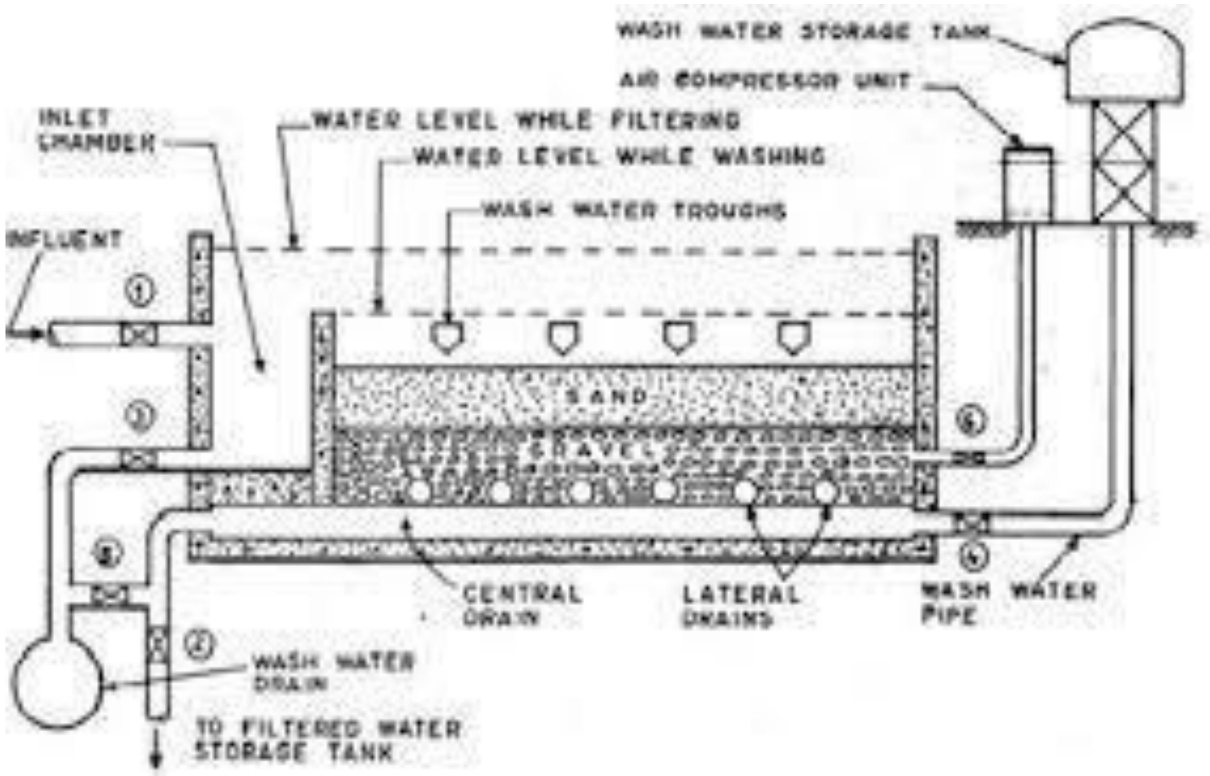
- ✓ Simplicity of design and high self-help compatibility, construction, operation and maintenance only require basic skills and knowledge and minimal effort.
- ✓ Ifconstructedwithgravityflowonly, no(electrical)pumpsrequired.
- ✓ Localmaterialscanbeusedfor construction.
- ✓ Highreliabilityandabilitytowithstandfluctuationsinwater quality.
- ✓ Nonecessityfor theapplicationofchemicals.
- ✓ Easy to install in rural, semi-urban and remote areas, Simplicity of design and operation.
- ✓ Longlifespan(estimated >10years).

Disadvantages:

- ✓ Veryregularmaintenanceessential.
- ✓ Requirement of a large land area, large quantities of filter media and manual labourfor cleaning, Low filtration rate.

Rapid Sand Filter:

- ➢ Therapid sand filter orrapidgravityfilter is a type offilter used in water purification and iscommonlyused inmunicipaldrinkingwaterfacilitiesaspartofa multiple-stage treatment system.
- ➢ Rapid sand filterswere first developed in the 1890s, and improved designs were developed by the 1920s.



ComponentsofRapid sandfilter:

Themajor partsofagravityrapidsandfilterare:

- ✓ Filtertankorfilterbox,
- ✓ Filtermedia,
- ✓ Gravelsupport,
- ✓ Underdrainsystem,and
- ✓ Washwater troughs.

WaterFilterTank:

- ✓ Thefiltertankisgenerallyconstructedofconcreteandismost oftenrectangular.
- ✓ Thesizesofthefiltersvaryaccordingtothe quantitytobetreated.
- ✓ The number of filters is selected to minimize the effect of removing the filter from service for washing on remaining filters.
- ✓ A minimum of four filters is desirable, although two to three filters may be used for small plants.
- ✓ Water treatment filter bed sizes vary from25 to 100 m^2 with lengths in the range of 4 to 12 m and widths in the range of 2.5 to 8 m and length to breadth ratio of 1.25 to 1.33.
- ✓ Thewashwatercollectionchannelislocatedononesidealongthelengthofthefilter.

- ✓ Filter beds oftwice this size can be constructed astwo identical beds separated bythe wash water collection channel, thus limiting the length of travelof feed water to 5 m.
- ✓ Aminimumoveralldepthof2.6mincludingafree boardof0.5 misadopted.

Filtermedia:

- ✓ The filter media is the important component of the water treatments filter which actually removes the particles from the water being treated.
- ✓ Water Treatment filter media is most commonly sand, though other types of mediacan be used, usually in combination with sand.
- ✓ Thesandusedinrapidsandfilters iscoarserthanthesandusedinslowsandfilters.
- ✓ This larger sand has larger pores which do not fill as quickly with particles removed from the water.
- ✓ Coarse sand also costs less and is more readily available than the finer sand used in slow sand filtration.
- ✓ The filter sand used in rapid sand filters is prepared from stock sand specifically for the purpose.
- ✓ Most rapid sand filters contain 60 to 75 cm thickness of sand, but some newer filters are deeper.
- ✓ The sand used as filter media in RSF is generally of effective size of 0.4 to 0.7 mm and uniformity coefficient of 1.3 to 1.7.
- ✓ Thestanding waterdepthoverfiltervariesbetween1.0 and 2.0 m.

Gravelsupport:

- ✓ The water filter gravel at the bottom of the water filter bed is not part of the filter media and it is merely providing a support for media above the underdrains and allowing anevendistributionofflow ofwateracrossthe filter bed during filtering and backwashing.
- ✓ Thegravelalsopreventsthefiltersandfrombeinglostduringtheoperation.
- ✓ The filter gravel is usuallygraded of size from2.5 to 50 mm(largest size being at the bottom) in four to five layers to total thickness of 45 to 50 cm, depending on the type of under drain system used.
- ✓ In case the under-drainage system with porous bottom or false floor no gravel base is required.
- ✓ The filter gravel shall be classified by sieves into four or more size grades, sieves being placed with the coarsest on top and the finest at the bottom.

Under-drainageSystem:

- ✓ The under-drainage system of thewater filter is intended to collect the filtered water andto distributethewashwater during backwashing insucha fashionthat allportions of thebedmay perform nearly thesameamountof workandwhenwashedreceive nearly the same amount of cleaning.

- ✓ Since the rateofwash water flow is several times higher than the rateof filtration, the former is the governing factor in the hydraulic design of filters and under drainage system, which are cleaned by backwashing.

WashwaterTroughs:

- ✓ Wash-water troughs placed above the filter media collect the backwash water and carry it to the drain system.
- ✓ Proper placement of these troughs is very important to ensure that the filter media is not carried into the troughs during the backwash operation and removed from the filter.
- ✓ The upper edge of the wash water troughshould be placed sufficiently nearer to the surface of sand so that a large quantity of dirty water is not left above the filter sand after completion of washing.
- ✓ At the same time, the top of the wash-water trough should be placed sufficiently high above the surface of the sand so that the sand will not be washed into the gutter.
- ✓ Maximumclear spacingbetweenthetroughs maybe180cm.
- ✓ Thehorizontaltravelofwash-watertotroughshouldnotbe morethan90cm.
- ✓ These wash water troughs are constructed in concrete, plastic, fiberglass, or other corrosion-resistant materials. The troughs are designed as free-falling weirs.

PROBLEMS

1. Design five slow sand filter beds from the following data for the water works of a town of population 75,000,

percapitademand=135litres/day/capita,

Rate of filtration = 210 litres/hour/m^2

Assume maximumdemand as 1.5 times the average demand. Out of5 units, one is to be kept as stand by and used while repairing other units.

Solution:

Average demandofthetown=135X75000

$=10.125 \times 10^6$ litres/day.

Maximumdemandofthetown=$1.5 \times 10.125 \times 10^6$ litres/day

$= 15.19 \times 10^6$ litres/day.

Rateoffiltration=210X24litres/day/m^2

=5040litres/day/m^2

Totalsurface areaoffiltersrequired,

$$= \frac{\text{Maximumdailydemand}}{\text{Rate of filtration/day}}$$

$$= \frac{15.19X\ 10^6 \text{litres/day}}{5040}$$

$=3014m^2$.

But asoutoffiveunitsonlyfourunitsaretobeused,therefore, surface

area of each unit, $= \frac{3014}{4}$

$=753.5m^2$.

Keepingthelengthoftheslowsandfilter as2.5timesits width,

$2.5B\ XB = 753.5$

$B = \frac{753.5}{2.5}$

B=17.4m.

L=2.5XB

=2.5X17.4=43.5m.

Sizeofeachslowsandfilterunit=43.5 X17.4 m.

2. Designset ofthreerapidgravityfilters for treatingthewater at awater works, whichhasto supply the water to a town of population 1,00,000. Per capita demand of the town is 270 litres/day. The rate of filtration of the rapid gravity filters may be taken as 4500litres/hour/m^2.

Solution:

Totalquantityofwatertobetreatedbythefilters=100000X270

$=27X10^6$litres/day

$= \frac{27X\ 10^6}{24} = 11.25X10^6$litres/hour

Totalarea offilterbedrequired$= \frac{\text{Quantityofwater treated}}{\text{Rateof filtration}}$

$= \frac{11.25X10^6}{4500} = 250m^2$.

Areaofeachrapidgravityfilter =250/3= 83.34m^2.

Keeping the length of the filter 1.5 times its width,

LXB=83.34

1.5B XB =83.34

1.5B^2=83.34 B

= 7.5 m.

L=1.5XB=1.5X7.5 L =

11.25 m.

Sizeofeachslowsandfilterunit=11.25 X7.5 m.

3. Design arapidsandgravity filterunitfortreating5.2X10^6litres/daysupplyforatown. The filter is to work dayand night. Take 4500 litres/hour/m^2as the rateof filtration.

Solution:

Let half an hour be lost in washing, draining and returning to the service after 24 hours. Therefore, totaltime willbe 23.5 hours. for which filters willwork. Now allowing 4 % as the allowance for washing the filter.

Quantityofwatertobetreatedperhour=$\frac{5.2X10^6 \text{litres.}}{23.5}$

Filterarearequired= $\frac{5.2 X 10^6}{23.5X 4500}$ =49.19 m^2Say49.2 m^2

Providingtwounits,areaofeachfilter= 24.6m^2.

Therefore, provide three units of 7 m X 3.5 m.

Twounitsoffilterwillalwayswork.

Third is required during repair work of any one of the others, which can also be used during emergency.

DISINFECTION:

- Disinfection istheprocess,whichinvolvestheeliminationofmostpathogenic microorganisms (excluding bacterial spores) on inanimate objects.
- Chemicalsusedindisinfectionarecalled disinfectants.
- Disinfection is the reduction in the number of bacteria, viruses, or fungi to a desiredconcentration.

Importanceofdisinfection:

- Tominimizenumberoforganisms inthepopulationworldwide.

- The method of disinfection is used internationally for the safetyof humans, to decrease the scale of transmission of diseases.

RequirementsofGood Disinfectants:

- ✓ Theyshould destroyall the harmfulpathogenic organisms fromthe water and make it perfectly safe for use.
- ✓ Theyshouldnottakemoretimeinkillingpathogens,butdotheirtaskwithinthe required time at normal temperature.
- ✓ Theyshouldbeeconomicalandeasilyavailable.
- ✓ Theyshouldnotrequirehighskillandcostlyrequirementfortheir application.
- ✓ Aftertheirtreatment,thewatershouldnotbecometoxicandobjectionabletotheuser.

MethodsofDisinfection:

- ByBoilingthewater
- Byultravioletrays
- Bythe use ofiodine andbromine
- Bytheuseofozone
- Bytheuseofexcessof lime
- Byusingpotassiumpermanganate
- Bytreatmentwithsilver.

ByBoilingTheWater:

- ✓ Thewater canbedisinfectedbyboilingfor15to20 minutes.
- ✓ By boiling water allthe disease-causing bacteria are killed and the water becomes for use.

ByUltraVioletRays:

- ✓ Ultravioletraysareinvisiblelightrayshavingwavelengthsof1000to4000m.
- ✓ Sun raysalsohaveultravioletrayswhich can alsobeutilizedin thedisinfection of water.

Bythe use ofIodineand Bromine:

- ✓ Ithasbeenseenthatadditionofiodineandbromineinthewaterkillsallthe pathogenic bacteria.
- ✓ Thequantityofiodineandbromineshouldnotexceed8ppmandtheycankillbacteria in minimum contact period of 5 minutes.

Bytheuseof Ozone:

- ✓ Ozoneisanexcellentdisinfectant.
- ✓ Itisusedingaseousform, whichis faintlyblueincolourofpungentodour.

Bythe use ofexcessof lime:

- ✓ Lime isusuallyusedatthewater worksfor reducingthehardnessofwater.

By usingpotassium permanganate:

- ✓ This is the most common disinfectant used in the village for disinfection of dug well water, pond water or private source of water.
- ✓ In addition to the killing of bacteria it also reduces the organic matters by oxidising them.

Bytreatmentwith silver:

- ✓ Thisisaverycostlymethod ofdisinfection,hencenotused atthewater works.
- ✓ In this method the metallic silver ions are introduced into the water by passing it through solid silver electrodes tubes and passing the current through 1,5 V D.C. battery.

WATERSOFTENING:

- ➢ Theremovalorreductionofhardnessfromthe waterisknownaswatersoftening.
- ➢ Fromhealthpoint ofview, it is necessaryat alltimes to remove the hardness fromthe water.
- ➢ Water softening is a process in which the ions ofcalcium, magnesium and sometimes iron are removed.
- ➢ Bydoingthis,thewater softening removestheoffendingminerals fromthewater.
- ➢ The resulting soft waterrequires less soap for the same cleaning effort, as soap is not wasted bonding with calcium ions.
- ➢ Hardwatercontains significant amounts of calcium and magnesium ions, which can clog pipes and complicate the dissolving of soap and detergent in water.
- ➢ It requires more consumption ofsoap in producing lather and washing ofclothes with hard water than soft water.
- ➢ The mainadvantageisreductionintheconsumptionofsoap.
- ➢ In industries hard water also causes various types of troubles and difficulties in the industrial processing.
- ➢ The hard water forms scale in the boiler and it requires more quantity of fuel for the production of steam.
- ➢ Thehardwater alsogreatlyinterfereswiththedyeingworks.

Description	Hardnessrange(mg/Las CaCO3)
Soft	0- 75
Moderatelyhard	75- 100
Hard	100 - 300
Veryhard	>3 00

CARBONATEHARDNESSisbecauseofpresenceof

$HCO_3^-$and $CO_3^{2-}$of Ca^{2+} and Mg^{2+} ;

Carbonatehardnessisalsoknownastemporaryhardnessasitcanberemovedby boiling.

NON-CARBONATEHARDNESSisassociatedwith

Cl^- and $SO_4^{2-}$of Ca^{2+} and Mg^{2+}

AndisoftentermedasPermanentHardness.

Typesof hardness:

TotalHardness=Ca^{2+}hardness+Mg^{2+}hardness

1. TemporaryHardness:

- Hardnessofwaterduetothepresenceofsolublebicarbonatesofcalciumand Magnesium is called temporary hardness.
- When water containing dissolved carbon-dioxide passes over solid carbonates (chalk or limestone deposits etc.), these compounds get dissolved in water.

- ✓ Rainwateranddistilledwaterarealwayssoftbecausetheydonothavedissolved (soluble) salts.

2. PermanentHardness:

- ✓ This isdue tothepresence ofchloridesand sulphatesof calciumandmagnesium.
- ✓ Suchahardnesscanberemovedbytheadditionofwashingsoda.
- ✓ Thisremovesboththetemporaryand thepermanenthardnessofwater.

METHODS OFSOFTENING OFWATER:

RemovalofTemporaryHardness:

- ✓ Temporaryhardnessisremovedinthefollowing ways:
- ✓ Byboilingthewater:Onboiling,thesolublebicarbonate isdecomposed into insoluble carbonate.
- ✓ Chemicalmethods:-Byaddingslakedlime[$Ca(OH)_2$]tohardwater,insolublecarbonates are formed.

RemovalofPermanentHardness:

- ✓ Removalofpermanenthardnessfromthewaterisdifficultandrequiresspecial methods and equipment for its removal.
- ✓ Followingarethemethods:
- ▪ LimesodaProcess
- ▪ BaseExchangeProcess
- ▪ DemineralizationProcess

LimeSoda Process:

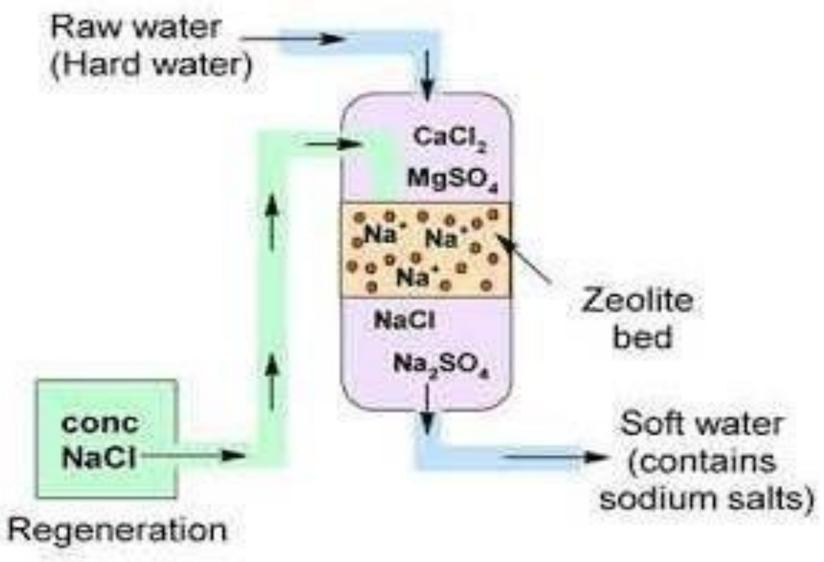
- ✓ Ifwater contains sulphates ofcalciumand magnesium, simplyadditionoflime cannot remove the hardness.
- ✓ Butifsodaashisaddedinlime, thenon-carbonatehardnesscanbeeasilyremoved.
- ✓ ThismethodisknownasLimeSodaprocess.
- ✓ Chemicalprecipitationisone ofthe morecommonmethodsusedtosoftenwater.
- ✓ Chemicalsnormallyusedarelime(calciumhydroxide,Ca(OH)2)andsodaash (sodium carbonate, Na2CO3).
- ✓ When lime and soda ash are added, hardness-causing minerals form nearly insoluble precipitates.
- ✓ Calcium hardness is precipitated as calcium carbonate ($CaCO_3$). Magnesium hardness is precipitated as magnesium hydroxide ($Mg\ (OH)_2$).

- ✓ These precipitates are then removed by conventional processes of coagulation/flocculation, sedimentation, and filtration.
- ✓ Because precipitates are very slightly soluble, some hardness remains in the water--usually about 50 to 85 mg/l (as $CaCO_3$).

BASEEXCHANGEorZEOLITEPROCESS:

- Ion-exchangeisusedextensivelyinsmallwatersystemsandindividualhomes.
- Ion-exchange resin, (zeolite) exchanges one ion from the water being treated for another ion that is in the resin (sodium is one component of softening salt, with chlorinebeingtheother). Zeoliteresinexchangessodiumfor calciumand magnesium.
- The following chemical reactions show the exchange process, where X represents zeolite, the exchange material.
- Removalofcarbonatehardness:
  - $Ca(HCO_3)_2 + Na_2X$ -------- $>CaX + 2NaHCO_3$
  - $Mg(HCO_3)_2 + Na_2X$ --------$>$ $MgX + 2NaHCO_3$
- Removalofnon-carbonatehardness:
  - $CaSO_4 + Na_2X$ --------$>CaX$ + Na2SO_4
  - $CaCl_2 + Na_2X$--------$>$ $CaX + CaCl_2$
  - $MgSO_4 + Na_2X$ --------$>MgX + Na_2SO_4$

$MgCl_2 + Na_2X$--------$>MgX$ + 2NaC1



Meritsofzeolite process:

- ✓ Itremovesthehardnessalmostcompletely(about10ppmhardness only).
- ✓ Theprocessautomaticallyadjustitselffor variationinhardnessofincomingwater.
- ✓ Thisprocessdoesnotinvolveany typeofprecipitation;thus,noproblem of sludge formation occurs.

Demeritsofzeoliteprocess:

- ✓ Theoutgoingwater(treatedwater)containsmoresodiumsalts.
- ✓ ThismethodonlyreplacesCa^{+2}andMg^{+2}ions byNa^{+}ions.
- ✓ Highturbiditywater cannotbesoftenedefficientlybyzeoliteprocess.

DEMINERALISATIONPROCESS:

- ➢ Demineralisationprocess involvesremovalofmineralsbymeansofIonExchange Resins.
- ➢ Demineralizationofwater is achieved by passing water through Cation Resin Column and then though Anion Resin Column.
- ➢ When minerals, whichare salts ofacid and base, dissolve inwater, theyget ionized in to Cations and Anions.
- ➢ Demineralized Water is Water completely free (or almost) of dissolved minerals as a result of one of the following processes:
- ✓ Distillation

- ✓ Deionization
- ✓ Membranefiltration(reverseosmosisornanofiltration)
- ✓ Electrodialysis
- ✓ Demineralized Water also known as Deionized Water; Water that has had its mineral ions removed.
- ✓ Mineral ions such as cations of sodium, calcium, iron, copper, etc and anions such as chloride, sulphate, nitrate, etc are common ions present in Water.

DESALINATION:

- ➢ Desalinationisaprocessthattakesawaymineralcomponentsfromsalinewater.
- ➢ More generally, desalinationrefers to the removal of salts and minerals from a target substance, as in soil desalination, which is an issue for agriculture.
- ➢ Desalination is a technique where the excess salts are removed from sea water or brackish water converting it into safe potable or usable water.

DEFLUORIDATION:

- ➢ Defluoridationisthedownwardadjustmentofthelevelofflurideindrinking water.
- ➢ Worldwide, fluoride isoneofthe mostabundantanionspresentingroundwater.
- ➢ Fluoride is more present ingroundwaterthansurface watermainlydue tothe leaching of minerals.

IRONANDMANGANESEREMOVAL:

- ➢ Whencombinedlevelsof ironandmanganese exceed10mg/L,themost effective treatment involves oxidation followed by filtration.
- ➢ In this process, a chemical is added to convert any dissolved iron and manganese into the solid, oxidized forms that can then be easily filtered from the water.
- ➢ Ironandmanganesecontrolisthemostcommontypeofmunicipalwatertreatment.
- ➢ Ironandmanganeseoccurnaturallyingroundwater.
- ➢ Water containing excessive amountsofironand manganese canstainclothes, discolor plumbing fixtures, and sometimes add a “rusty” taste and look to the water.
- ➢ Surface watergenerallydoes not contain large amountsofironormanganese, but iron and manganese are found frequently in water systems that use groundwater.
- ➢ The Safe Drinking Water Act secondary standards for iron in drinking water is 0.3 parts per million (ppm) and 0.05 ppm for manganese.
- ➢ If water contains more than 0.05 ppm iron, or 0.01 ppm manganese, the operator should implement an effective hydrant-flushing program in order to avoid customer complaints.

UNIT – III WATER STORAGE and DISTRIBUTION Storage and Balancing Reservoirs - Types, Location and Capacity. Distribution System: Layout, Hydraulics of Pipe Lines, Pipe Fittings, Valves Including Check and Pressure Reducing Valves, Meters, Analysis of Distribution Systems, Leak Detection, Maintenance of Distribution Systems, Pumping Stations and Their Operations - House Service Connections.

INTRODUCTION

GENERALREQUIREMENTSOFGOODDISTRIBUTIONSYSTEM:

- The objective of Water distribution system is to deliver water to individualconsumerswithappropriatequality, quantityandpressure.
- Thedistributionsystemdescribescollectivelythe facilitiesusedto supply water from its source to the point of usage.
- Thewatershouldreacheveryconsumerwiththerequiredpressure head.
- Thismayincludeextensivesystemofpipes,storagereservoirs,pumps and related appurtenances.
- Thequalityofthepipes laidshouldbegoodanditshouldnotburst.
- The proper functioning of a water distribution system is critical to providingsufficient drinkingwatertoconsumersaswellasproviding sufficient water for fire protection
- Distributionsystemshouldbeeconomicalandeasyto maintainand operate.
- Forefficient distributionsystemadequatewaterpressurerequiredat various points.
- Itshould bewatertight andthewaterlossesduetoleakageshouldbe minimum as far as possible.

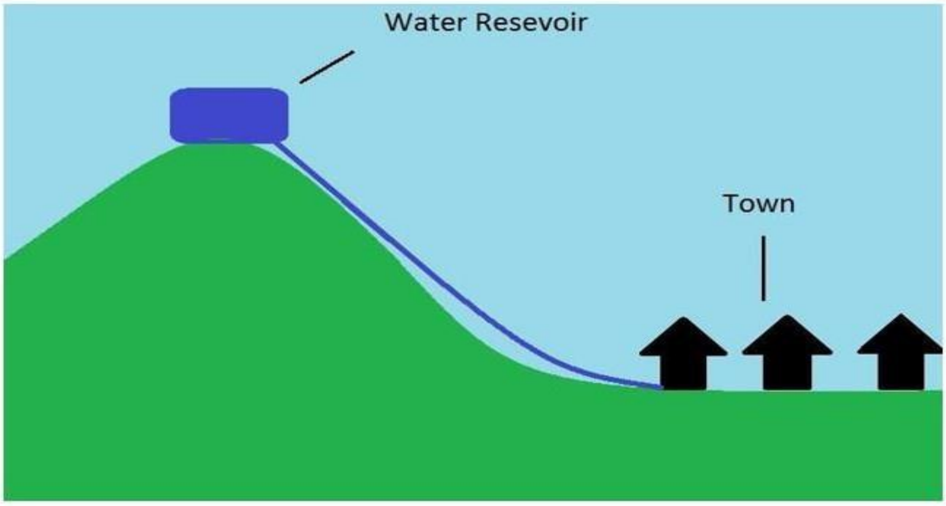
METHODOFDISTRIBUTION SYSTEM:

- Gravitysystem
- Pumpingsystem
- Combinedgravityandpumpingsystem

Gravitysystem:

- Whensomeground,sufficientlyhighabovethecityarea, isavailable, this can be best utilized for the distribution system in maintaining pressure in water pipes.
- This method issuitablewhensourceofwatersupplysuchas lake, river or impounding reservoir is at sufficient height than city.
- Thewater flowsinthemainsduetogravitationalforce.
- Asnopumpingisrequired,thereforeit isthemostreliablesystemfor the water distribution.
- Mostreliableandeconomicaldistributionsystem.

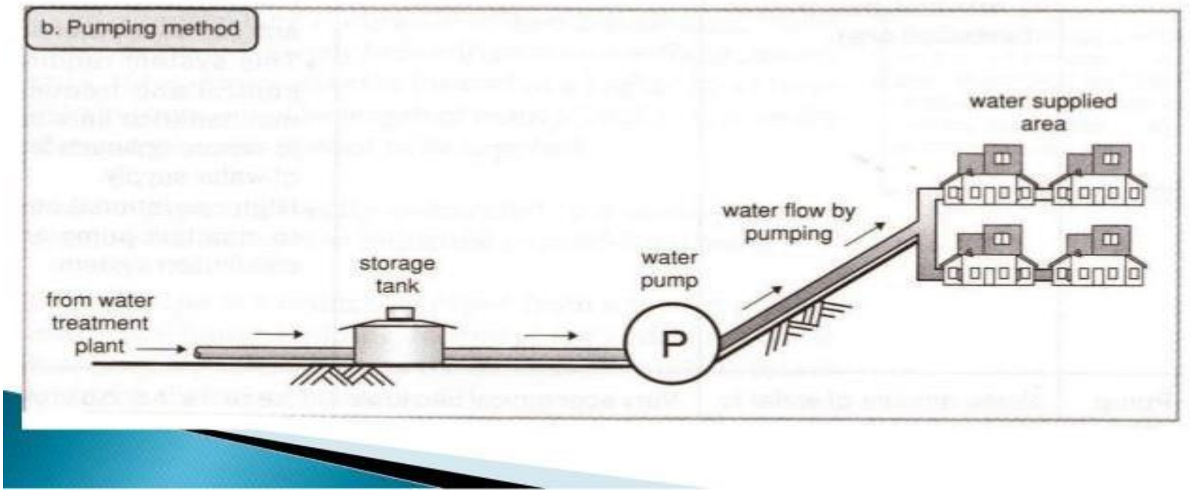
- Thewaterheadavailableattheconsumerisjustminimumrequired.
- Theremainingheadisconsumedinthefrictionalandotherlosses.
- Butinthiscase, thewater willhavetobepumpedduringfires.



Pumpingsystem:

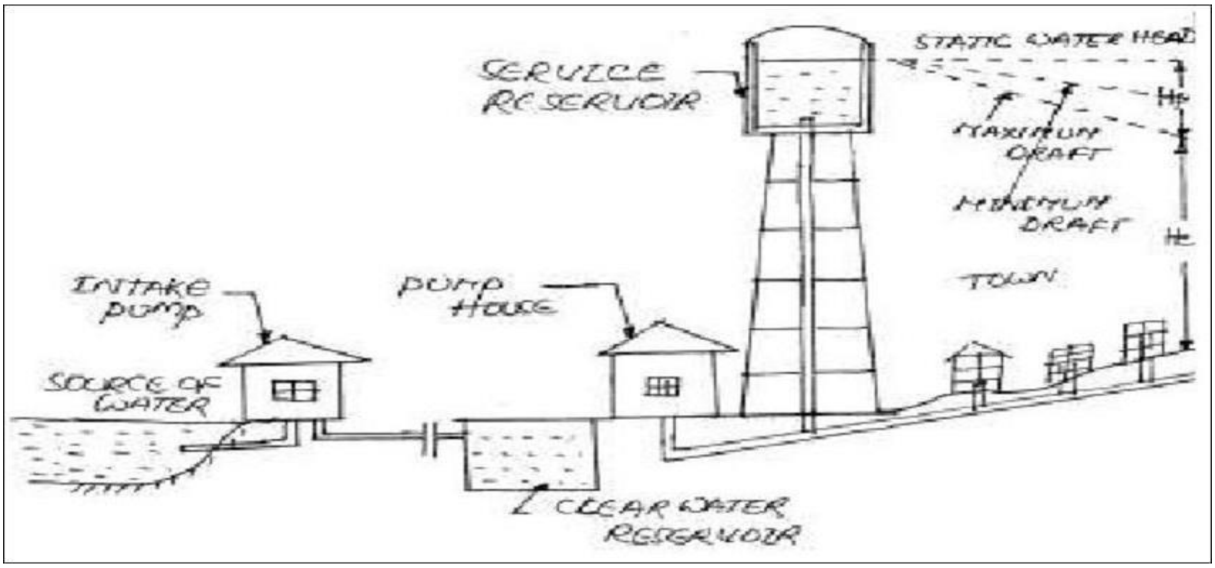
- Treatedwaterisdirectlypumped intothedistributionmainwithout storing.
- Also calledpumpingwithoutstoragesystem.
- Ifpowersupplyfails,completestoppageofwatersupply.
- Thismethod isnotgenerallyused.
- During fires,thewatercanbepumped intherequiredquantitybythe stand by units also.
- Highliftpumpsarerequiredandtheiroperationsarecontinuously watched.

PUMP SYSTEM



Combinedgravityandpumpingsystem:

- Itismostcommonlyused system.
- Treatedwaterispumpedandstoredinanelevateddistribution reservoir.
- Thensuppliestoconsumerbyactionofgravity.
- Theexcesswaterduring lowdemandperiodsget storedinreservoirand get supplied during high demand period.
- As inthissystemwatercomes fromtwosourcesone fromreservoirand second from pumping station, it is called dual system.
- Economical,efficientandreliablesystem.



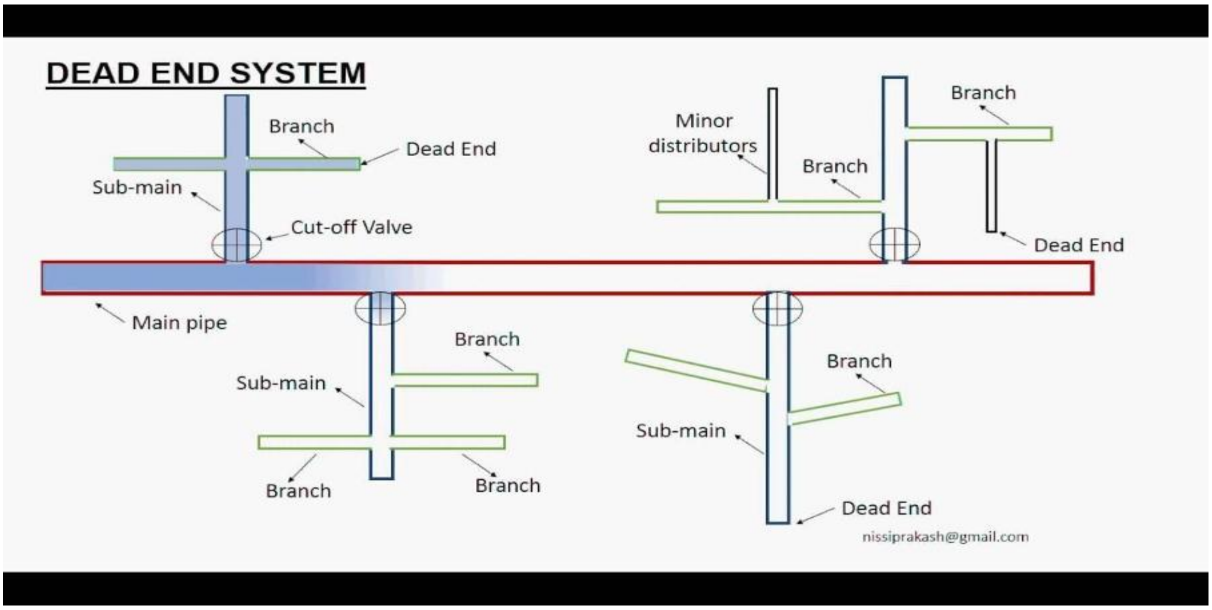
LAYOUTSOFDISTRIBUTION SYSTEM:

- Thedistributionpipesaregenerallylaid belowtheroadpavements,and as such their layouts generally follow the layouts of roads.
- Thereare, ingeneral, fourdifferenttypesofpipe networks;anyoneof which either singly or in combinations, can be used for a particular place.
- Theyareclassified asfollows:
  - ✓ DeadEndSystem
  - ✓ RadialSystem
  - ✓ GridIronSystem
  - ✓ RingSystem

DEADENDSYSTEMorTREE SYSTEM:

- Itissuitableforirregulardevelopedtownsorcities.
- Inthissystemone mainstartsfromservicereservoir alongthe main road.
- Sub-mainsareconnectedtothe mainin boththedirectionsalongother roads.
- In streets, lanes and other small roads which meet the roads carrying sub-mains, branchesandminordistributorsarelaidandareconnected to mains.

➢ Fromthesebranches,serviceconnectionsaremadetoindividual houses.



➢

Advantages:

✓ Relativelycheap.

✓ Determinationofdischargesandpressureeasierduetoless number of valves.

Disadvantages:

✓ Duetomanydeadends,stagnationofwateroccursinpipes.

✓ Ifpipebreaksdownorisclosedforrepair,thewholelocality

✓ beyondthepointgoeswithoutwater.

GRIDIRON SYSTEM:

➢ Thissystemisalsoknownasreticulated system.

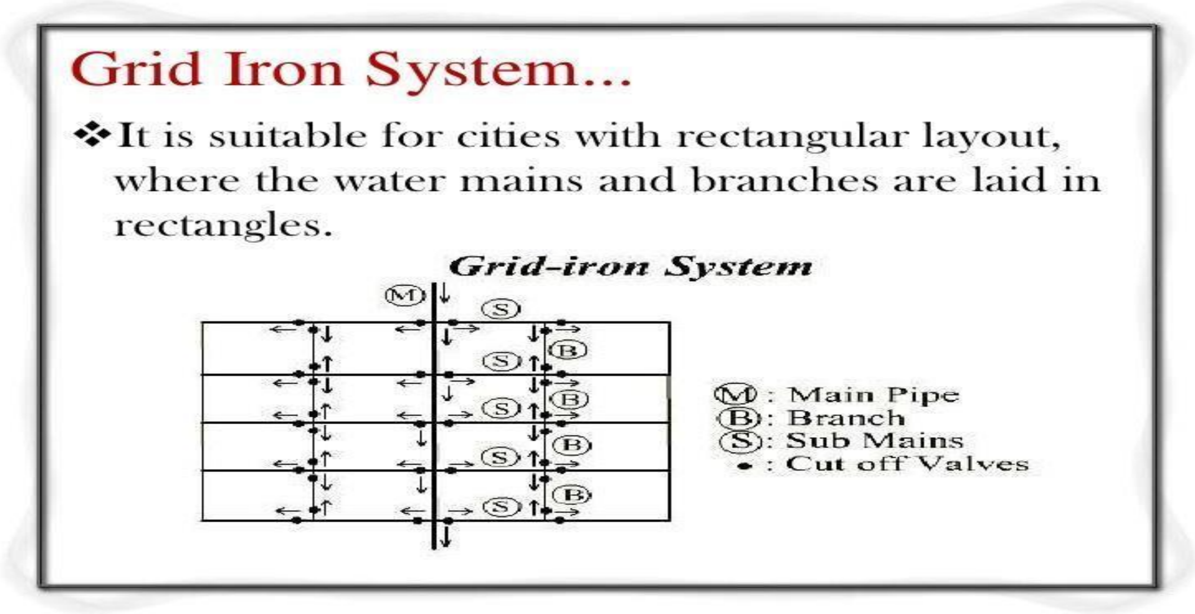
➢ It is suitable for cities with rectangular layout, where the water mainsand branches are laid in rectangles.

➢ Mainline islaidalongthe mainroad.

➢ Submainsaretakeninbothdirectionsalongotherminorroadsand streets.

➢ Fromthesesub mainsbranchesaretakenoutand areinterconnected.

➢ It is an improvement over dead-end system. All the dead ends are interconnectedwitheachotherandwatercirculates freelythroughout the system.



Advantages:

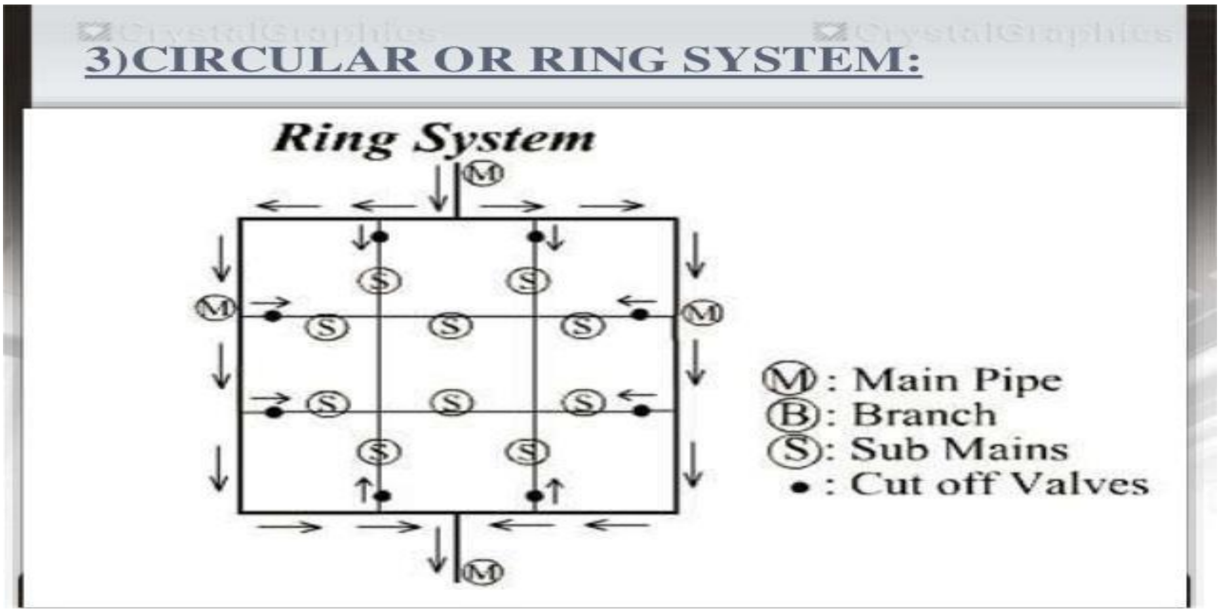
- ✓ Wateriskept ingoodcirculationduetotheabsenceofdead ends.
- ✓ Inthecasesofa breakdowninsomesection,waterisavailable from some other direction.
- ✓ Incaseoffire, morequantityofwaterdivertedtowardsthe affected area by closing the valves of nearby localities.

Disadvantages:

- ✓ Exact calculationofsizesofpipesis notpossibledueto provision of valves on all branches.
- ✓ Morenumberofvalvesand longer lengthofpipe isrequired in this system, thereby increase in the overall cost.

CIRCULARORRINGSYSTEM:

- ➢ Thesupplymain islaidallalongtheperipheralroadsandsubmains branch out from the mains.
- ➢ Thissystemalsofollowsthegridironsystemwith the flow
- ➢ patternsimilarincharactertothatofdead endsystem.
- ➢ So,determinationofthesizeofpipesiseasy.



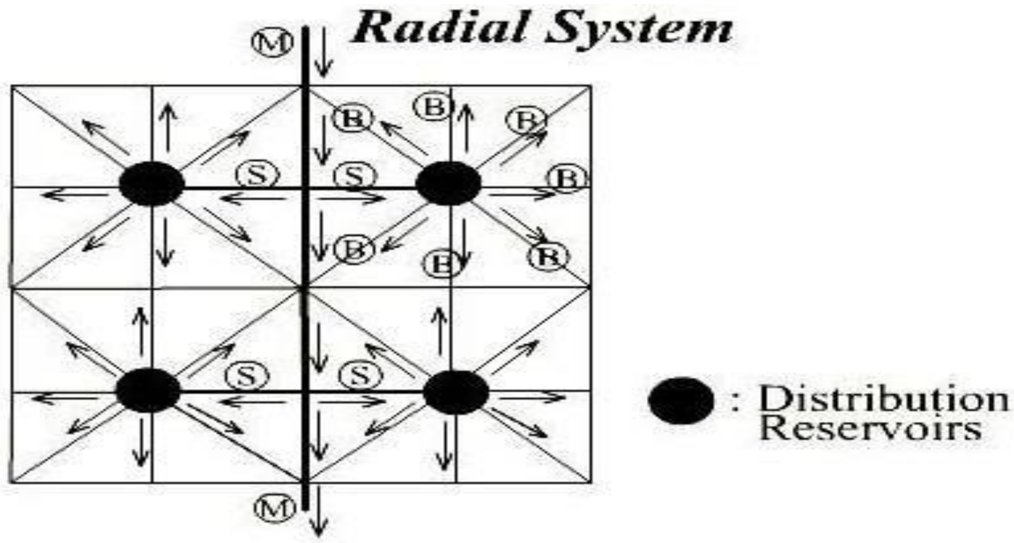
RADIALSYSTEM:

- Theareaisdividedintodifferentzones.
- Thewaterispumped intothedistributionreservoir keptinthe middle of each zone.
- Thesupplypipesarelaid radiallyending towardsthe periphery.

Advantages:

It gives quick service.

Calculationofpipesizesiseasy.



STORAGEANDDISTRIBUTIONRESERVOIRS:

- Distribution reservoirs, also called service reservoirs, are the storage reservoirs, which store the treated water for supplying water during emergencies (such as during fires, repairs, etc.) and also to help in absorbing the hourly fluctuations in the normal water demand.

Functionsofdistributionreservoirs:

toabsorbthehourlyvariationsindemand.

tomaintainconstantpressureinthedistributionmains. water

stored can be supplied during emergencies.

Locationandheightofdistributionreservoirs:

shouldbelocatedascloseaspossibletothecentreofdemand.

Waterlevelinthereservoirmustbeatasufficientelevationtopermit gravity flow at an adequate pressure.

TypesofReservoirs:

- Depending upon their elevation with respect to ground it may be classified into:
  - ✓ Surfacereservoirs
  - ✓ Elevatedreservoirs
- Dependinguupontheirmaterialofconstructionitmaybeclassifiedinto
  - ✓ SteelReservoir
  - ✓ R.C.C
  - ✓ Masonry

SurfaceReservoir:

- Thesealso calledgroundreservoir.
- Mostlycircular orrectangulartank.
- Undergroundreservoirsarepreferredespeciallywhenthesizeislarge.
- These reservoirs are constructed on high natural grounds and are usually made of stones, bricks, plain or reinforced cement concrete.
- The side walls are designed to take up the pressure of the water, when the reservoir is full and the earth pressure when it is empty.

EarthernReservoirs:

- When large quantity of water is to be stored before the treatment, usually earth reservoirs are provided because these are the cheapest.
- These reservoirs are excavated to the required depth below the ground surface and using the excavated material for the building of embankments to the necessary height above the ground.
- Tomakeearthenreservoirsimpermeable, corewallsare constructed.
- The embankments should have minimum top width of 1.3 m or one fourth of the total height.
- As far aspossible,greatertopwidthshouldbeused.
- Thesideslopesshouldnotbesteeperthan11/2 horizontalto1vertical.
- The embankments should be keyed down to the bottom by removing roots, loose soil and permeable material.
- To prevent the leakage and loss of water, the sides and bottom of the reservoirs should be properly lined with bricks, stones, asphalts or concrete etc.
- Outlet pipes should be provided in the embankments walls at various places to minimize the seepage of water.

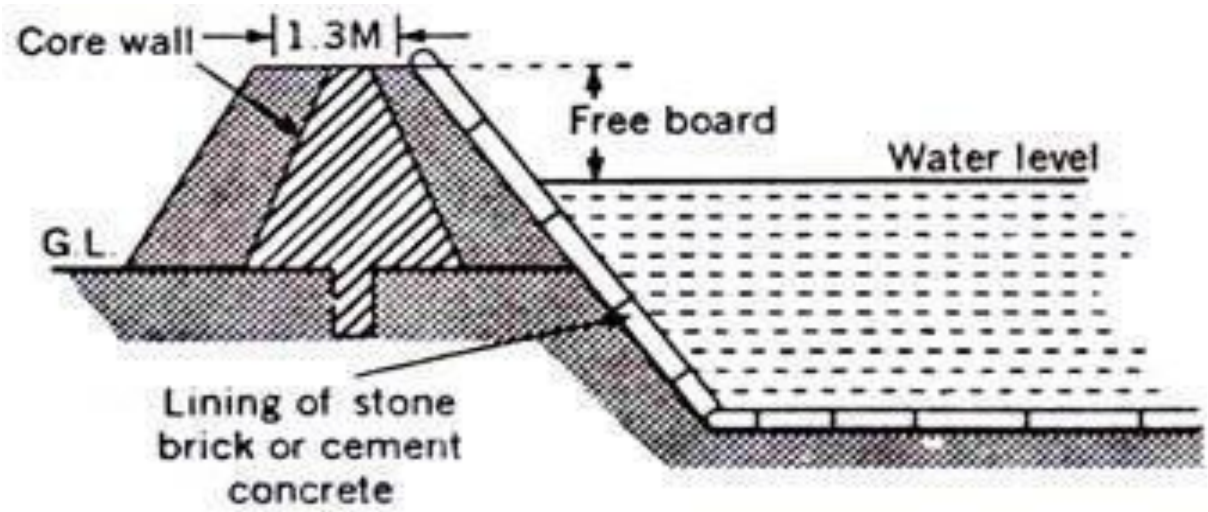


Fig. 18.11. Earthen Reservoir.

ElevatedStorageReservoirs:

- ElevatedStorageReservoirs(ESRs)alsoreferredtoasOverheadTanks arerequiredat distributionareaswhichare not governedandcontrolled by the gravity system of distribution.
- Thesearerectangular,circularorellipticalinshape.
- Ifthetopographyofthetownnotsuitable forundergravity, the elevated tank or reservoir are used.
- Theyareconstructedwherecombinegravityandpumpingsystemof water distribution is adopted.
- These tanksmaybe steelorRCC.
- NowRCCiscommonlypreferred.

TheaccessoriesofESRare:

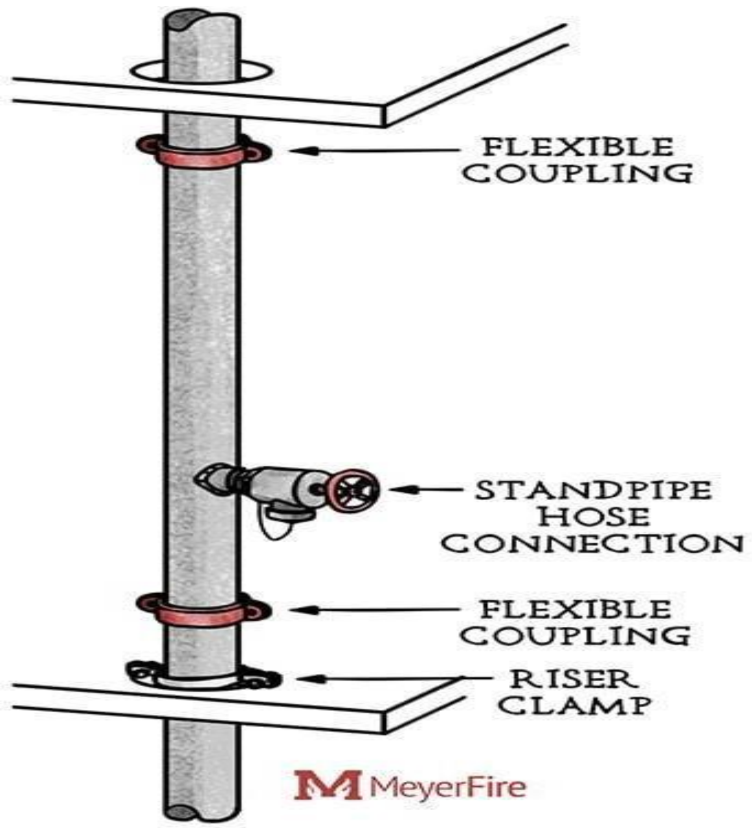
- ✓ Inletandoutlet pipe,overflowpipedischarging intoadrain
- ✓ Floatgauge,indicatingdepthofwater.
- ✓ Automaticdevicetostoppumpingwhenthetankisfull.
- ✓ Amanholeandladder.
- ✓ Ventilatorfor circulationoffreshair.

TypesofElevated Reservoirs:

- ✓ Standpipes
- ✓ ElevatedTanks

StandPipes:

- ➢ Theseareusuallymadeofsteelandarecircularin plan.
- ➢ The useful storage capacity of these are the volume of tank above the elevation of the high point of distribution.
- ➢ Water in tank below this point serves as additional storage for low distribution area which can be used with booster pumps or for firefighting where fire pumping engines are used.
- ➢ Manhole is provided at the top with ladder for inspection and repair work.



TypesofElevated Tanks:

- R.C.C.TANKS:
  - R.C.Ctanksare verypopularbecause
    - ✓ Theyhavelonglife
    - ✓ Verylittlemaintenance
    - ✓ decentappearance
    - ✓ G.I.TANKS:
  - G.I.tanksaregenerallyinrectangularorsquareinshape. Nowa days G.I. tanks are not preferring because
    - ✓ Lifeofthetankisless
    - ✓ Corrosionofmetal
    - ✓ maintenancecostmaybemore.
- HDPETANKS:
- ✓ NowadaysHDPEtanksareverypopular for storing lessquantityof water and hence useful for residential purpose.

- ✓ ThefollowingaretheadvantagesofHDPEtanks
- ✓ Handlingiseasybecauseoflightweight
- ✓ Cheapincost
- ✓ Maintenancecost islow
- ✓ Cleaningoftanksare easy.

StorageCapacityofDistributionReservoirs:

Thetotalstoragecapacityofadistributionreservoir isthesummationof:

BALANCING STORAGE:

The quantity of water required to be stored in the reservoir for equalizing or balancing fluctuating demand against constant supply is known as the balancing storage (or equalizing or operating storage).

BREAKDOWNSTORAGE:

The breakdown storage or often called emergency storage is the storage preserved in order to tide over the emergencies posed by the failure of pumps, electricity, or any other mechanism driving the pumps.

A value of about 25% of the total storage capacity of reservoirs, or 1.5 to 2 times ofthe average hourlysupply, may be considered as enoughprovision for accounting this storage.

FIRESTORAGE:

Thethird componentofthetotalreservoirstorageisthefirestorage.

This provision takes care of the requirements of water for extinguishing

fires.Aprovisionof1to4perpersonperdayissufficient tomeet the requirement.

When reservestorage is elevated,amountof firereservemay be determined by, R=(F-P) T

- R=Reservestorage(liters)F=Firedemand,liters/min
- P=Reserve firepumpingcapacity,liters/min
- T=Durationofthefirein min.

The total reservoir storage can finally be worked out by adding all the three storages.

VALVESAND FITTINGS:

- ➢ Valvesareusedthroughoutthe distributionsystem.
- ➢ Valvesare used to isolate equipment, buildings, and other areas of the water systemfor repair as well as to control the direction and rate of flow.

➢ Theyare used todrainthesystemforseasonalshutdown.

Typesof Valves:

- ✓ GateorSluice Valve
- ✓ CheckorrefluxorNonreturnValve
- ✓ PressureReliefValve
- ✓ AirReliefValve
- ✓ DrainorScourorBlow offValve

Gate orSluiceValve:

- ✓ Agatevalve,alsoknownasa sluicevalve,isa valvethatopensby lifting a barrier (gate) out of the path of the fluid.
- ✓ Gatevalvesrequireverylittlespacealongthepipeaxisandhardly restrict the flow of fluid when the gate is fully opened.
- ✓ Sluice Valveand/or Gate Valve functions strictly to either start or stop the flow.

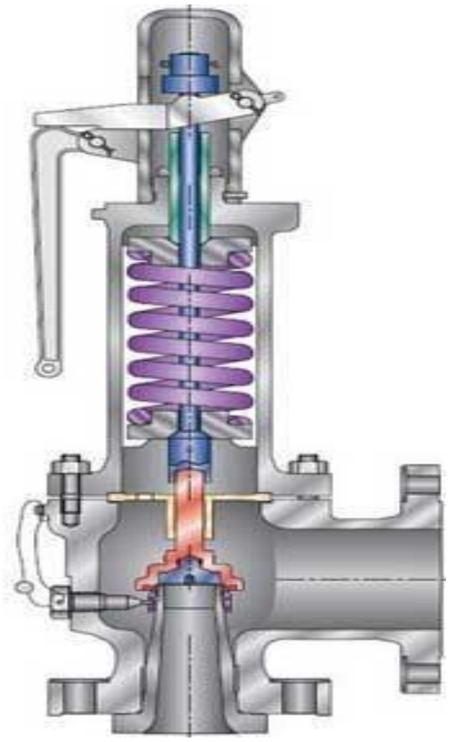
CheckorRefluxorNon-ReturnValve:

- ✓ Refluxvalve iscommonlyknownas Checkvalve and Non-Return Valve (NRV).
- ✓ Watertendstoflowfromhigherpressuretolower pressure.
- ✓ Mainspressureiskepthighertosufficewaterdistributioninahouse.

- ✓ Thesevalvesarevery usefulinpreventingbackflowof water tothe pump.

PressureReliefValve:

- ✓ Areliefvalveorpressurereliefvalve (PRV)isatypeofsafety valve used to control or limit the pressure in a system.
- ✓ ApressureReliefValve isasafetydevicedesignedtoprotecta pressurized vessel or system during an overpressure event.



AirReliefValve:

- ✓ AirReleaseValves,orAirReliefValve functiontoreleaseair pockets that collect at each high point of a full pressured pipeline.
- ✓ An air release valve can open against internal pressure, because the internallever mechanismmultipliesthefloat forcetobegreaterthan the internal pressure.

DrainorScourorBlow OffValve:

- ✓ DrainValveisalsocalledasBlow –offValve and ScourValve.
- ✓ Theseareordinaryvalvesbut used foraspecificpurposeofscouringor emptying or cleaning the main and water storage tank.
- ✓ Scourvalveor blowoffordrainvalveareprovidedatthedead-endof the pipeline function to remove the sand silt, etc from pipeline.

ANALYSISOFCOMPLEX NETWORKS:

- ➢ Indistributionsystemfor anyclosednetworkofpipes, thefollowing conditions must be fulfilled.
- ➢ Theentering flowmust beequaltothe leavingflow.ie.Lawof continuity must be satisfied.
- ➢ Thealgebraicsumofthepressuredropsaroundaclosed loopmust be zero.
- ➢ Therearevarious methodsfortheanalysisofflowinapipenetwork.
  - ✓ Circlemethod
  - ✓ Equivalentmethod

- ✓ ElectricalAnalogy method
- ✓ Hardycrossmethod.

PROBLEMS

1.Designapipesection ABasapartofdistribution networkwiththedata given below.

Length of pipe section AB = 900 m

PiezometricreadingofpressureatA=10m

Piezometric reading of pressure at A = 8 m

C =100

Q =2MLD

Solution:

UsingHazenWilliam'sformula, V

$= 0.85 X C X m^{0.63} X i^{0.54}$

$Q/\pi d^2/4=0.85XCX(d/4)^{0.63} X(h_f/L)^{0.54}$ $h_f=$

$h_1 – h_2 = 10 – 8 = 2$

$h_f/L=2/900=1/450$

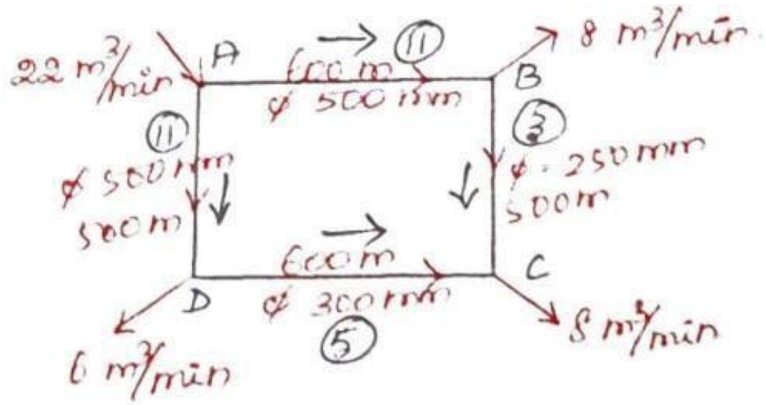
$0.023/\pi d^2/4=0.85X100X(d/4)^{0.63}X(1/450)^{0.54}$

d=233mmor230mm.

EquivalentPipeMethod:

Forthepurposeofanalysis,entirenetworkofpipesisconsidered tobe

- ✓ Pipesinseries(AssumeDischarge)
- ✓ Pipes inparallel(AssumeHeadLoss)



AB → 11 m³/min ⇒ 0.183 m³/sec. DA → -11 ⇒ -0.183 m³/

BC → 3 " ⇒ 0.05 "

CD → -5 " ⇒ -0.083 "

PIPE	L(m)	d	Q_a orQ (m/s)	$d^{4.87}$	K=L/470 $d^{4.87}$	HorH$_L$ =K $Q_a^{1.85}$	H_L/Q_a
AB	600	0.5	0.183	0.034		1.62	8.85
BC	500	0.25	0.05	0.0011	910.03	3.56	71.2
CD	600	0.3	-0.083	0.0028	449.5	-4.49	54.09
DA	500	0.5	-0.183	0.034	31.28	-1.35	7.37

$$q = \frac{-H}{1.85H/Q_a}$$

$$= \frac{-(-0.66)}{1.85X141.51}$$

$=0.00252m^3/sec or 0.003m^3/sec$ Hence

Corrected flow rates are :

QinAB=0.183+0.003=0.186m^3/sec Q in

BC = 0.05 + 0.003 = 0.053 m^3/sec

Q in CD = - 0.083 +0.003 = - 0.08 m^3/sec

QinDA=- 0.183+0.003=-0.18m^3/sec.

GRAPHICALMETHOD:

Using Nomograph,

PIPE	L(m)	D(mm)	QorQ$_a$ l/s	S	HorH$_L$ =SXL	H$_L$/Q$_a$
AB	600	500	183	0.0025	1.5	0.008
BC	500	250	50	0.007	3.5	0.07
CD	600	300	-83	0.0072	-4.32	0.052
DA	500	500	-183	.0025	-1.25	0.006

$$q = \frac{H}{1.85H/Q} = \frac{-(-0.57)}{1.85X0.137} = 2.24 l/s.$$

Hencecorrectedflowratesare,

QinAB=183+2.24=185.24l/s Q in

BC = 50 + 2.24 = 52.24 l/s

Q inCD=-83+2.24=-80.76l/s

QinDA=-183+2.24=-180.76l/s.

UNIT – IV PLANNING and DESIGN of THE SEWERAGE SYSTEM Characteristics and Composition of Sewage - Population Equivalent - Sanitary Sewage Flow Estimation - Sewer Materials - Hydraulics of Flow in Sanitary Sewers - Sewer Design - Storm Drainage-Storm Runoff Estimation - Sewer Appurtenances - Corrosion in Sewers - Prevention and Control – Sewage Pumping-Drainage in Buildings - Plumbing Systems for Drainage

INTRODUCTION

SANITARY ENGINEERING:

It is defined as the branch of public health engineering deals with the collection, conveyance, treatment and safe disposal of wastes for preventing the communicable diseases.

STAGES OF SANITARY ENGINEERING:

Conveyance of sewage
Collection of sewage
Treatment of sewage
Disposal of sewage

OBJECTIVES OF SANITARY ENGINEERING:

To maintain the environment and to prevent the effect of sewage to public health in general.

To prevent the effect of disposal of sewage on land or nearby water bodies from pollution.

To prevent the environment from mosquitoes, flies, bacteria etc.

To dispose the human excreta to a safe place before it starts decomposition.

SEWAGE:

It is a dilute mixture of the wastes of various types from the residential, public and industrial places.

It includes sullage water and foul discharge from the water closets, urinals, hospitals, stables etc.

STORM WATER:

It is the surface runoff obtained during and after the rainfall which enters sewers through inlet.

Storm water is not foul as sewage and hence it can be carried in the open drains and can be disposed off in the natural rivers without any difficulty.

SANITARY SEWAGE:

It is the sewage obtained from the residential buildings & industrial

effluents Establishments.

Being extremely foul it should be carried through underground conduits.

DOMESTIC SEWAGE:

It is the sewage obtained from the lavatory basins, urinals & water closets of houses, offices & institutions.

It is highly foul on account of night soil and urine contained in it.

Night soil starts putrefying & gives offensive smell.

It may contain large number of bacteria due to the excremental wastes of patients.

This sewage requires great handling &disposal.

INDUSTRIAL SEWAGE:

It consists of spent water from industries and commercial areas.

The degree of foulness depends on the nature of the industry concerned and processes involved.

SEWERAGE SYSTEM:

The entire system of collection of sewage and conveyance of sewage to treatment units by using sewers is called sewerage system.

The sewerage system carries two types of flow.

DRY WEATHER FLOW (DWF):

Domestic sewage and industrial sewage collectively, is called as DWF.

It does not contain storm water.

It indicates the normal flow during dry season.

WET WEATHER FLOW (WWF):

The flow of storm water is called WWF.

SULLAGE:

It is defined as the waste water from domestic buildings especially from bathrooms, kitchens etc.

It is merely waste water and does not create any bad smell or odour.

SLUDGE:

It is the organic matter deposited in the sedimentation tank during treatment.

SEWERAGE:

The entire system of collecting, carrying & disposal of sewage through sewers is known as sewerage.

SEWERS:

Sewers are underground pipes which carry the sewage to a point of disposal.

TRUNK SEWERS:

A trunk sewer is a one which collects the waste water or sewage from two or more main sewers.

MAIN SEWERS:

A main sewer is a one which collects the sewage from two or more sub main sewers.

SUB MAIN or BRANCH SEWERS:

A sub main or branch sewer is a one which collects the sewage from lateral sewers and discharges into main sewer.

LATERAL SEWER:

The sewer collecting the sewage directly from the building and discharging to the branch sewer is called lateral sewer.

COMBINED SEWER:

A sewer carries domestic sewage and storm water is called combined sewer.

SEWERAGE SYSTEMS

Separate system of sewage
Combined system of sewage
Partially combined or partially separate system

SEPARATE SYSTEM OF SEWERAGE:

In this system two sets of sewers are laid.

The sanitary sewage is carried through sanitary sewers while the storm sewage is carried through storm sewers.

The sewage is carried to the treatment plant and storm water is disposed of to the river.

ADVANTAGES:

Size of the sewers are small
Sewage load on treatment unit is less
Rivers are not polluted
Storm water can be discharged to rivers without treatment.

DISADVANTAGES:

Sewerage being small, difficulty in cleaning them.

Frequent choking problem.

System proves costly as it involves two sets of sewers.

The use of storm sewer is only partial because in dry season the will be converted in to dumping places and may get clogged.

COMBINED SYSTEM OF SEWAGE:

When only one set of sewers are used to carry both sanitary sewage and surface water.

This system is called combined system.

Sewage and storm water both are carried to the treatment plant through combined sewers.

ADVANTAGES:

Size of the sewers being large, chocking problems are less and easy to clean.

It proves economical as 1 set of sewers are laid.

Because of dilution of sanitary sewage with storm water nuisance potential is reduced.

DISADVANTAGES:

Size of the sewers being large, difficulty in handling and transportation.

Load on treatment plant is unnecessarily increased.

It is uneconomical if pumping is needed because of large amount of combined flow.

Unnecessarily storm water is polluted.

PARTIALLY COMBINED OR PARTIALLY SEPARATE SYSTEM:

A portion of storm water during rain is allowed to enter sanitary sewer to treatment plants while the remaining storm water is carried through open drains to the point of disposal.

ADVANTAGES:

The sizes of sewers are not very large as some portion of storm water is carried through open drains.

Combines the advantages of both the previous systems.

Silting problem is completely eliminated.

The problem of disposing storm water from houses is simplified.

DISADVANTAGES:

The quantity of storm water admitted in sewer may increase the load on pumping and treatment units.

The velocity of flow is low in dry weather.

SUITABLE CONDITIONS FOR SEPARATE SEWERAGE SYSTEMS: -

A separate system would be suitable for use under the following situations:

Where rainfall is uneven.

Where sanitary sewage is to be pumped.

The drainage area is steep, allowing to runoff quickly.

Sewers are to be constructed in rocky strata. The large combined sewers would be more expensive.

SUITABLE CONDITIONS FOR COMBINED SYSTEM: -

Rainfall in even throughout the year.

Both the sanitary sewage and the storm water have to be pumped.

The area to be sewered is heavily built up and space for laying two sets of pipes is not enough.

Effective or quicker flows have to be provided.

METHODS OF COLLECTION

The sanitation of a town or city is done by two methods:

Conservancy system

Water Carriage system

SEWERAGE SYSTEMS:

CONSERVENCY SYSTEM	WATER CARRIAGE SYSTEM
Very cheap in initial cost.	It involves high initial cost.
Due to foul smells from the latrines, they are to be constructed away from living room so building cannot be constructed as compact units.	As there is no foul smell latrines remain clean and neat and hence are constructed with rooms, therefore buildings may be compact.
The aesthetic appearance of the city cannot be improved	Good aesthetic appearance of city can be obtained.
For burial of excremental matter large area is required.	Less area is required as compared to conservancy system.
Excreta is not removed immediately hence its decomposition starts before removal,	Excreta are removed immediately with water, no problem of foul smell or hygienic trouble.
This system is fully depended on human agency .In case of strike by the sweepers; there is danger of insanitary conditions in	As no human agency is involved in this system ,there is no such problem as in case of conservancy system

SOURCES OF SEWAGE

SANITARY SEWAGE IS PRODUCED FROM THE FOLLOWING SOURCES:

When the water is supplied by water works authorities or provided from private sources, it is used for various purposes like bathing, utensil cleaning, for flushing water closets and urinals or washing clothes or any other domestic use.

The spent water for all the above needs forms the sewage.

Industries use the water for manufacturing various products and thus develop the sewage.

Water supplied to schools, cinemas, hotels, railway stations, etc., when gets used develops sewage.

Ground water infiltration into sewers through loose joints.

Unauthorized entrance of rain water in sewer lines.

QUANTITY OF SANITARY SEWAGE AND STORM WATER

The determination of sanitary sewage is necessary because of the following factors which depend on this:

To design the sewerage schemes as well as to dispose a treated sewage efficiently.

The size, shape and depth of sewers depend on quantity of sewage.

The size of pumping unit depends on the quantity of sewage.

FACTORS AFFECTING THE QUANTITY OF SANITARY SEWAGE FLOW: -

Rate of water supply

Population

Type of area served as residential, industrial or commercial

Infiltration and exfiltration

RATE OF WATER SUPPLY:

The rate of sewage may be 60 to 70 percent of water supply due to various reasons such as consumption, evaporation, use in industries etc.

This may be changes daily, seasonal and also standard of living of people.

POPULATION:

As the population increases the quantity of sewage also increases because the consumption of water is more.

TYPE OF AREA SERVED:

The quantity of sewage depends upon the type of area as residential, industrial or commercial.

The quantity is depending on population if it is residential, type of industry if it is industrial, Commercial and public places can be determined by studying the developing of other such places.

INFILTRATION AND EXFILTRATION:

Infiltration is the leakage of water from the ground surrounding the sewer.

Exfiltration is the leakage of sewage from the sewer into the ground surrounding the sewer.

The quantity of water increased through infiltration depends on the following factors:

- Length of sewer
- Size of sewer
- Sub soil water head

Nature and type of soil.

FACTORS AFFECTING THE QUANTITY OF STORM WATER FLOW: -

Intensity of rainfall

Catchment areas

Duration of rainfall

ESTIMATION OF QUANTITY OF STORM WATER: -

Rational method

Empirical Method

DESIGN OF SEWERS

Average daily flow = (70 – 80) % average water consumption

i.e. Average Daily Flow (ADF) of Sewage = 75%

Maximum Daily Flow = 1.5 x ADF

RATIONAL METHOD:

According to this method, the run off Q depends on the following factors,

Catchment area (A)

Intensity of rainfall (R)

Impermeability factor or Run-off co-efficient (I)

Quantity of storm water, $Q = \frac{C\ i\ A}{360}$

TIME OF CONCENTRATION:

It is defined as the total time required by the flow to reach to the maximum limit.

The addition of inlet time and flow time gives the time of concentration.

$$t_c = t_i + t_f$$

INLET TIME (t_i):

The time required by the storm water to reach the uppermost inlet of the sewer line known as the inlet time or time of entry.

FLOW TIME (t_f):

The time taken by the storm water to flow down the sewer upto a particular point of consideration is known as time of flow.

R or i = 25.4 a / t_c + b

Where, R or i = intensity of rainfall in mm/hr.

When t_c is 5 to 20 minutes, constant a = 30 and b = 10.

When t_c is 20 to 100 minutes, constant a = 40 and b = 20.

PROBLEMS

1.The catchment area of a city is 200 hectares. Assuming that the surface on which the rainfalls is classified as follows: Calculate the impervious factor. If the maximum intensity of rainfall is 40 mm/hour. Calculate the quantity of storm water which will reach the sewer lines.

TYPE OF SURFACE	% AREA	RUNOFF CO-EEFICIENT
Roofs	20	0.9
Pavement and Yards	15	0.8
Lawns and Gardens	30	0.15
Macadamised Roads	20	0.40
Vacant Plots	15	0.10

Solution:

Impervious factor, $i = \dfrac{A_1 C_1 + A_2 C_2 + \ldots\ldots + A_n C_n}{A_1 + A_2 + \ldots\ldots\ldots + A_n}$

$$= \frac{200\,(0.2X0.9 + 0.15X0.8 + 0.3X0.15 + 0.2X0.4 + 0.15X0.10)}{200\,(0.2 + 0.15 + 0.30 + 0.20 + 0.15)}$$

$i = 0.44$

Quantity of storm water, $Q = \dfrac{C\,i\,A}{360} = \dfrac{0.44 X 40 X 200}{360}$

$Q = 9.778\ m^3/sec.$

2. In the above example if the density of population is 300 persons/hectare and the rate of water supply is 250 litres/capita/day, Calculate the quantity of sanitary sewage for i) separate system and ii) for partially separate system.

Solution:

i) Quantity of sanitary sewage for separate system,

Quantity of water supplied = 200 X 300 X 250 = 15 X 10^6 litres/day

$$15 \times 10^6 / (24 \times 3600) = 173.6 \text{ litres/sec.}$$

But peak discharge for design purpose will be twice of this, 173.6 X 2 = 347 litres/sec.

Quantity of sanitary sewage for partially separate system,

= Quantity of sanitary sewage for separate system + Storm water drained from roof and pavement yards

$$\text{Quantity of storm water, } Q = \frac{C\,i\,A}{360} = \frac{200\,(0.2 \times 0.9 + 0.15 \times 0.8) \times 40}{360}$$

$$= 6.67 \text{ m}^3\text{/sec} = 6.67 \times 10^3 \text{ litres/sec.}$$

Quantity of sanitary sewage for partially separate system = $173.6 + 6.67 \times 10^3$

= 6843.5 litres/sec. or

= 6.843×10^3 litres/sec.

3. Estimate the storm water from 10 hectares of a surface having the following characteristics if the maximum rain intensity in the area is 5 cm/hr.

TYPE OF SURFACE	**% AREA**	**RUNOFF CO-EEFICIENT**
Roofs	30	0.9
Pavement	10	0.85
Paved Yards	5	0.80
Lawns and Gardens	25	0.10
Macadamised Roads	25	0.40
Thick vegetation	5	0.05

Solution:

$$\text{Impervious factor, } i = \frac{A_1 C_1 + A_2 C_2 + \ldots\ldots + A_n C_n}{A_1 + A_2 + \ldots\ldots\ldots + A_n}$$

$$= \frac{10\,(0.3\text{X}0.9 + 0.1\text{X}0.85 + 0.05\text{X}0.8 + 0.25\text{X}0.1 + 0.25\text{X}0.4 + 0.05\text{X}0.05)}{200\,(0.3 + 0.1 + 0.05 + 0.25 + 0.25 + 0.05)}$$

$$i = 0.5225$$

$$\text{Quantity of storm water, } Q = \frac{C\,i\,A}{360} = \frac{0.5225 \times 50 \times 10}{360}$$

$$Q = 0.7257 \text{ m}^3\text{/sec.}$$

4. A combined sewer of circular section is to be laid to serve a particular area. Design the sewer from the following:

Area to be served = 100 hectares

Population = 90000

Impermeability factor = 0.50

Time of entry = 3 min.

Time of flow = 17 min.

Rate of water supply = 240 lpcd. Assume any other data if necessary.

Solution:

$$\text{Average Discharge} = \frac{90000 \text{ X } 240}{24 \text{ X } 60 \text{ X } 60} = 250 \text{ litres/sec.}$$

Maximum Discharge = 2 X Average Discharge

= 2 X 250 = 500 litres/sec = 0.5 m^3/sec.

$t_c = t_i + t_f = 3 + 17 = 20$ min.

$R = 25.4\, a / t_c + b = 25.4 \text{ X } 30 / 20 \text{ X } 10$

$R = 25.4$ mm/hr.

$$Q = \frac{C\, i\, A}{360} = \frac{0.50 \text{ X } 25.4 \text{ X } 100}{360}$$

$Q = 3.52\ m^3/\text{sec.}$

Total Sewage = Dry Weather Flow + Wet Weather Flow

=0.5 + 3.52

= 4.02 m^3/sec.

Q = A X V

A =Q/V =4.02/3

$A=1.34 m^2$

$$A = \frac{\pi \text{ X } d^2}{4} = 1.34$$

$d^2 = 1.34 \text{ X } 4 / \pi = 1.706 \quad d = 1.306$ m.

DESIGN PERIOD

The future period for which the provision is made in designing the capacities of the various components of the sewerage scheme is known as the design period.

The design period depends upon the following:

Ease and difficulty in expansion.

Amount and availability of investment.

Anticipated rate of population growth, including shifts in communities, industries and commercial investments.

Hydraulic constraints of the systems designed, and

Life of the material and equipment.

Following design period can be considered for different components of sewerage scheme:

Trunk or main sewers: 40 to 50 years

Treatment Units: 15 to 20 years

Pumping plant: 5 to 10 years

FLUCTUATIONS IN SEWERS

The sewage flow, like the water supply flow, is not constant in practice but varies.

The fluctuation may, in a similar way, be seasonal or monthly, daily and hourly.

Fluctuation in flow occurs from hour to hour and from season to season.

The seasonal variations are due to climatic effect, more water being used in summer than in winter.

The daily fluctuations are the outcome of certain local conditions, involving habits and customs of people.

Thus, in U.S.A. and other European countries, Monday is the washing day, as such, amount of sewage flow would be much greater than on any other day.

In India, however, Sundays or other holidays involve activities which permit greater use of water.

Hourly variations are because of varying rates of water consumption in different hours of the day.

The first peak flow generally occurs in the late morning it is usually about 200 percent of the average flow while the second peak flow generally occurs in the early evening between 6 and 9 p.m. and the minimum flow occurring during the night after twelve or early hours of the morning is generally about half of the average flow.

HYDRAULICS OF SEWERS

SELF CLEANSING VELOCITY:

The sewers should be laid at such a gradient that a minimum velocity, which will prevent the silting of particles in sewers are developed. Such a minimum velocity is known as self-cleansing velocity.

Self-cleansing velocity is generally,

0.6 m/s for sanitary sewer

1m/s for storm sewer.

NON-SCOURING VELOCITY:

The upper limit of velocity is set by scouring action of sewage.

If the velocity of flow exceeds a certain limit, the particles of solid matter start to damage the inside surface of sewers or in other words, a scouring action takes place.

The maximum permissible velocity at which no such scouring action will occur is known as non-scouring velocity and it mainly depends on the material of sewers.

Generally,

Sanitary sewer = 2.4 m/sec

Storm sewer = 3 m/sec

SHAPES OF SEWERS

Circular sewer section

Non circular sewer section

CIRCULAR SEWER SECTION:

Sewers are generally circular in shape.

The sewers are running at least half full.

If the depth in a circular sewer is less than one-half, there is considerable reduction in velocity and discharge and it results in poor performance.

ADVANTAGES OF CIRCULAR SEWERS:

The perimeter of circular sewer is the least with respect to the sewer of other shape.

The inner surface is smooth hence the flow of sewage is uniform and there is no chance of deposition of suspended particles.

From hydraulic point of view, circular section provides more hydraulic mean depth.

Construction cost and material requirement is less.

Non-circular shaped sewers are also adopted for the following reasons:

They can be construct in such a convenient shape and size so that a man can enter the sewer for cleaning, maintenance, etc.

The process of construction is easy.

The structural strength is more.

Cost of construction is low.

NON-CIRCULAR SEWER SECTIONS:

Standard Egg Shape

New Egg Shape

Horse Shoe Shape

Parabolic Shape

Semi Elliptical Shape

Rectangular Shape

U- Shaped

Semi Circular Shape

Basket Handle Shape

STANDARD EGG SHAPE

It is preferred for combined sewers.

Its advantage over circular shape is that it gives higher velocity during low flow of same capacity.

It is difficult to construct and less stable.

It requires additional bedding of brick masonry or concrete to make it stable.

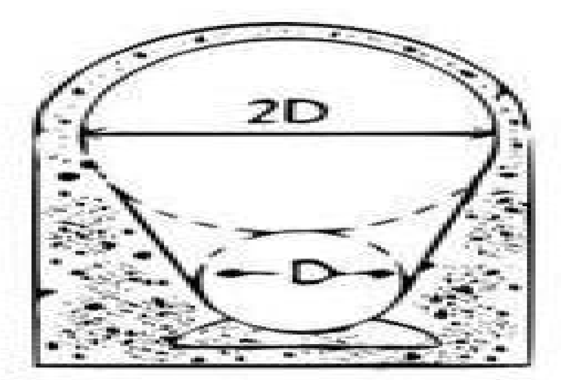


Figure No.1

HORSE SHOE SHAPED SEWER:

This may be used for large sewers with heavy discharges such as for trunk and outfall sewer.

Such sewer is suitable when headroom for the construction of sewer is limited.

The invert of this section may be flat, parabolic or circular.

Its height is more than its width.

Its wall most inclined with semicircular arch at top.

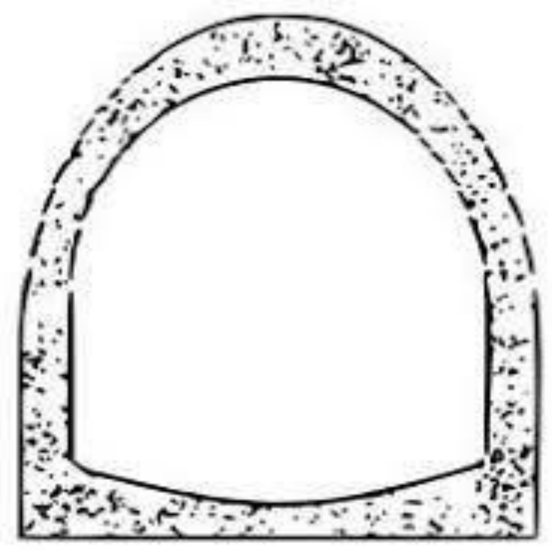


Figure No.2

PARABOLIC SHAPED SEWER:

The upper arch of the sewer forms the shape of parabola.

This may be used for carrying comparatively small quantities of sewage.

The invert may be elliptical or parabolic.

It is found to be economic in construction.

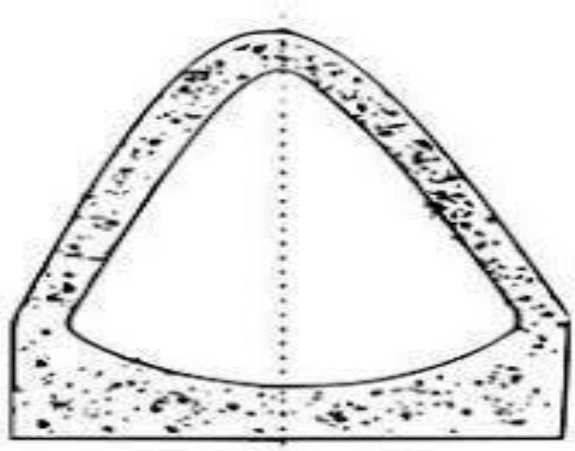


Figure No.3

SEMI ELLIPTICAL SHAPED SEWER:

It may be used for soil i.e. soft soil as it is more stable.

It is useful only for carrying large number or amounts of sewage.

It is adopted when sewers are greater than 1.8m in diameter.

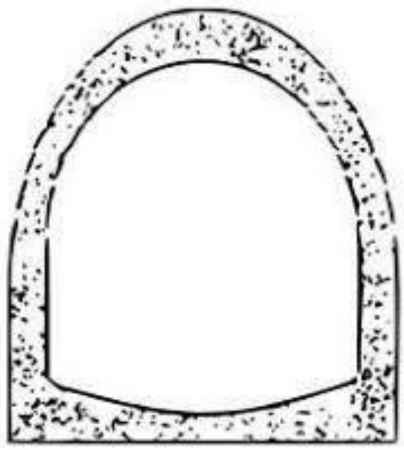


Figure No.4

RECTANGULAR SHAPED SEWER:

Generally, it is used for covered storm water drains.

It is stable and easy to construct.

Sometimes it is used to work as a storage tank.

Figure No.5

U SHAPED SEWER:

The section may have true shape of letter ‘U’, or a small trench of

U-Shape can be set up in the large section.

That trench is known as cunette.

Such type of sewer used for combined sewer having maximum flow of storm water.

It is used for longer sewers and especially in open cuts.

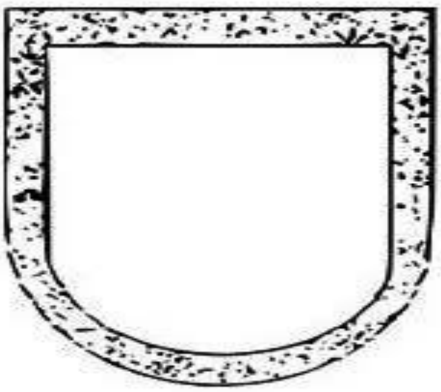


Figure No.6

SEMI CIRCULAR SHAPED SEWER:

This section gives a wider base at bottom and hence it becomes suitable for constructing large sewers with less available headroom.
It is out dated.

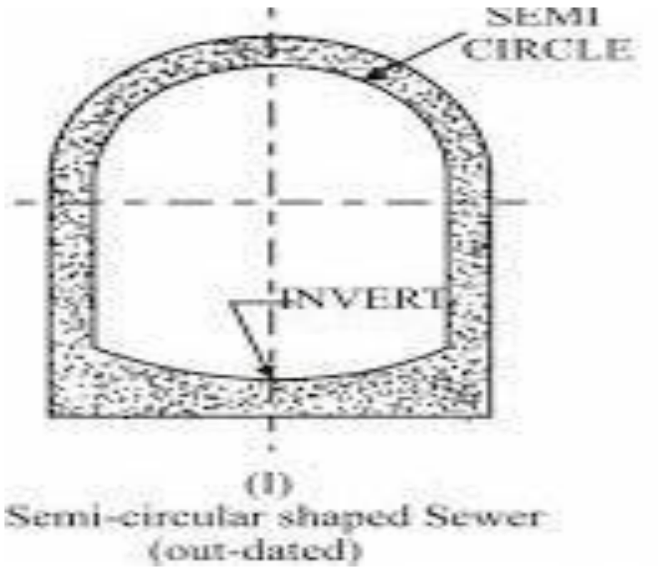


Figure No.7

BASKET HANDLE SHAPED SEWER:

In this type of sewer, the upper portion of sewer has got the shape of a basket- handle.
The bottom portion is narrower in width than the upper portion.
It carries small discharge through the bottom narrow portion and during monsoon it runs full.
It is also out dated.

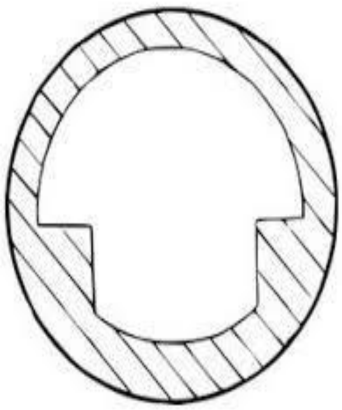


Figure No.8

FACTORS CONSIDERED WHILE SELECTING MATERIAL FOR SEWER

Resistance to corrosion
Resistance to abrasion
Strength and durability
Weight of the material

Imperviousness
Economy and cost
Hydraulically efficient

RESISTANCE TO CORROSION:

Sewer carries wastewater that releases gases such as H_2S.
This gas in contact with moisture can be converted in to sulfuric acid.
The formation of acids can lead to the corrosion of sewer pipe.
Hence, selection of corrosion resistance material is must for long life of pipe.

RESISTANCE TO ABRASION:

Sewage contain considerable number of suspended solids, part of which are inorganic solids such as sand or grit.
These particles moving at high velocity can cause wear and tear of sewer material.
This abrasion can reduce thickness of pipe and reduces hydraulic efficiency of the sewer by making the interior surface rough.

STRENGTH AND DURABILITY:

The sewer pipe should have sufficient strength to withstand all the forces that are likely to come on them.
Sewers are subjected to considerable external loads of backfill material and traffic load, if any.
They are not subjected to internal pressure of water.
To withstand external load safely without failure, sufficient wall thickness of pipe or reinforcement is essential.
In addition, the material selected should be durable and should have sufficient resistance against natural weathering action to provide longer life to the pipe.

WEIGHT OF THE MATERIAL:

The material selected for sewer should have less specific weight, which will make pipe light in weight.
The lightweight pipes are easy for handling and transport.

IMPERVIOUSNESS:

To eliminate chances of sewage seepage from sewer to surrounding, the material selected for pipe should be impervious.

ECONOMY AND COST:

Sewer should be less costly to make the sewerage scheme economical.

HYDRAULICALLY EFFICIENT:

The sewer shall have smooth interior surface to have less frictional coefficient.

SEWER MATERIALS

Asbestos Cement (AC) Sewer
Brick Sewer
Cement Sewer
Cast iron (C.I) Sewer
Steel Sewers
Plastic Sewers
Vitrified Clay or Stoneware Sewers
Lead Sewers

ASBESTOS CEMENT SEWERS:

Asbestos Cement (AC) Sewers are manufactured from a mixture of cement and asbestos fiber.
Asbestos Cement (AC) Sewers are suitable for carrying domestic sanitary sewage.
Asbestos fibers are thoroughly mixed with cement to act as reinforcement.
These pipes are available in size 10 to 100 cm internal diameter and length up to 4.0 m.
These pipes can be easily assembled without skilled labour with the help of special coupling, called 'Ring Tie Coupling' or Simplex joint.
The pipe and joints are resistant to corrosion.
These pipes are used for vertical transport of water. For example, transport of rainwater from roofs in multistoried buildings, for transport of sewage to grounds, and for transport of less foul sullage i.e., wastewater from kitchen and bathroom.

ADVANTAGES OF ASBESTOS CEMENT (AC) SEWER

Smooth.
Light in weight.
Can easily be cut, fitted and drilled.
Durable against soil corrosion.

DISADVANTAGES OF ASBESTOS CEMENT (AC) SEWER

Brittle cannot withstand heavy loads.
They are easily broken in handling and transport.

BRICK SEWERS:

Brick Sewers are made at site and used for construction large size sewer.
Brick Sewers are very useful for construction of storm sewer or combined sewer.
Nowadays brick sewers are replaced by concrete sewer.
Brick sewers my get deformed and leakage may take place.
A lot of labour work is required.
To avoid leakage the brick sewer should be plastered.
This material is used for construction of large size combined sewer or particularly for storm water drains.

The pipes are plastered from outside to avoid entry of tree roots and ground water through brick joints.
These are lined from inside with stone ware or ceramic block to make them smooth and hydraulically efficient.
Lining also make the pipe resistant to corrosion.

CEMENT CONCRETE SEWERS:

PCC - for dia up to 60 cm
Suitable for small storm drains.
Not durable.
RCC - for dia > 60 cm
They may be cast in situ or precast, resistant to heavy loads, corrosion and high pressure.
These are very heavy and difficult to transport.
These pipes can be cast in situ or precast pipes.
Precast pipes are better in quality than the cast in situ pipes.

ADVANTAGES OF CONCRETE PIPES:

Strong in tension as well as compression.
Resistant to erosion and abrasion.
They can be made of any desired strength.
Easily moulded, and can be in situ or precast pipes.
Economical for medium and large sizes.
These pipes are available in wide range of size and the trench can be opened and backfilled rapidly during maintenance of sewers.

DISADVANTAGES OF CONCRETE PIPES:

These pipes can get corroded and pitted by the action of H_2SO_4.
The carrying capacity of the pipe reduces with time because of corrosion.
The pipes are susceptible to erosion by sewage containing silt and grit.

CAST IRON (C.I) SEWERS:

These types of sewer are High strength and durability water tight.
Cast Iron sewers can withstand high internal pressure and can bear external load.
These pipes are stronger and capable to withstand greater tensile, compressive, as well as bending stresses.
However, these are costly.
Cast iron pipes are used for outfall sewers, rising mains of pumping stations, and inverted siphons, where pipes are running under pressure.
These are also suitable for sewers under heavy traffic load, such as sewers below railways and highways.
They are used for carried over piers in case of low-lying areas.
They form 100% leak proof sewer line to avoid ground water contamination.

They are less resistant to corrosion; hence, generally lined from inside with cement concrete, coal tar paint, epoxy, etc.
These are joined together by bell and spigot joint.
Cast Iron sewers are suitable for the following conditions:
When the sewage is conveyed under high pressure.
When there is considerable difference in temperature.

STEEL SEWERS:

Steel sewers are Impervious, light, resistant to high pressure, flexible.
They are generally used for outfall and trunk sewers.
These are used under the situations such as pressure main sewers, under water crossing, bridge crossing, necessary connections for pumping stations, laying pipes over self-supporting spans, railway crossings, etc.
They can withstand internal pressure, impact load and vibrations much better than CI pipes.
They are more ductile and can withstand water hammer pressure better.
These pipes cannot withstand high external load and these pipes may collapse when negative pressure is developed in pipes.
They are susceptible to corrosion and are not generally used for partially flowing sewers.
They are protected internally and externally against the action of corrosion.

PLASTIC SEWERS:

Nowadays PVC sewers are used for carrying sewage.
Plastic sewers are resistant to corrosion.
Such types of sewer are light in weight, smooth and can be bent easily.
But Plastic sewers are having high co-efficient of thermal expansion and cannot be used in very hot areas.
Plastic is recent material used for sewer pipes.
These are used for internal drainage works in house.
These are available in sizes 75 to 315 mm external diameter and used in drainage works.
They offer smooth internal surface.
The additional advantages they offer are resistant to corrosion, light weight of pipe, economical in laying, jointing and maintenance, the pipe is tough and rigid, and ease in fabrication and transport of these pipes.
High Density Polyethylene (HDPE) Pipes Use of these pipes for sewers is recent development.
They are not brittle like AC pipes and other pipes and hence hard fall during loading, unloading and handling do not cause any damage to the pipes.
They can be joined by welding or can be jointed with detachable joints up to 630 mm diameter.
These are commonly used for conveyance of industrial wastewater. They offer all the advantages offered by PVC pipes. Glass Fiber Reinforced Plastic Pipes This martial is widely used where corrosion resistant pipes are required.

GRP or FRP can be used as a lining material for conventional pipes to protect from internal or external corrosion.

It is made from the composite matrix of glass fiber, polyester resin and fillers.

These pipes have better strength, durability, high tensile strength, low density and high corrosion resistance.

These are manufactured up to 2.4 m diameter and up to 18 m length.

VITRIFIED CLAY OR STONEWARE SEWERS:

These pipes are used for house connections as well as lateral sewers.

The size of the pipe available is 5 cm to 30 cm internal diameter with length 0.9 to 1.2 m.

These pipes are rarely manufactured for diameter greater than 90 cm.

These are joined by bell and spigot flexible compression joints.

ADVANTAGES OF STONEWARE SEWERS:

Resistant to corrosion, hence fit for carrying polluted water such as sewage.

Interior surface is smooth and is hydraulically efficient.

The pipes are highly impervious.

Strong in compression.

These pipes are durable and economical for small diameters.

The pipe material does not absorb water more than 5% of their own weight, when immersed in water for 24 h.

DISADVANTAGES OF STONEWARE SEWERS:

Heavy, bulky and brittle and hence, difficult to transport.

These pipes cannot be used as pressure pipes, because they are weak in tension.

These require large number of joints as the individual pipe length is small.

LEAD SEWERS:

They are smooth, soft and can take odd shapes.

This pipe has an ability to resist sulphide corrosion.

However, these pipes are very costly.

These are used in house connection.

DESIGN CRITERIA FOR SEWER SYSTEM

For the design of sewer, the following factors are to be considered.

Rate of water supply
Intensity of rainfall
Type of sewer material
Velocity of flow
Slope of the ground
Shape of the sewer.

VELOCITY OF FLOW

The velocity of flow in a sewer line is determined by the following formulae:

Chezy's Formula
Kutter's Formula
Basin's Formula
Manning's Formula
Crimp and Burge's Formula
Hazen's Williams Formula

CHEZY'S FORMULA:

$V = C\sqrt{mi}$ m/sec.
Where, V – Velocity of flow in m/sec.
C – Chezy's Constant
m – hydraulic mean depth (A/P) in m.
i - hydraulic gradient or hydraulic slope

KUTTER'S FORMULA:

According to this formula, value of Chezy's constant (C) is given by,

$$C = \frac{23 + \frac{0.00155}{i} + \frac{1}{N}}{1 + \left(23 + \frac{0.00155}{i}\right)\frac{N}{\sqrt{m}}}$$

BASIN'S FORMULA:

$$C = \frac{157.6}{[1.81 + (K/R^{1/2})]}$$

MANNING'S FORMULA:

$$V = \frac{1}{n} m^{2/3} i^{1/2}$$

Where, n – manning's constant.

m – hydraulic mean depth (A/P) in m.

i - hydraulic gradient or hydraulic slope

CRIMP AND BURGE'S FORMULA

$V = 83.50\ m^{2/3}\ i^{1/2}$

Where,

m – hydraulic mean depth (A/P) in m.

i - hydraulic gradient or hydraulic slope.

HAZEN'S WILLIAMS FORMULA:

$V = 0.85\ C_H \times m^{0.63}\ i^{0.54}$

Where,

C_H - Hazen's Williams constant.

m – hydraulic mean depth (A/P) in m.

i - hydraulic gradient or hydraulic slope

1. Calculate the velocity of flow in a sewer of diameter 1.36 m. The gradient of sewer line is 1 in 420. If n = 0.012 in Manning's formula, what is the discharge when running one-half full.

Solution:

Velocity of flow,

$$V = \frac{1}{n}\ m^{2/3}\ i^{1/2}$$

$$m = A/P = \frac{\pi d^2/4}{\pi d} = d/4 = 1.36 / 4 = 0.34 \text{ m.}$$

$$= \frac{1 \times 0.34^{2/3} \times (1/420)^{1/2}}{0.012}$$

$V = 1.981$ m/sec.

Discharge,

$Q = A \times V = ½ \times \pi d^2/4 \times 1.981$

$Q = 1.438\ m^3/sec.$

2.Calculate the discharge for a stoneware sewer, running full. The diameter of the sewer is 200 mm and it is laid at a slope of 1 in 72. Take n = 0.013 in Manning's formula.

Solution:

Discharge,

$$V = \frac{1}{n} m^{2/3} i^{1/2} \qquad m = A/P = \frac{\pi d^2/4}{\pi d} = d/4 = 0.2/4$$

$$= \frac{1 \times 0.05^{2/3} \times (1/72)^{1/2}}{0.013} \qquad m = 0.05 \text{ m.}$$

V = 1.23 m/sec.

$Q = A \times V = \pi d^2/4 \times 1.23$

$Q = 0.038 \text{ m}^3/\text{sec.}$

3.Calculate the discharge of a sewer, running full having a diameter of 200 mm and laid at a slope of 1 in 240 by using crimp and Burge's formula.

Solution:

Discharge,

$$V = 83.50\, m^{2/3} i^{1/2} \qquad m = A/P = \frac{\pi d^2/4}{\pi d} = d/4 = 0.2/4$$

$$= 83.50 \times 0.05^{2/3} (1/240)^{1/2}$$

V = 0.55 m/sec. m = 0.05 m.

$Q = A \times V = \pi d^2/4 \times 0.55$

$Q = 0.017 \text{ m}^3/\text{sec.}$

VENTILATION OF SEWERS

Sewage flowing in sewer has got lot of organic and inorganic matters present in it.

Some of the matters decompose and produce gases. These gases are foul smelling, corrosive and explosive in nature.

If these gases are not disposed of properly, they may create a number of difficulties.

They may cause air locks in sewers and affect the flow of sewage.

They may prove to be dangerous for the maintenance squad working in sewers.

They may also cause explosions and put the sewer line out of commission.

For the disposal of these gases, ventilation of sewer line is a must.

Various gases are produced in sewers due to the purification of organic materials of sewage.

These gases are very foul in nature, cause harm to human health and corrode the sewers.

The gases so produced are highly explosive and may cause accidents.

Due to the above difficulties, the sewers must be properly ventilated.

METHODS OF VENTILATION

Proper construction of sewers

Proper design of sewers

Running the sewer at half full or 2/3 depth.

Providing manholes with gratings.

Providing manholes with chemicals.

Proper house drainage system

Providing the ventilating columns or shafts.

PROPER CONSTRUCTION OF SEWERS:

The sewer should be laid at such a gradient that self-cleansing velocity is developed and hence the swage will have no chance of staying at one point for longer period.

PROPER DESIGN OF SEWERS:

The sewers are designed to run two-third or even one-half full and the remaining top space is reserved for the accumulation of sewer gases.

The proper design of sewers also ensures enough ventilation.

PROVIDING MANHOLES WITH GRATINGS:

The manhole covers are sometimes provided with perforations, through which the sewer gets exposed to the atmosphere.

This will help in achieving some ventilation, but it will cause air pollution, hence adopted in isolated places.

The other disadvantage of this method is that it permits road dust, storm water etc. to enter the sewer.

PROVIDING MANHOLES WITH CHEMICALS:

In this method, chemicals are placed in the manhole covers.

These chemicals react with the sewer gases and make them harmless.

As this method is costly, it is rarely adopted.

PROPER HOUSE DRAINAGE SYSTEM:

The lateral sewers are ventilated independently by suitable provision of ventilating shafts or columns.

The sewer gases are carried in these columns and they are relieved in the atmosphere above the height of the building.

PROVIDING THE VENTILATING COLUMNS OR SHAFTS:

The ventilating shaft is provided along the sewer line at an interval of 150 m to 300 m.

They are also provided at the upper end of every branch sewer and at every point where sewer diameter changes.

Ventilating shaft helps to remove the foul and explosive gases produced in the sewer.

They provide fresh air to the workers working in the manholes.

They also help to prevent the formation of air locks in the sewage and thereby ensure the continuous flow of sewage inside the sewer.

CLEANING AND MAINTENANCE OF SEWERS

The sewers should be properly cleaned and maintained in good working condition.

It should be noted that sewers which are once laid and buried into the ground should not be forgotten as they are also liable to corrosion, deterioration, erosion etc.

CAUSES

Breakage of sewers
Clogging
Odours

BREAKAGE OF SEWERS:

The sewers are sometimes broken after being laid under the ground.
Several factors may contribute to the breakage of sewers, being poor foundation, excessive superimposed loads, impact due to vibrations etc.
The presence of corrosive matter in sewage will slowly eat away the material of sewer and it will ultimately result in the breakage of sewer.

CLOGGING:

Clogging mainly occurs in sewers of small size as it is possible for a man to enter such sewers and clean them.
The clogging may be due to waste building materials, ashes, deposition of sand and grit.
It may also be caused by the contribution of greasy matter from garages, hotels, soap industries.
It may be noted that clogging is predominant in sewers lay at flat slopes such that the self-cleansing velocities are not developed.

ODOURS:

The organic matter present in sewer decomposes and gives out unpleasant odours.
It is essential to clean the sewers to bring down the intensity of such unpleasant odours to the minimum possible extent.

METHODS OF CLEANING OF SEWERS

Cleaning and Flushing
Cleaning of catch pits
Inspection
Periodical Repairs
Proper Connections

CLEANING AND FLUSHING:

The cleaning of large sewers is done manually.

The man enters the sewers through manholes and scraps the dies of sewer by hand.

The scraped material is removed through manholes.

The cleaning of small sewers is affected by flushing.

For this purpose, the automatic flushing tanks are sometimes installed on the sewer line.

CLEANING OF CATCH PITS:

The catch pits used to collect storm water are cleaned after every storm.

The catch pits contain debris, silt, sand etc. and even the water contained in catch pits is likely to give rise to the growth of mosquitoes.

A slight trace of organic matter in silt will give unpleasant odour.

The oil and grease traps are also periodically cleaned to avoid the nuisance due to unpleasant odours.

INSPECTION:

The sewer and its appurtenances should be inspected at regular intervals to ascertain their proper working.
The inspection includes examination of structures, measuring rate of flow, determining the amount of clogging.
In case of small sewers, inspection may be also carried out through lamp holes.
In case of large sewers, inspection is carried out by entering and examining the condition of sewer.
Extreme care should be taken before entering the sewer and absence of poisonous and explosive gases in sewer should be confirmed before entering the sewer.
A fire-hose with nozzle may be also inserted in the sewer and the water under pressure may be discharged through the nozzle to clean the sewer.

When flushing is inadequate to remove obstructions in the sewer, the following methods are employed to make the sewer clean.

Flexible rod.

Mechanical tools.

Use of pills.

The precautions to be taken during inspection, only experienced workers should be allowed to enter the sewer for inspection.

The explosion proof electric lighting equipment should only be used for inspection inside the manhole.

The workers should be provided with proper protective measures such as gas masks, rubber gloves, gum boots, non-sparkling tools, safety belt etc.

The workers should be trained to guard against the water borne diseases through sewage. They should also be advised to keep excellent personal hygiene.

The warning signs for traffic should be placed on the road on which manholes are opened out for inspection.

PERIODICAL REPAIRS:

The damaged portions of sewers should be immediately repaired.

The brick sewers require frequent repairs.

The broken bricks should be replacing and pointing to the brickwork should be done at regular intervals.

The manholes also should be periodically examined and repaired, if necessary.

The damaged or broken covers of street inlet or catch basin should be replaced.

The manhole covers which have loose by traffic should be tightened.

The defective connections between the house sewers and the street sewers should be immediately repaired.

The ventilating columns or shafts should be checked at regular intervals and it should be ensured that they are functioning properly.

PROPER CONNECTIONS:

The connection of lateral sewers with branch sewers should be carried out by authorized licensed plumbers only.

The plumbing work of house drainage should be carefully done and the joints should be made water tight.

- ✓ Generally, cement mortar joints are more rigid in nature.
- ✓ If any repair work or replacement of joint is to be made, it leads to the breakage of sewer or joint.

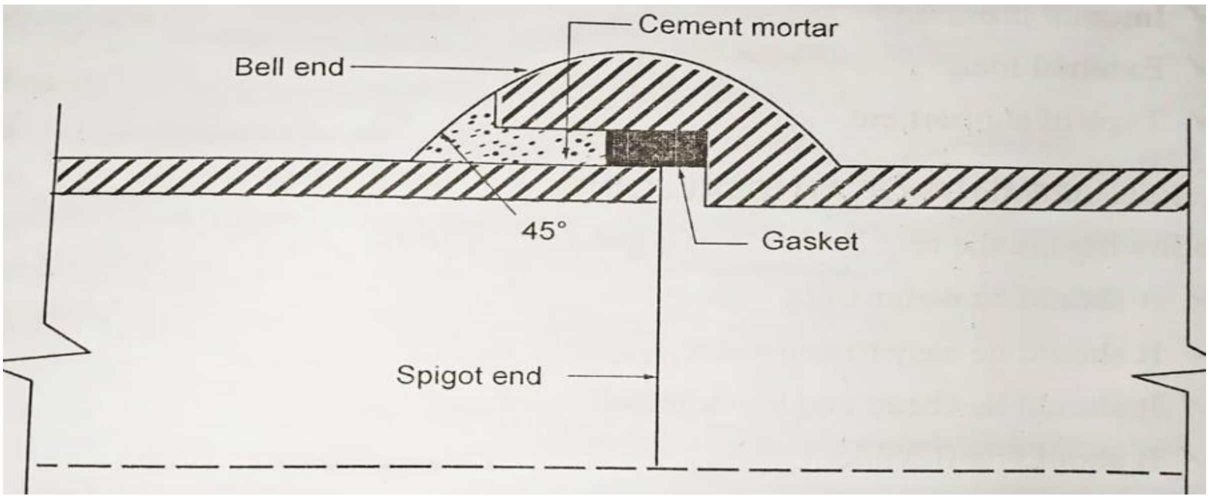


Figure No.7

SEWER APPURTENANCES

Sewage flowing in the sewer line contains a large number of impurities in the form of silt, fats, oils, rags etc.

Under normal flows they are not likely to settle and choke the sewers, but during small flows self-cleansing velocity is not likely to develop and the chances of choking of the sewers are increased.

Chokings have to be removed time to time, and facilities should be provided on the sewer lines for this purpose.

Therefore, for proper functioning and to facilitate maintenance of the sewage system, various additional structures have to be constructed on the sewer lines.

These structures are known as sewer appurtenances.

Following are the important appurtenances:

- Manholes
- Drop manholes
- Lamp holes
- Street Inlets
- Catch basins

- Flushing Tanks
- Grease and oil traps
- Regulators
- Inverted siphons

MANHOLES:

- ✓ The manholes are R.C.C or masonry chambers constructed on the sewer line to facilitate a man to enter the sewer line and make the necessary inspection and repairs.
- ✓ These are fitted with suitable cast iron covers.
- ✓ The manholes should be installed at every point where there is a change in direction, change in pipe size, or considerable change in gradient.
- ✓ As far as possible sewer line between two subsequent man holes should be straight.
- ✓ The centre distance between manholes is less for sewers of smaller size while it may behave such a size that man can easily enter in the working chamber.
- ✓ The minimum size is 50cm diameter.

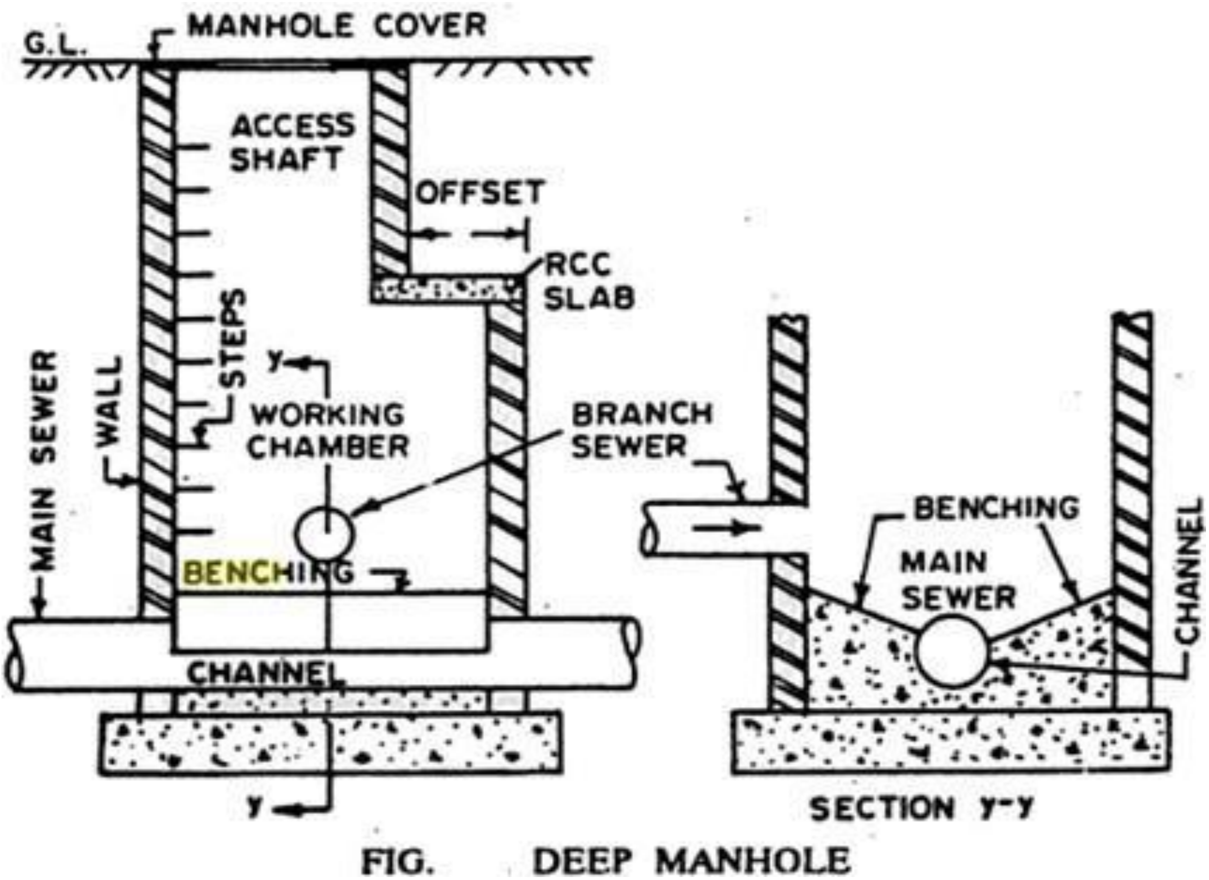


Figure No.8

DROP MANHOLE:

- ✓ A manhole in which a lateral service line or the main line enters a manhole above the manhole's channel or above the flow line so that the flow drops to a lower level is called a drop manhole.
- ✓ The drop manhole is a type of manhole in which a vertical pipe is provided.
- ✓ It is a measure of connecting high level branch sewer to low level main sewer. They are connected through a vertical pipe.
- ✓ The installation of a drop manhole becomes necessary when there is difference in levels is more than 60cm between branch sewer and the main sewer, which can be avoided by increasing the sewer grade.

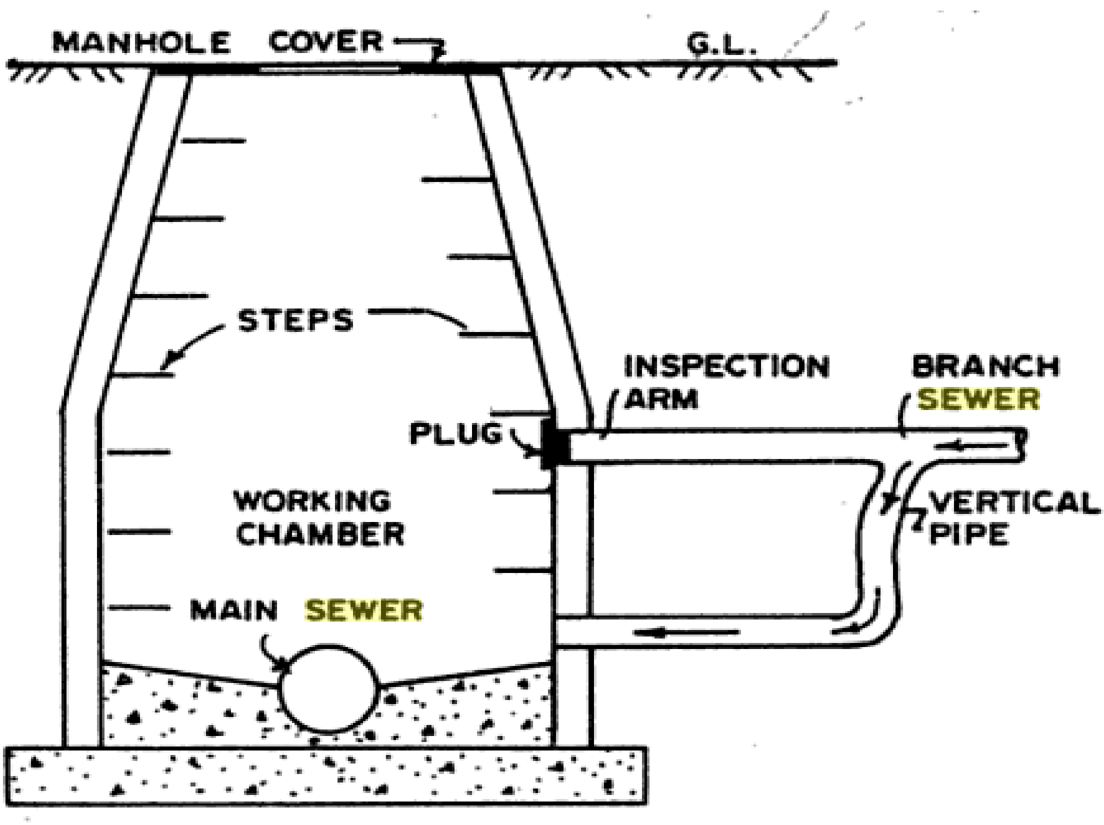


Figure No.9

LAMP HOLES:

- ✓ In narrow lanes, change of gradient and slight curves where space is insufficient for the construction of manholes, a vertical shaft of 20-30 cm diameter is connected to the sewer by a T – bend.
- ✓ These small size openings are covered by a cast iron or R.C.C cover flush with the road level at the top.

- ✓ A small, vertical pipe or shaft extending from the surface of the ground to a sewer.
- ✓ A light (or lamp) may be lowered down the pipe for the purpose of inspecting the sewer.

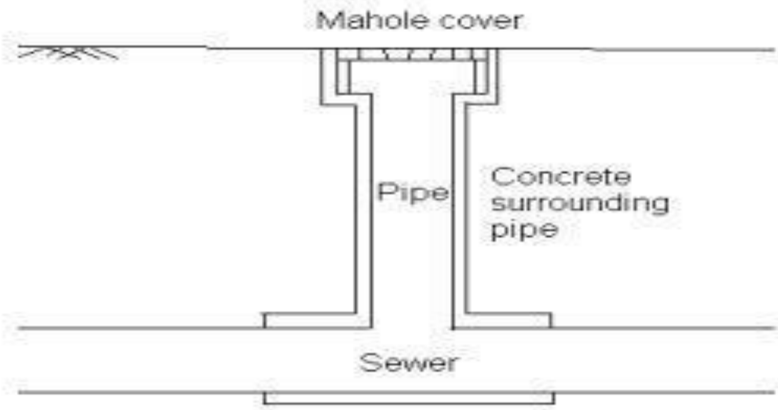


Figure 8.12 Lamp hole

Figure No.10

STREET INLETS:

- ✓ These are meant to admit the surface runoff to the sewers and form a very important part of the system.
- ✓ Their location and design should therefore be given careful consideration.
- ✓ Storm water inlets may be categorized under three major groups viz, curb inlets, gutter inlets, and combination inlets, each being either depressed or flush depending upon their elevation with reference to the pavement surface.
- ✓ The actual structure of an inlet is usually made of brick work.
- ✓ The clear opening shall not be more than 25mm.
- ✓ The connecting pipe from the street inlet to the main street sewer should not be less than 200mm dia. and should have sufficient slope.
- ✓ Maximum spacing of inlets would depend upon various conditions of road surface, size and type of inlet and rainfall. A maximum spacing of 30m is recommended.
- ✓ Inlets are of three types:
- ✓ Curb inlet, Gutter inlet, Combined Curb and Gutter inlet

CURB INLETS:

- ✓ Curb inlets are vertical openings in the road curbs through which the storm water flows and are preferred where heavy traffic is anticipated.
- ✓ These inlets are more suitable than gutter inlets, because less quantity of floating solids enter in the catch pits.

Figure No.11

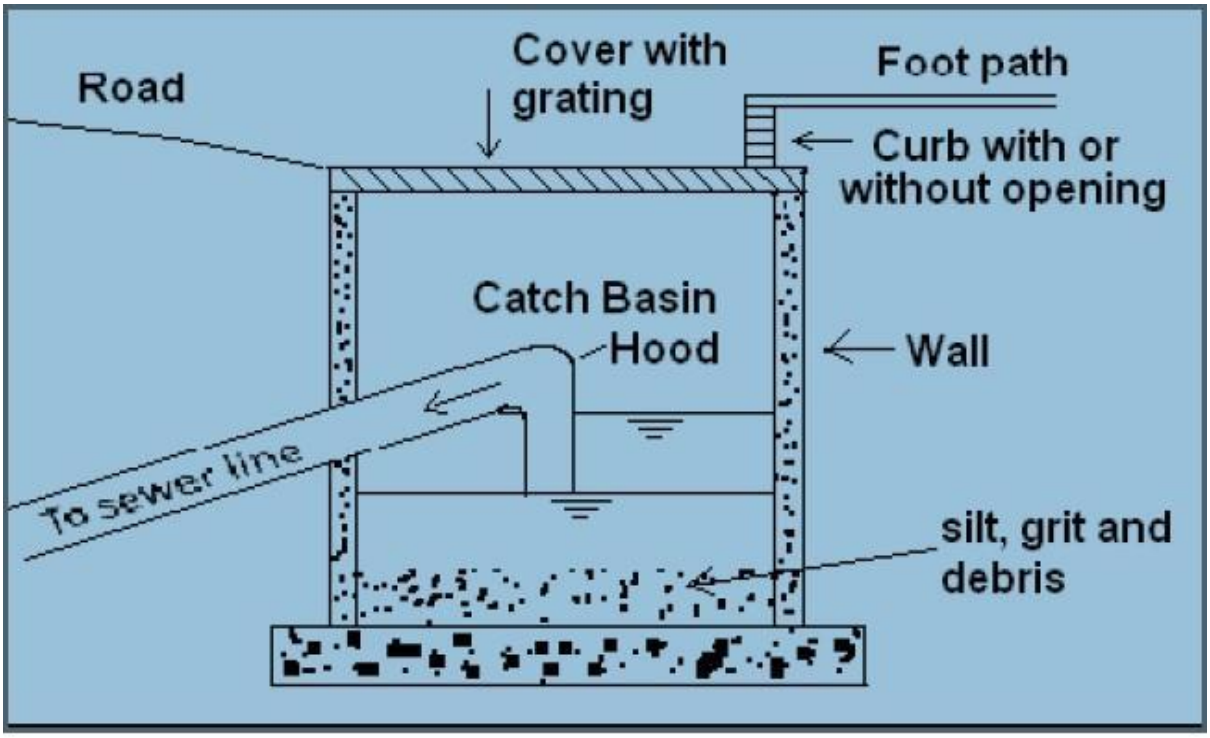
GUTTER INLETS:

- ✓ Gutter inlet is sometimes called horizontal inlet also.
- ✓ This inlet is constructed in road gutter and storm water enters directly into it through horizontal grating provided at the top of the inlet.
- ✓ Such inlets are suitable for roads having steep slope, because its capacity to handle storm water is quite large.

Figure No.12

CATCH BASINS:

- ✓ Catch basins are the structures of pucca chamber and a stout cover.
- ✓ They are meant for the retention of suspended grit, sludge and other heavy debris and floating rubbish from rainwater which otherwise might have entered and cause choking problems.
- ✓ The outlet pipe from the catch basin may be submerged in order to prevent the escape of odours from the sewer and provision that also causes retention of floating matter.
- ✓ Their use is not recommended since they are more of a nuisance and a source of mosquito breeding apart from posing substantial maintenance problems.



Catch Basins

Figure No.13

FLUSHING TANKS:

- ✓ Flushing tanks are provided to flush the sewers.
- ✓ They are seldom used.
- ✓ At such places where self-cleansing velocity is not developed or when the ground is flat and it is not possible to lay the sewer lines at designed gradients, flushing tanks required to flush the sewer line.

- ✓ They are installed at suitable intervals to clean the sewers of choking and obstructions.
- ✓ It resembles a manhole but it is equipped with a siphon at the bottom.
- ✓ This is called the automatic flushing tank in which the water is automatically released from the tank at suitable intervals which may be water supply pipe tap.

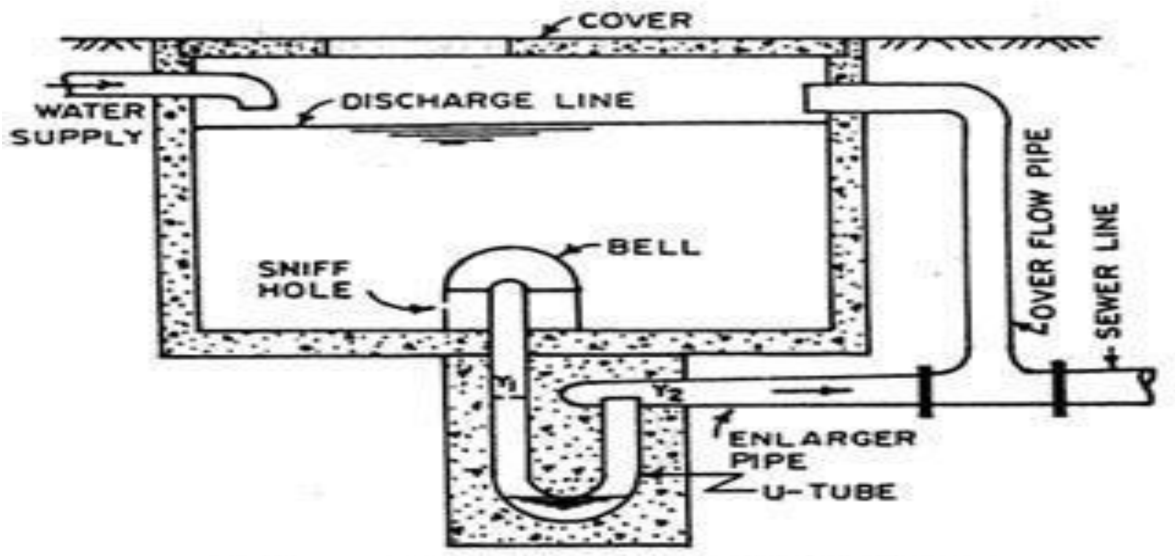


FIG. AUTOMATIC FLUSHING TANK

Figure No.14

GREASE AND OIL TRAPS:

- ✓ The sewage from kitchens of hotels and restaurants and industries contains oil and grease and fats
- ✓ If these oils and greases are not removed from the sewage they will stick to the interior of the sewer and clogging.
- ✓ Sewage from garages, particularly from floor drains and wash racks, contains oil, mud and sand.
- ✓ The principle, on which oil and grease trap work, is since oil and grease being lighter than water float on the surface of sewage, and the outlet is provided well below the surface so the water is excluded from oil and grease.
- ✓ If silt also has to be excluded, it is done by providing outlet at top.
- ✓ The silt settles at bottom and silt free water can be drained through outlet.

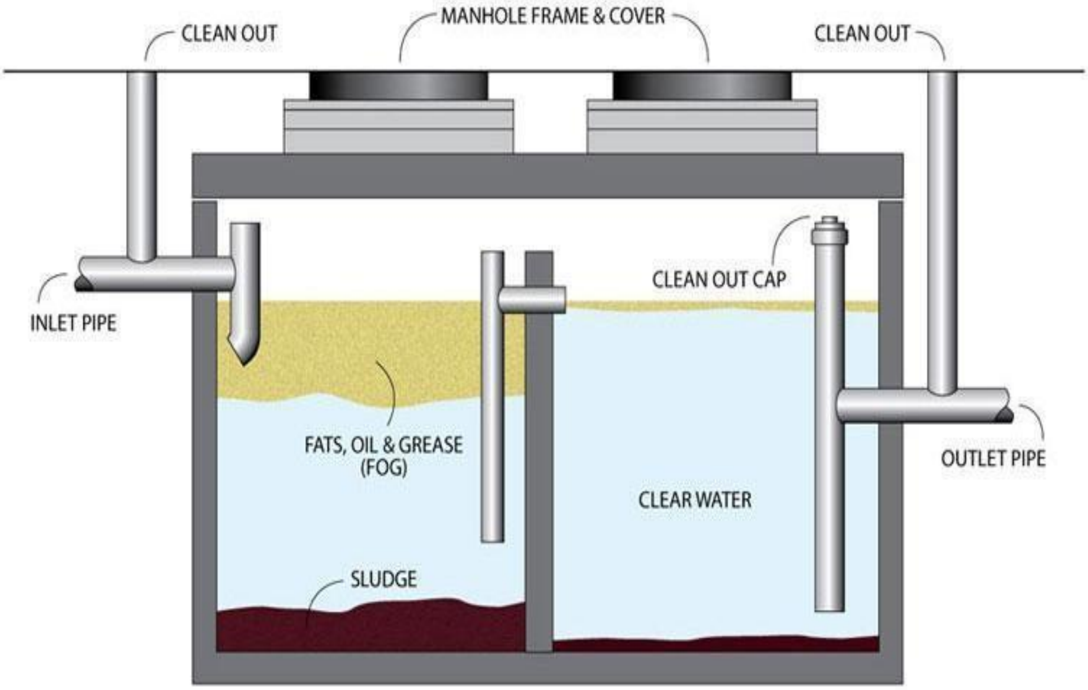


Figure No.15

REGULATORS:

- ✓ A Regulator is a device that diverts sewage flow from one sewer into another.
- ✓ The regulator usually goes into action when the sewage flow reaches a predetermined amount.
- ✓ It may then divert all the sewage or only that part above the predetermined flow at which it begins to function.
- ✓ Regulators are mostly used where combined sewers discharge into interceptors.
- ✓ The interceptor takes the dry-weather flow, but the storm water is diverted into a sewer which flows to the nearest water course.

INVERTED SIPHONS:

- ✓ Inverted siphons are used to carry sewage or stormwater under streams, highway cuts, or other depressions in the ground.
- ✓ Inverted siphons (also called depressed sewers) allow stormwater or wastewater sewers to pass under obstructions such as rivers.

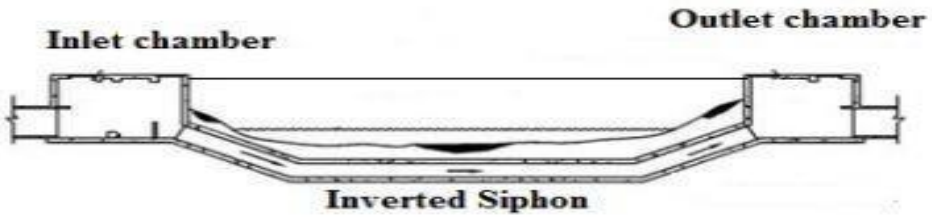


Figure 8.5 Inverted siphon

Figure No.16

PRINCIPLES GOVERNING THE DESIGN FOR DRAINAGE IN BUILDINGS

- House Drainage should be **preferable laid by side of the building** to facilitate easy repair and better maintenance.
- House sewer joints should be **leek proof** because leekage if any shall create an odour problem and leaked wastewater shall infilterate in the ground and shall reduce **bearing capacity of soil** below foundation, which is not desirable.
- The sewage or sullage should **flow under the force of gravity**.
- The house sewer should **always be straight**.
- The entire system should be **well ventilated** from start to the end.
- The house sewer should be connected to the manhole such that the invert level is sufficiently higher to avoid back flow of sewage in house sewer.
- Where ever there is change in direction of sewer line in the premises, provide **inspection chamber at the junction**.
- **Rain water** from roofs or open courtyards **should not be** allowed to flow through the **house sewers**.
- **Siponage action** can never be permitted and therefore adequate **ventilation systems** should be installed.

PLUMBING SYSTEMS FOR DRAINAGE:

Following are the four systems of plumbing for the building drainage:

- ✓ One pipe system
- ✓ Two pipe system
- ✓ Single stack system
- ✓ Single stack partially ventilated system

ONE PIPE SYSTEM:

- ✓ In this system only one main pipe is provided which collects both the foul soil waste as well as unfoul waste from the buildings.

- ✓ The main pipe is directly connected to the drainage system.
- ✓ If this system is provided in multistoried buildings the lavatory blocks of various floors are so placed one over the other, so that the waste water discharged from the different units can be carried through short branch drains.
- ✓ All the traps of the W.C., basins sink, etc. are fully ventilated and connected to the ventilation pipe.
- ✓ But all gully traps and waste pipes are completely dispensed with.

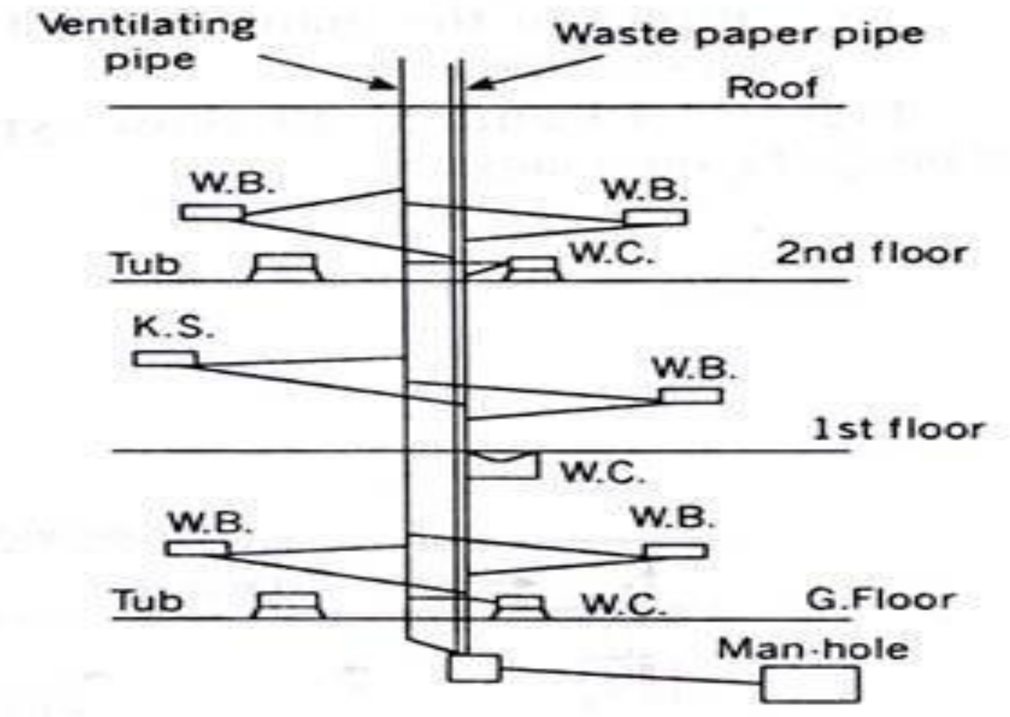


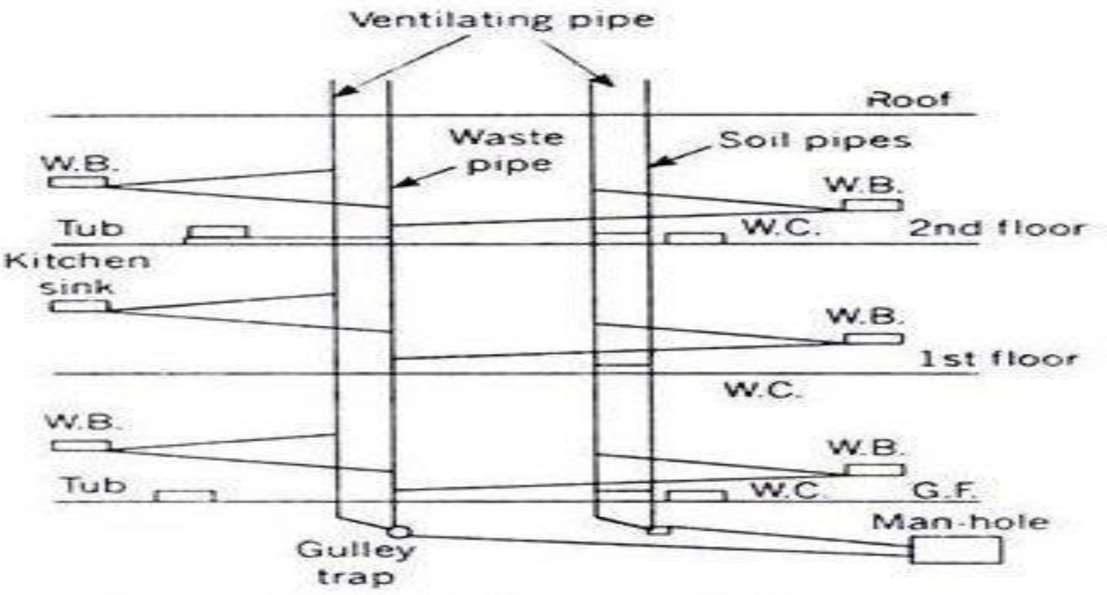
Fig. 24.22. One-pipe system.

Figure No.17

TWO PIPE SYSTEM:

- ✓ This is the most common system used in India.
- ✓ In this system, two pipes are provided.
- ✓ One pipe collects the foul soil and lavatory wastes, whereas the second pipe collects the unfoul water from kitchen, bathrooms, house washings, rain water etc.

- ✓ The soil pipes (pipes carrying the soil waste) are directly connected to the drain, whereas the waste pipes (pipes carrying unfoul water) are connected through the trapped gully.
- ✓ All the traps used in this system are fully ventilated.



Two-pipe system.

Figure No.18

SINGLE STACK SYSTEM:

- ✓ This is similar to single pipe system, the only difference being that no ventilation is provided even in the traps too.
- ✓ Hence it uses only one pipe which carries the sewage as well as the sullage and is not provided with any separate vent pipe.

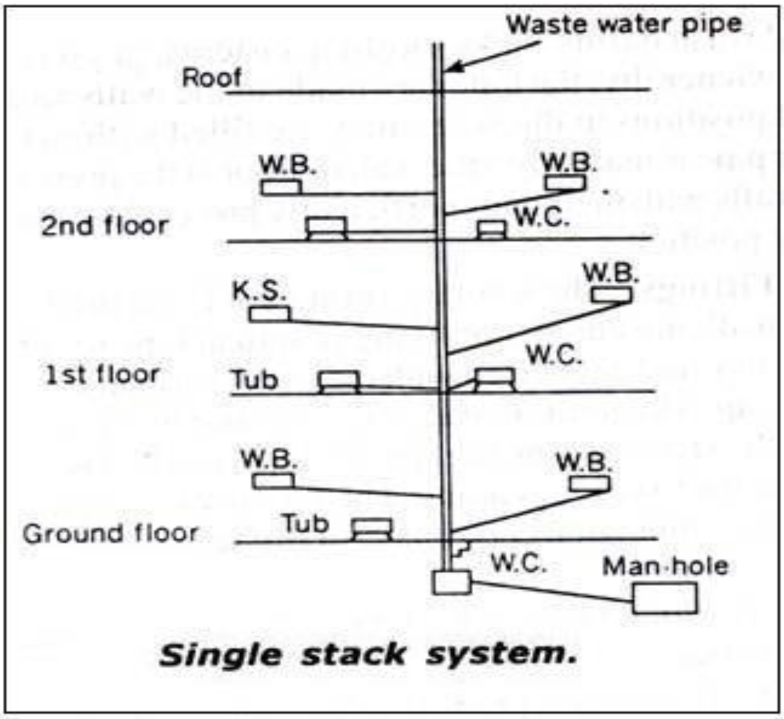


Figure No.19

SINGLE STACK PARTIALLY VENTILATED SYSTEM:

- ✓ This is an improved form of single stack system in the sense that in this system, the traps of the water closets are separately ventilated by a separate vent pipe called relief vent pipe.
- ✓ This system is in between the one pipe and single-stack system.
- ✓ In this system only one pipe is provided to collect all types of waste water foul as well as unfoul.

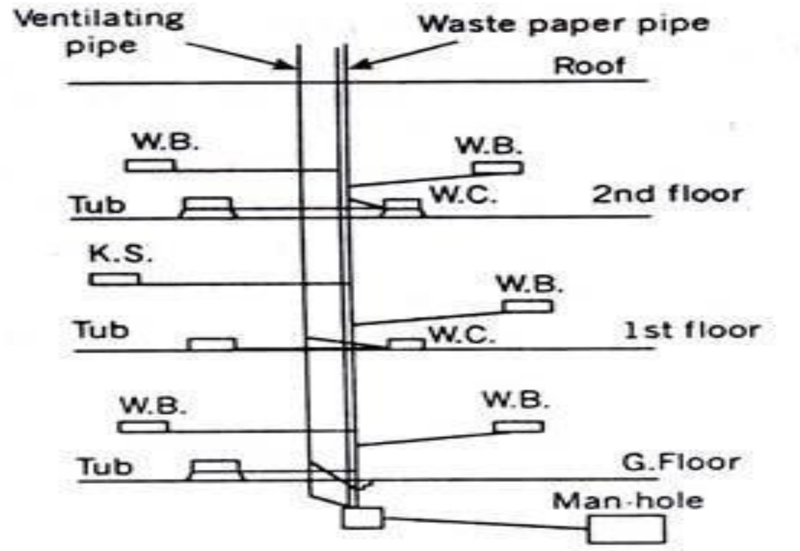
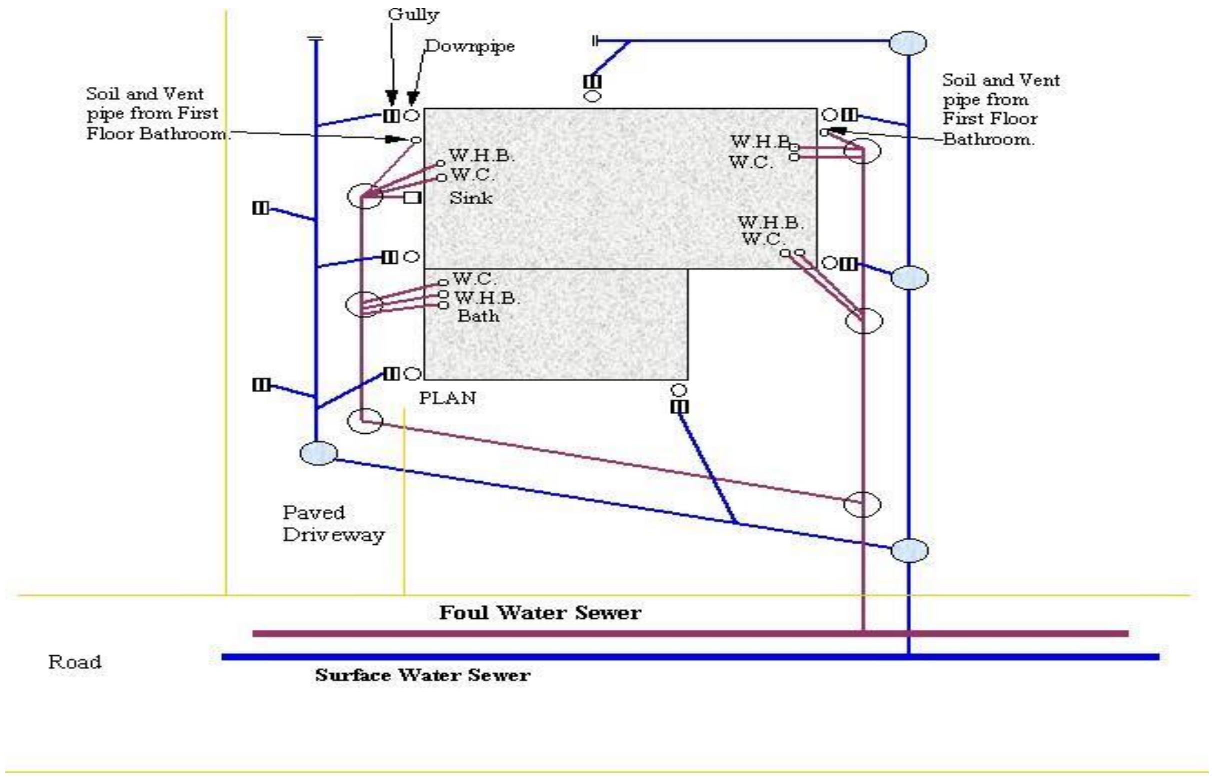


Fig. 24.24. Single-stack partially ventilated system.

Figure No.20

TYPICAL LAYOUT PLAN SHOWING HOUSE DRAINAGE CONNECTIONS



DRAINAGF LAYOUT

Figure No.21

IMPORTANT TERMS:

Pipes:

In house drainage system pipes may be designated depending upon the function as shown below.

Soil Pipe: A pipe carrying human Sewage from W.C.

Waste Pipe: A pipe carrying sullage.

Vent Pipe: It is a pipe installed to provide flow of air to or from the drainage system or to provide circulation of air in the drainage system to protect the water seal of traps against Siphonage and backflow.

Antisiphonage Pipe: It is the pipe which is installed to preserve the water seal in the trap through proper ventilation

Rain water Pipe: A pipe carrying only rain water.

Pipe Sizes:

Soil pipe:	100mm
Waste pipe: horizontal:	30-50mm
Waste pipe: vertical :	75mm
Rainwater pipe :	75mm
Vent pipe:	50mm

Traps:

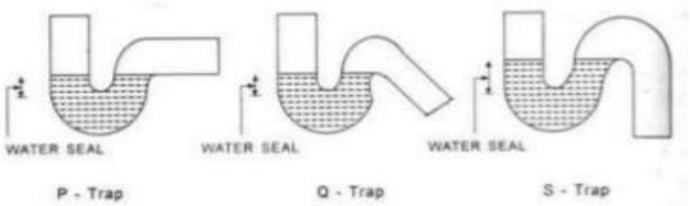
Traps are U shaped fixtures that have Water seal in it. This water in the **trap** creates a seal that prevents sewer gas from passing from the **drain** pipes back into the occupied space of the building. Essentially all plumbing fixtures including sinks, bathtubs, and toilets must be equipped with either an internal or external **trap.**

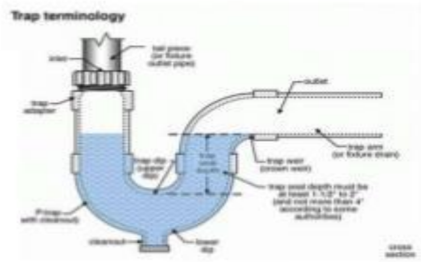
Depending upon the shapes the traps are classified as:

P-Trap: P-traps exit into the wall behind the sink.

Q-Trap: This trap is used in toilet under water closet.

S-Trap: This trap is usually used with Siphonage pipe.





TRAPS:

- ✓ A trap is a device which is used to prevent sewer gases from entering the buildings.
- ✓ The traps are located below or within a plumbing fixture and retains small amount of water.
- ✓ The retaining water creates a water seal which stops foul gases going back to the building from drain pipes.
- ✓ Therefore, all plumbing fixtures such as sinks, washbasins, bathtubs and toilets etc. are equipped with traps.

- ✓ This article tells you the features of traps, various types of traps and water seal.
- ➢ A trap has following features:
- ✓ It may be manufactured as an integral trap with the appliance as in some models of European WC, or it may be a separate fitting called an attached trap, which is connected to waste or foul water outlet of appliances.
- ✓ The traps should be of a self-cleansing pattern.
- ✓ Traps for use in domestic waste should be convenient for cleaning.
- ✓ A good trap should maintain an efficient water seal under all conditions of flow.

Traps:

Based on the Use, the traps are classified as:

Floor Traps (Nahni Trap): This trap is generally used to admit sullage from the floors of rooms, bathrooms, kitchen etc. in to the sullage pipe. This is provided with cast iron or stainless steel or galvanized gratings (Jallis) at its top so that the entry of larger matter is prevented thereby chances of blockage are reduced.

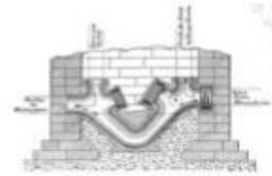
Gully Traps: A Gully trap or gully is provided at a junction of a roof drain and other drain coming from kitchen or bathroom.

Intercepting Traps: Intercepting Traps: Intercepting traps is provided at junction of a house sewer and municipal sewer for preventing entry of foul gases of municipal sewer in to the house drainage system.


Nahni Trap


Gully Trap


Intercepting Trap


Section through Intercepting trap

Sanitary Fittings:

Following sanitary fittings are used in the house drainage system.

Wash Basin: These are plumbing fixtures mainly used for handwashing.

Sinks: Sinks are the plumbing fixtures provided in kitchens for cleaning utensils.

Bath tubs: A circular waste hole at the bottom of bath tub is provided for drainage purpose. Bath Tub is the plumbing fixtures provided in the bathroom for taking bath.

Water Closets: A water closets is a pan like water flushed plumbing fixture designed to remove human excreta directly and dispose the same in to the soil pipe through trap.

Urinals: a bowl or other receptacle, typically attached to a wall in a toilet, into which men may urinate.


Wash Basin


Water Closet


Sink


Bath Tub


Urinal

SEWAGE PUMPING STATION

A pumping station is made up of a large tank, known as a wet well, that acts as the receiver for sewage from a building or a group of buildings.

Sewage from individual houses flows into the wet well.

The sewage will then sit in the well until it reaches a predetermined level.

Once it reaches this level, a pump will kick in to pressurize the sewage so that it will travel out of the wet well, uphill, to a point where it enters the main sewer, or that it can then travel into the main sewer using gravity.

ADVANTAGES OF A SEWAGE PUMP STATION

- ✓ A pump station offers convenience when installing a sewage system, and has a potential of cutting construction cost.
- ✓ Pump stations are fitted with remote monitoring systems, which keep operators updated.
- ✓ Sewage is pumped automatically without any human contact, which eliminates the risk of health problems.
- ✓ Different sizes of pumps are available for domestic applications and commercial applications.
- ✓ The intake of the pumps is often wide to prevent blocking.
- ✓ Sewage pumping systems are fitted with alarms to alert you to problems with the system.
- ✓ This minimizes the risk of sewage overflowing as you are alerted quickly.

DISADVANTAGES OF A SEWAGE PUMP STATION:

- ✓ Design and installation need to be done expertly to ensure that the system is reliable and fit for purpose.
- ✓ This requirement for expertise means that it can be costly.
- ✓ Although the pump systems generally don't use much power, there is still a cost to the electricity over using a gravity system.
- ✓ It can be difficult to source parts for your pump.
- ✓ This can be avoided by taking up a maintenance contract with Pumping Solutions.

- ✓ Fat and grease build-ups can impact reliability.
- ✓ Although pumps are selected to minimize the risk of blockages, there is still potential for blockages to occur.

PUMPS FOR SEWAGE PUMPING:

- ✓ Centrifugal pump
- ✓ Reciprocating pump
- ✓ Air pressure pump or ejectors

CENTRIFUGAL PUMPS:

- ✓ Centrifugal pumps are most commonly used for pumping sewage, because these pumps can be easily installed in pits and sumps, and can easily transport the suspended matter present in the sewage.

RECIPROCATING PUMPS:

- ✓ Reciprocating pumps are much less employed these days for sewage pumping, because of their high initial cost, difficulty in maintenance and greater wear and tear of valves.
- ✓ However, in cases where it is required to deal with difficult sludges and where large quantity of sewage is to be pumped against low heads, reciprocating pumps may be used after passing the sewage through screen with 20 mm spacing.

AIR PRESSURE PUMPS OR PNEUMATIC EJECTORS:

- ✓ Pneumatic ejectors are used for pumping or lifting small quantities of sewage.
- ✓ The conditions favouring installation of pneumatic ejectors are:
- ▪ Where small quantity of sewage is to be lifted from basement of a building to a high-level sewer.
- ▪ Where the quantity of sewage from a low-lying area does not justify the construction of a pumping station.
- ▪ Where a centrifugal pump of small capacity is likely to clog.

UNIT – V SEWAGE TREATMENT and DISPOSAL Objectives - Selection of Treatment Methods - Principles, Functions, - Activated Sludge Process and Extended Aeration Systems - Trickling Filters - Sequencing Batch Reactor(SBR) - UASB - Waste Stabilization Ponds - Other Treatment Methods - Reclamation and Reuse of Sewage - Recent Advances in Sewage Treatment - Construction, Operation and Maintenance Aspects. - Discharge Standards-Sludge Treatment -Disposal of Sludge

Surface loading = Quantity/Surface area = 225000 X 24 /(2 X 4 X 33)

$= 20455\ l/m^2/day < 30000\ l/m^2/day.$

Hence Safe.

2. Design an Imhoff tank for a town having population of 17000 persons. The rate of sewage is 150 l/day. Assume suitably any other data need.

Solution:

Total flow of sewage = 17000 X 150 = 255 X 10^4 l/day.

Assume detention period as 2 hours.

DESIGN OF UPPER FLOW CHANNEL:

Capacity of flow channel = 255 X 10^4 X 2 /(24 X 1000) = 212.5 m^3

Provide 2 channels of 2 m X 32 m having 1 m vertical depth and 1.5 m sloping depth.

Volume of the channels = 2 X [2 X 32 X 1 + 2 X 32 X 1.5/2]

= 224 m^3 > 212.5 m^3

Hence Safe.

DESIGN OF DIGESTION TANK:

Assuming 0.05 m^3/cap space required.

Total Capacity = 0.05 X 17000 = 850 m^3

Provide 5 m width, vertical depth 4 m and inclined depth 3 m.

Volume of the tank = 5 X 32 X 4 + 5 X 32 X 3/2 = 880 m^3 > 850 m^3

Hence Safe.

SECONDARY TREATMENT OF WASTE WATER

- The effluent from the primary sedimentation tank consists of 45 to 60 % of unstable organic matters, originally present in the sewage.
- The larger and medium sized solids have been removed by settling in sedimentation tanks and the organic matter present in the sewage as colloidal matter is carried away by effluent from the settling tanks.
- The further treatment of sewage is called secondary treatment or biological treatment and in which the conversion of organic matter into stable forms by oxidation or nitrification.
- The secondary treatment of sewage involves various methods and are classified into two important processes.

✓ Filtration process

- ✓ Activated-sludge process.
- ➢ All the secondary treatment processes are designed to work on aerobic bacterial decomposition.
- ➢ In secondary treatment, dissolved or colloidal organic matters are present in sewage are removed by utilizing microorganisms.
- ➢ In this steps, microorganisms utilizes organic matter and converts them into inorganic minerals.
- ➢ Following changes occurs in sewage during secondary treatment:
    - ➢ Organic matter (carbon) is oxidized into CO_2 and H_2O
    - ➢ Organic nitrogen compounds are first converted into NH3 and then into NO3
    - ➢ Colloidal matters are coagulated or precipitated out.
- ➢ Thus main purpose of secondary treatment of sewage is to reduce BOD level.
- ➢ **FILTRATION PROCESS:**
- ✓ In secondary treatment, the filter units consists of open beds of coarse aggregate overwhich the sewage is spreaded or sprinkled intermittently.
- ✓ The necessary contact surface for the growth of aerobic bacteria is provided by the aggregates in the bed.
- ✓ By doing this, the aeration is provided by nature.
- ➢ **DIFFERENT TYPES OF FILTERS:**
- ✓ Contact Beds
- ✓ Intermittent Sand Filters
- ✓ Trickling Filters

CONTACT BEDS

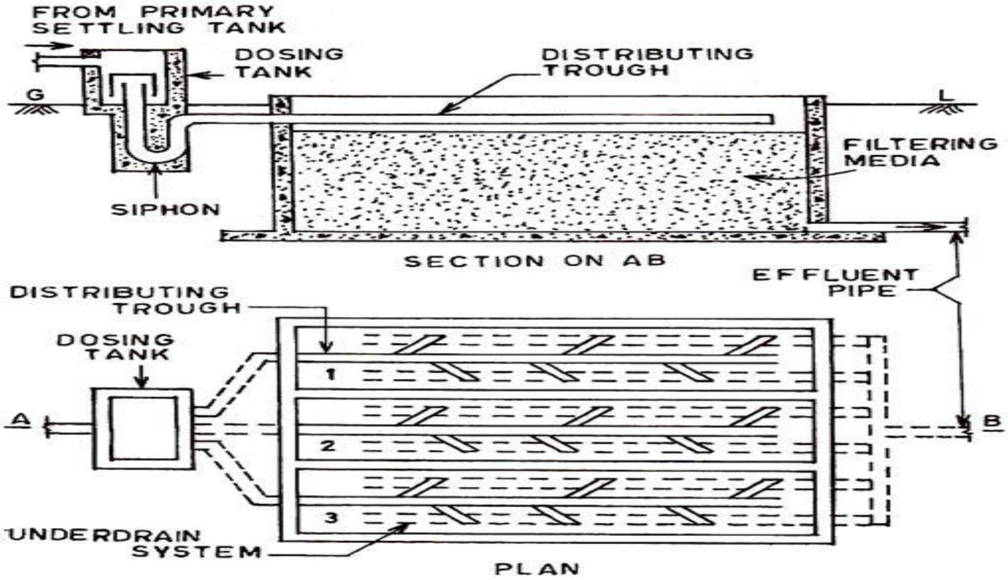


Fig. 14.2 Contact bed sewage filter.

Figure No.9

- In ancient time contact beds were very popular in the treatment of sewage, but now a days these are similar in construction to the intermittent sand filters, the only difference being in the filtering media.
- The filtering media consists of 2 to 2.5 cm size broken stone ballast or brick ballast.
- The depth of the filtering media is between 90-150 cm.
- The sewage is uniformly applied over the whole surface of the filtering media, by means of distribution troughs and is collected at the bottom by means of a system of under drain pipes.

OPERATION OF THE CONTACT BEDS:

- **FILLING:**

✓ In this operation the sewage is applied on the surface of contact beds as quickly as possible by means of dosing siphon.

✓ The sewage is allowed to be filled 5-10 cm above the top surface of filter media. The filling process may take 1 to 1.5 hours.

- **CONTACT:**

✓ In this operation, the dosing is stopped and the applied sewage is allowed to come in contact for about 2 hours.

✓ During this period, the colloidal matters and dissolved matters get transferred to the filter media and comes in contact with the bacterial film covering the filter media..

✓ Within this time the soluble contents of sewage are absorbed by the organic film and are stabilized.

- **EMPTYING:**
- ✓ The contact beds are then slowly emptied and drained.
- ✓ This operation is carried out for 1 to 2 hours.
- ✓ So that the absorbed soluble contents of the sewage are not washed out with the sewage, which is being drained.
- **RESTING:**
- ✓ After emptying, the contact beds are allowed to remain at rest for 5-6 hours and this period is called second contact period.
- ✓ Within this period the atmospheric air enters in the voids of the contact media and makes it ready for taking another sewage load.
- ✓ By supplying oxygen to the aerobic bacteria, which oxidize the organic matter present in the sewage which is transferred by sewage on the surface of the filtering media.
- ✓ The complete cycle of operation takes 8-12 hours.
- ✓ The stabilized organic matter from the voids is finally taken in the next cycle of operation.
- ✓ As these contact beds are intermittent in action, therefore more numbers of units are constructed in parallel and the sewage is applied in turn to each unit.
- ✓ For this purpose continuous supervision is required.
- ✓ The effluent obtained from these beds is also clear and odourless.
- ✓ These beds remove 80 to 90% suspended solids and 60 to 75% B.O.D.
- ✓ The rate of loading is very low 4500 to 6500 m^3/hectare/day.
- ✓ The voids inside the filtering media continuously go on reducing due to accumulation of the solids in them.
- ✓ After 4-5 years the filtering media is taken out, washed, dried and filled again.
- ✓ Similarly the under drain pipes are also washed and cleaned after 3-4 years.
- ✓ These are also not common these days.
- ✓ Generally, the contact beds are also intermittent in their operation.
- **EFFICIENCY:**
- ✓ Bacterial Removal – 50 to 75 %.
- ✓ Organic matter Removal – 60 to 80 %.
- ✓ Suspended matter Removal – 80 to 90 %.

- **ADVANTAGES:**

- ✓ Contact bed can be operated without exposing the sewage to view.
- ✓ Contact bed consumes relatively small amount of head.
- ✓ No nuisance of filter flies.
- ✓ Odour problems are also very less.

- **DISADVANTAGES:**

- ✓ For effective working of contact bed, primary treatment of sewage is necessary otherwise the contact bed will be easily clogged.
- ✓ The cost of the contact bed is relatively more.
- ✓ The operation of contact bed requires skilled supervision.
- ✓ The rate of treatment of sewage is very low.
- ✓ It requires long rest period.(about 8 hours)

- **USES:**

- ✓ The contact beds are the best treatment method for small isolated structures, where the quantity of sewage is very less and head availability is also less and further pumping is not required.

INTERMITTENT SAND FILTERS:

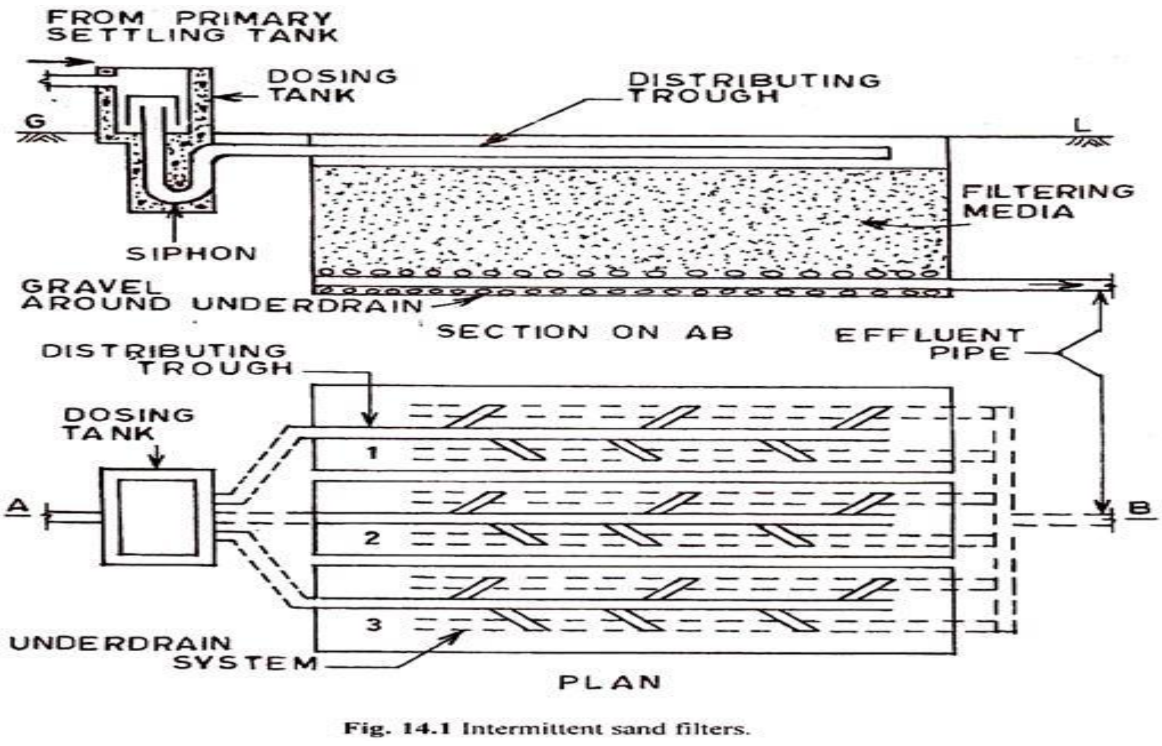


Fig. 14.1 Intermittent sand filters.

Figure No.10

- These are the early development of sewage treatment units.
- These are similar in Construction to the slow-sand filter of water treatment.
- These require larger area, due to which these are not commonly employed in modern sewage treatment works.
- The filter media is finer than that in the contact beds.
- There is no concrete lining around the filter media, as was there in contact beds.
- **CONSTRUCTION:**

- ✓ It consists of layers of sands with an effective size of 0.2 to 0.5 mm and of uniformity coefficient 2 to 5.
- ✓ The depth of the sand media is about 75 cm to 100 cm.
- ✓ The bottom of the tank is sloping gently towards the under drains.
- ✓ The under drains are placed at about 9 m apart in trenches below the bottom of the filter media.
- ✓ If the soil itself is sandy, there is no need of providing extra sand.
- ✓ But if the soil is of other variety, sands of the above specifications are laid in a depth of about 100-120 cm.
- ✓ To carry off the effluent the open joint drainage pipes are laid in the bottom of the sand bed in 90 to 120 cm depth.
- ✓ Their drainage pipes are surrounded with layers of coarse stone and gravel graded from coarse to fine, to keep and the sand out.
- ✓ In some cases when the soil itself-sandy, the percolating effluent may reach the ground water table, and no effluent may reach the drainage pipes.
- ✓ The sewage is applied evenly on the surface of the sand bed by influent waste water troughs.
- ✓ The distribution trough has side openings to distribute the sewage uniformly.
- ✓ To prevent the scouring and displacement of sand the distribution trough is kept on concrete apron or protective stone.
- ✓ The effluent from the intermittent sand filters is very clear and contains suspended solids less than 10 ppm which is well nitrified and stable.
- ✓ The effluent also has B.O.D. less than 5ppm and is free from odours.
- ✓ Therefore, the plant works without creating any nuisance at the site.
- ✓ If the quantity of sewage is more 3 to 4 such beds can be constructed in parallel.
- ✓ For cleaning these filters, the sand from the top is scraped from time to time and are refilled with fresh clean sand.

- **ADVANTAGES:**
- ✓ Smaller head is required.
- ✓ It does not require skilled supervision.
- ✓ There is no trouble of odour or insects.
- ✓ In some cases, no further treatment is needed except chlorination.
- ✓ The effluent obtained from this filter is of good quality with suspended solids level of less than 10 mg/l and BOD of less than 5 ppm.
- **DISADVANTAGES:**
- ✓ Very slow process.
- ✓ Requires larger area of land.
- ✓ Not suitable for very cold climates.
- ✓ Their rate of loading is very small.
- ✓ They cannot treat large quantity of sewage, therefore cannot be employed at big plants.
- **USES:**
- ✓ It is the best treatment for small isolated structures such as hotels, hospitals etc, where land and sand is easily available.
- ✓ These filters are also sometimes used to treat the effluent of coagulated sedimentation tanks or trickling filters.
- ✓ For such cases, the rate of filtration is kept as about 200000 to 250000 litres/hectare/hour.
- ✓ The effluent thus treated has an attractive appearance and it is free from any suspended matters.

TRICKLING FILTERS:

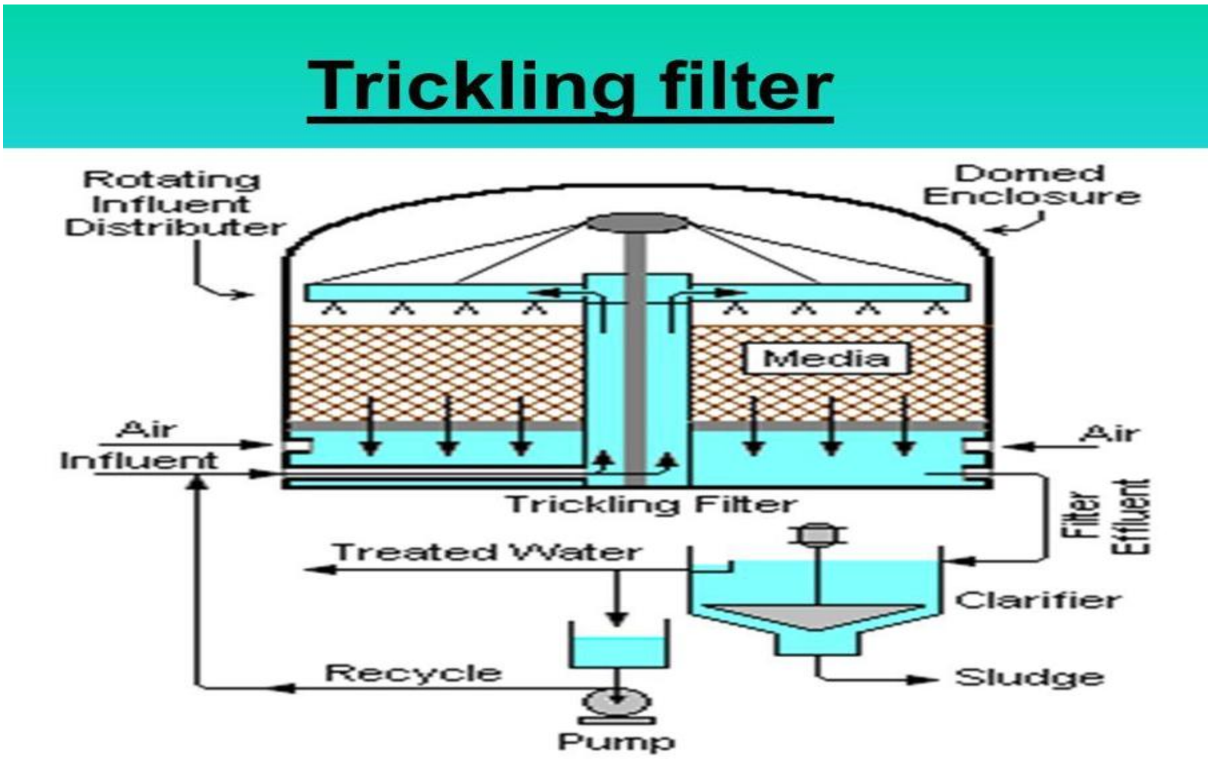


Figure No.11

- Trickling filters (TFs) are used to remove organic matter from wastewater.
- The TF is an aerobic treatment system that utilizes microorganisms attached to a medium to remove organic matter from wastewater.
- This type of system is common to a number of technologies such as rotating biological contactors and packed bed reactors (biotowers).
- These systems are known as attached-growth processes.
- Trickling filter is an attached growth process i.e. process in which microorganisms responsible for treatment are attached to an inert packing material.
- Packing material used in attached growth processes include rock, gravel, slag, sand, redwood, and a wide range of plastic and other synthetic materials.
- The wastewater in trickling filter is distributed over the top area of a vessel containing non-submerged packing material.
- Air circulation in the void space, by either natural draft or blowers, provides oxygen for the microorganisms growing as an attached biofilm.
- During operation, the organic material present in the wastewater is metabolized by the biomass attached to the medium.
- The biological slime grows in thickness as the organic matter abstracted from the flowing wastewater is synthesized into new cellular material.

- The thickness of the aerobic layer is limited by the depth of penetration of oxygen into the microbial layer.
- The micro-organisms near the medium face enter the endogenous phase as the substrate is metabolized before it can reach the micro-organisms near the medium face as a result of increased thickness of the slime layer 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 treated wastewater are collected by an underdrainage which also allows circulation of air through filter.
- The collected liquid is passed to a settling tank used for solid- liquid separation.
- **ADVANTAGES:**

✓ Can be operated at a range of organic and hydraulic loading rates.

✓ The mechanical wear and tear is small as it contains less mechanical equipment.

✓ Resistant to shock loadings.

✓ Efficient nitrification (ammonium oxidation)

✓ High effluent quality in terms of BOD and suspended solids removal; in combination with a primary and tertiary treatment also in terms of pathogens.

✓ The moisture content of sludge obtained from the trickling filters is as high as

99 %.

✓ Low power requirements.

✓ The working of trickling filters is simple and it does not require skilled supervision.

✓ The trickling filters may reduce the B.O.D and colloidal matter to the extent of about 75 % and 80 % respectively.

✓ The trickling filters are flexible in operation.

- **DISADVANTAGES:**

✓ The cost of construction of trickling filters is high.

✓ Requires large land area and regular operator attention.

✓ Vector and odour problems.

✓ Incidence of clogging is relatively high.

✓ The process requires primary treatment of sewage and hence, the raw sewage cannot be purified by this process.

- **USES:**

✓ The process of trickling filters is becoming popular at present and the trickling filters, especially of high rate type are adopted in the modern treatment plant of sewage.

TYPES OF FILTERS:

- Conventional or Ordinary or Standard rate or Low rate trickling filter.
- High rate trickling filter.

Efficiency of Low rate trickling filter, $\eta = \dfrac{100}{1 + 0.44\sqrt{U}}$

Where, U – Organic loading Kg/ m^3/day

Efficiency of high rate trickling filter, $\eta = \dfrac{100}{1 + 0.44\sqrt{Y/VF}}$

Where, Y – Total Org. loading in Kg/day.

V - Filter Volume in m^3

F – Recirculation Factor.

COMPARISON OF LOW RATE & HIGH RATE TRICKLING FILTER

Table 4.3. Comparison between Standard Rate and High Rate Trickling Filters

Sl. No.	Feature	Standard rate trickling filter	High rate trickling filter
1.	Cost of operation	It is more.	It is less for equal performance
2.	Depth	1.8m to 2.4m.	900mm to 1.8m.
3.	Dosing interval	It generally varies from 3 to 10 minutes, the sewage is usually not applied continuously but it is applied at intervals.	It is not more than 15 seconds and the sewage is to be applied continuously.
4.	Effluent	The effluent is highly nitrified and stabilized.	The effluent is nitrified up to nitrite stage only and hence, it is of inferior quality.
5.	Land requirement	It requires more area of land.	It requires less area of land.
6.	Method of operation	Continuous application, less flexible and requires less skilled supervision.	Continuous application, more flexible and requires more skilled supervision.
7.	Quality of secondary sludge produced.	It is black and highly oxidized with slight fine particles.	It is brown and not fully oxidized with fine particles.
8.	Rate of filter loading in the following units: (i) kg of B.O.D. per hectare- metre of filter media.	1000 to 2200	8000 to 14000
	(ii) kg of B.O.D. per day per 100 m3 of filter media.	15 to 30	Above 45
	(iii) Million litres per hectare of surface area per day.	25 to 40	100 to 300
9.	Recirculation system.	It is generally not included but it can be adopted, if the rate of loading is not exceeded.	It is always included. However, in some types, it may be used during periods of low flow only.
10.	Size of filter media.	30 mm to 80 mm.	30 mm to 60 mm.

PROBLEMS

1.The sewage flows from a primary settling tank to a standard rate trickling filter at a rate of 5 ML/day having 5 day BOD of 150 mg/l. Determine the depth and volume of filter adopting a surface loading of 2500 $l/m^2/day$ and an organic loading of 165 $gm/m^3/day$. Also determine the efficiency of filter unit using NRC formula.

Solution:

Total 5 day BOD/day = $5 \times 10^6 \times 150 \times 10^{-3} = 75 \times 10^4$ gm.

Volume of filter media required = Total BOD/Organic loading = $75 \times 10^4 / 165$

$= 4545.5\ m^3$

Surface area required = Total Flow/Hydraulic loading

$A = 5 \times 10^6 / 2500 = 2000\ m^2$

Depth of bed = Volume/surface Area = 4545.5/2000 = 2.273 m or 2.3 m.

Hence provide a filter depth of 2.3 m.

$A = \pi \times d^2/4$

$2000 = \pi \times d^2/4$

$d^2 = 2000 \times 4/\pi$

$d = 50.5$ m.

Hence provide a filter of 50 m diameter.

Actual surface area $= \pi \times 50^2/4 = 1963.5\ m^2$

Actual Volume $= 1963.5 \times 2.3 = 4516\ m^3$

Actual Org.loading,U = Total BOD/Volume of filter = $75 \times 10^4 / 4516$

$= 166.1\ gm/m^3/day$

$U = 166.1\ gm/m^3/day$ or $0.1661\ Kg/m^3/day$

Efficiency, $\eta = \dfrac{100}{1 + 0.44\sqrt{U}}$

$= \dfrac{100}{1 + 0.44\sqrt{0.1661}}$

$= 84.8$ %.

2. The sewage is flowing @ 4.5 ML/day from a primary clarifier to a standard rate trickling filter. The 5 day BOD of influent is 160 mg/l. Organic loading is 160 gm/m/day and surface loading 2000 l/m/day. Determine the volume, depth and efficiency of filter.

Solution:

Total 5 day BOD/day = $4.5 \times 10^6 \times 160 \times 10^{-3} = 72 \times 10^4$ gm.

Volume of filter media required = Total BOD/Organic loading = $72 \times 10^4 / 160$

$= 4500 \text{ m}^3$

Surface area required = Total Flow/Hydraulic loading

$$A = 4.5 \times 10^6 / 2000 = 2250 \text{ m}^2$$

Depth of bed = Volume/surface Area = 4500/2250 = 2 m.

Hence provide a filter depth of 2 m.

$A = \pi \times d^2/4$

$2000 = \pi \times d^2/4$

$d^2 = 2250 \times 4/\pi$

$d = 53.52$ m or 54 m.

Hence provide a filter of 54 m diameter.

Actual surface area $= \pi \times 54^2/4 = 2290.2 \text{ m}^2$

Actual Volume $= 2290.2 \times 2 = 4580.4 \text{ m}^3$

Actual Org.loading,U = Total BOD/Volume of filter = $72 \times 10^4 / 4580.4$

$= 157.19 \text{ gm/m}^3\text{/day}$ or $0.1567 \text{ Kg/ m}^3\text{/day}$

$$\text{Efficiency, } \eta = \frac{100}{1 + 0.44\sqrt{U}}$$

$$= \frac{100}{1 + 0.44\sqrt{0.157}}$$

$= 85.1$ %.

3.Determine the size of a high rate trickling filter for the following data:

Flow - 4.5 MLD

Recirculation Ratio (R/I)= 1.4

BOD of raw sewage = 250 mg/l.

BOD removed in primary clarifier = 25 %

Final effluent BOD desired = 50 mg/l.

Calculate also the size of the standard rate trickling filter to accomplish the above requirement.

Solution:

Total BOD present in raw sewage/day = 4.5 X 250 = 1125 X ($10^6/10^6$) = 1125 Kg.

BOD removed in the primary clarifier = 25 %

BOD entering/day in the filter units = 1125 X (75/100) = 843.75 Kg.

BOD concentration in the effluent = 50 mg/l.

BOD allowed to go into the effluent = 50 X 4.5 X ($10^6/10^6$) = 225 Kg.

BOD removed by the filter/day = 843.75 – 225 = 618.75 Kg.

Efficiency of filter = (BOD removed/Total BOD) X 100

= (618.75/843.75) X 100 = 73.3 %

Efficiency of high rate trickling filter, $\eta = \dfrac{100}{1 + 0.44\sqrt{Y/VF}}$

$$F = \frac{1 + R/I}{[1 + 0.1\,(R/I)]^2} = \frac{1 + 1.4}{(1 + 0.1 \times 1.4)^2} = 1.85$$

$$73.3 = \frac{100}{1 + 0.44\sqrt{Y/VF}}$$

V = 665.4 m^3.

Assume a depth of filter as 1.5 m.

Surface area required, A = 665.4/1.5 = 413.6 m^2.

$$A = \pi \times d^2/4$$

$$413.6 = \pi \times d^2/4$$

$$d^2 = 413.6 \times 4/\pi$$

$$d = 23.8 \text{ m.}$$

For an equivalent standard filter, F = 1.

$$73.3 = \frac{100}{1 + 0.44\sqrt{Y/VF}}$$

V = 1231 m^3.

Using depth of filter as 1.5 m, A = 1231/1.5 = 820.8 m^2.

$$A = \pi \times d^2/4$$

$$820.8 = \pi \times d^2/4$$

$$d^2 = 820.8 \times 4/\pi$$

$$d = 32.3 \text{ m.}$$

ACTIVATED SLUDGE PROCESS

- In secondary treatment, the ASP consists of aeration tanks of long detention period, in which activated sludge is mixed with sedimented sewage is agitated and aerated.
- The sludge coming from the secondary sedimentation tank is called activated sludge and contains more quantity of biologically active oxygen.
- In the sewage treatment there are two de-composition process takes place.
- ✓ Aerobic Decomposition Process
- ✓ Anaerobic Decomposition Process

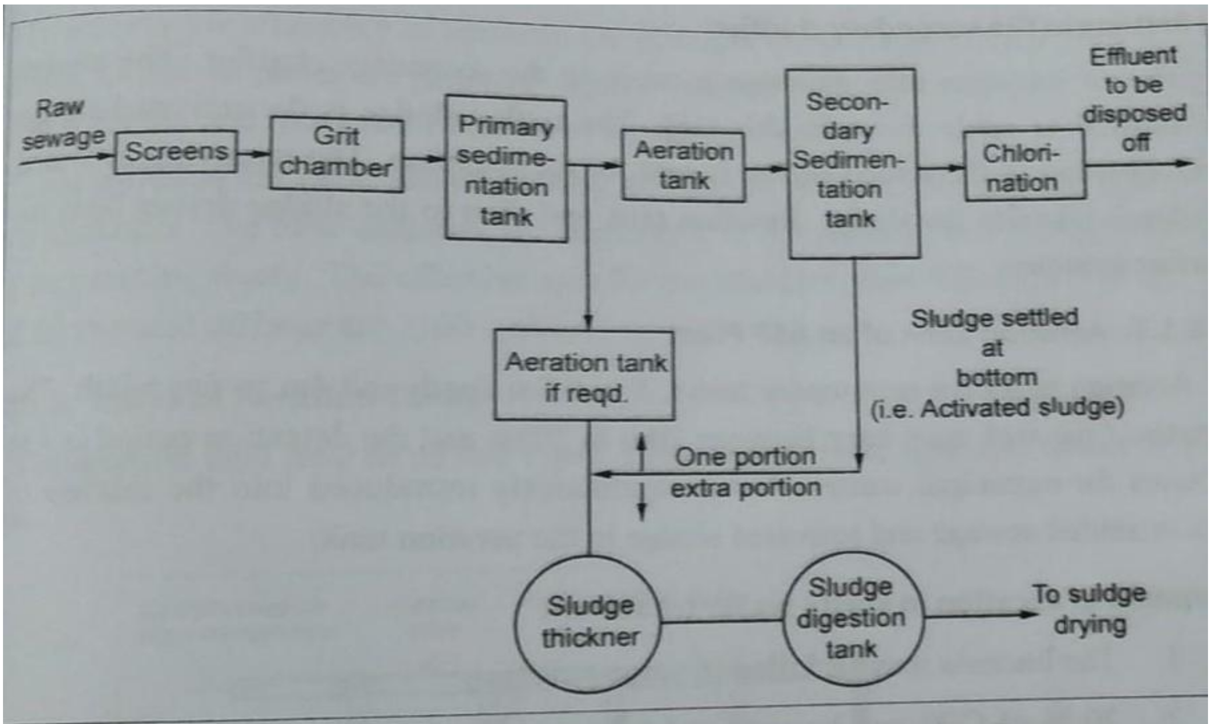


Fig. 4.12. Flow diagram of Activated Sludge Process

Figure No.12

- In secondary treatment process, only aerobic decomposition occurs and aerobic decomposition has the following advantages over anaerobic decomposition.
- ✓ Aerobic decomposition does not produce bad smells and gases.
- ✓ More active than anaerobic bacteria – the rate of doing work by aerobic bacteria is three times the work doing by anaerobic bacteria at 30°C.
- Activated sludge process is a process for treating sewage and waste water commonly referred as effluent using bacteria (to degrade the biodegradable organics) and air (Oxygen for respiration).
- Activated sludge refers to a mixture of microorganisms and suspended solids.
- The sewage effluent from the primary sedimentation tank is mixed with 25 % of its own volume of activated sludge.
- The activated sludge contains a larger concentration of highly active aerobic micro-organism.
- The mixture of sewage effluent and activated sludge enters an aeration tank, where micro-organism is mixed together with a large quantity of air, for a period of about 4 to 8 hours.
- Under this condition, the micro-organisms will oxidize the organic matter and the suspended and colloidal matter tends to coagulate and form a precipitate.
- This precipitate settles down in the secondary sedimentation tank instantly.

- The settled sludge called activated sludge is again recycled to the head of aeration tank and again mixed with raw sewage.
- Activated sludge is being produced continuously by this process and a portion of produced activated sludge is utilized in aeration tank.
- The excess of activated sludge is disposed of properly along with the sludge collected during primary treatment after digestion.
- **PROPERTIES OF ASP:**

✓ It contains fertilizing constituents.

✓ The colour of activated sludge indicates the degree of aeration.

✓ The colours of under-aerated, well-aerated and over-aerated sludges are light brown, golden brown and muddy brown respectively.

✓ The moisture content of the activated sludge is about 95 to 97 %.

- **PURPOSE OF ASP:**
- In a sewage (or industrial wastewater) treatment plant, the activated sludge process can be used for one or several of the following purposes:

✓ Oxidizing carbonaceous matter: biological matter.

✓ Oxidizing nitrogenous matter: mainly ammonium and nitrogen in biological materials.

✓ Removing phosphate.

✓ Driving off entrained gases carbon dioxide, ammonia, nitrogen, etc.

✓ Generating a biological floc that is easy to settle.

✓ Generating a liquor low in dissolved or suspended material.

- **OPERATIONS OF ASP:**

✓ Mixing of activated sludge

✓ Aeration

✓ Settling in the secondary clarifier.

✓ **MIXING OF ACTIVATED SLUDGE:**

- The activated sludge is mixed with raw or settled sewage properly.

✓ **AERATION:**

- The mixed liquor containing activated sludge and effluent is agitated or aerated in the aeration tank or aeration chamber.
- The removal of grit and larger solids by screening, grit chambers and primary sedimentation tank is necessary for aeration.

- The pre-removal of these settleable solids is helpful in preventing deposits on aeration devices and thereby not reducing their efficiencies.
- Moreover, the grit and larger solids are not pre-removed they may settle down in aeration tank and reduce the speed and efficiency of aeration process.

✓ **SETTLING IN THE SECONDARY CLARIFIER:**

- The mixed liquor after agitation is taken to the secondary clarifier.
- The sludge is allowed to settle down in this tank.
- The settled sludge is the activated sludge and a portion of the settled sludge is sent for recirculation.
- The removing activated sludge is taken to the sludge digestion tank and then to the sludge drying beds for further treatment.

➢ **ADVANTAGES:**

✓ The cost of installation is low.

✓ The effluent of good quality is obtained.

✓ The process requires small area of land and hence the design may be made compact.

✓ There is comparatively very small loss of head through the treatment plant.

✓ There is freedom from fly and odour nuisance due to high degree of treatment given to the sewage in this process.

➢ **DISADVANTAGES:**

✓ The cost of operating the process is relatively high.

✓ The process is sensitive to certain types of industrial wastes.

✓ The process requires skilled supervision for its efficient working.

➢ **FOOD TO MICRO-ORGANISM RATIO (F/M RATIO):**

$$\text{F/M RATIO} = \frac{\text{Daily BOD load given to aeration system (in gram)}}{\text{Total microbial mass in the aeration system (in gram)}}$$

➢ **SLUDGE VOLUME INDEX:**

✓ The sludge volume index is defined as the volume occupied by one gram of activated sludge after a settling period of 30 minutes.

✓ The term SVI is used to indicate the degree of concentration of sludge and it reflects the physical state of sludge.

UPFLOW ANAEROBIC SLUDGE BLANKET :

➢ Upflow anaerobic sludge blanket (UASB) technology, normally referred to as UASB reactor, is a form of anaerobic digester that is used for wastewater treatment.

- The UASB reactor is a methanogenic (methane-producing) digester that evolved from the anaerobic clarigester.
- UASB uses an anaerobic process whilst forming a blanket of granular sludge which suspends in the tank.
- Wastewater flows upwards through the blanket and is processed (degraded) by the anaerobic microorganisms.
- Biogas with a high concentration of methane is produced as a by-product, and this may be captured and used as an energy source, to generate electricity for export and to cover its own running power.

OXIDATION POND:

- Oxidation pond is a type of wastewater treatment which also refers as lagoons or water stabilization pond.
- It is a secondary treatment of wastewater coming from industries, residential areas etc.
- It makes the use of microorganisms like bacteria, algae and light energy (sunlight) to stabilize the wastewater.
- Oxidation pond is constructed 1-1.5m deep inside the soil and have inlet and outlet systems.
- Oxidation pond can define as the stabilization pond that stabilizes the domestic, trade, industrial wastes etc. by the microbial interaction, primarily bacteria and algae.
- It is the large, shallow ponds having 2-6 feet height of water body.
- Oxidation pond requires the presence of sunlight and oxygen for the secondary treatment of domestic and trade wastes.
- The secondary treatment of the organic and inorganic waste coming from raw sewage and industrial effluents is necessary.
- The direct disposal of the wastewater to the aquatic system can affect the life of water-bodies and the quality of water as well.

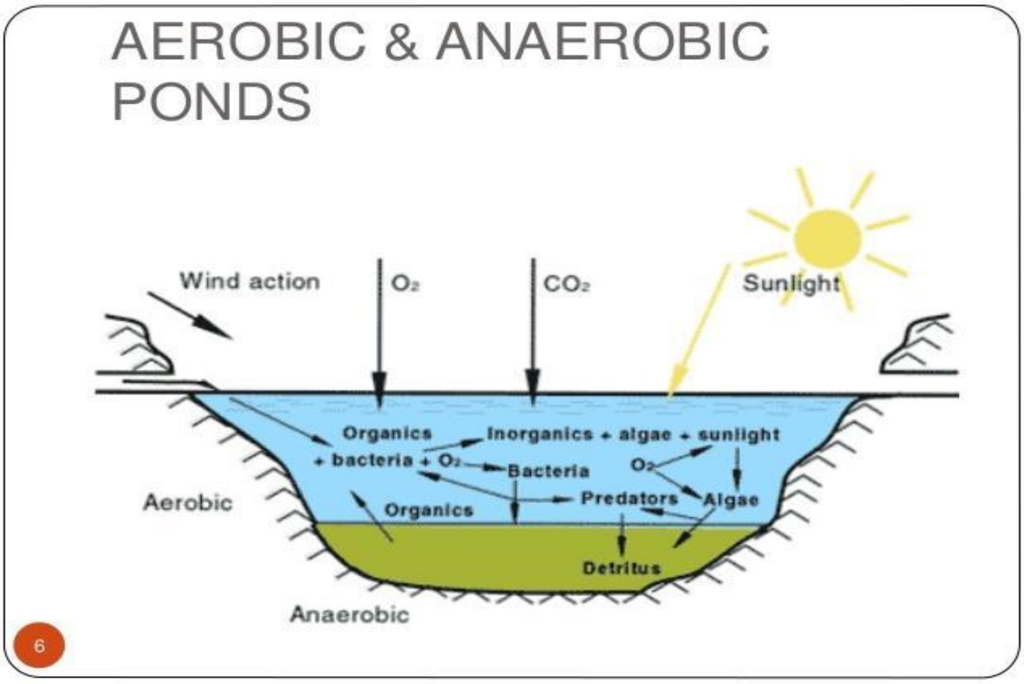


Figure No.13

- **ADVANTAGES:**

✓ The stabilization pond can reduce the biological oxygen demand up to 90% naturally.

✓ It is a simple method to operate, does not require sophisticated equipment.

✓ Oxidation pond is a practical and effective method for the wastewater treatment of domestic and trade wastes in the tropical areas.

✓ The operation of a stabilization pond does not require much labour-power.

✓ It is an economical method for the treatment of wastewater from small and isolated units.

- **DISADVANTAGES:**

✓ The construction of a stabilization pond requires more land area.

✓ The maintenance is quite intricate.

✓ Sometimes, it gives a foul smell and mosquito menace during the process if not appropriately maintained.

✓ There may get a chance of effluent seepage into the ground water, which can ultimately cause ground water pollution.

TERTIARY OR FINAL TREATMENT OF WASTE WATER:

- Tertiary treatment of waste water is final treatment process in which all the chemical and biological agents are completely removed from sewage before disposal into river.

- After the primary and secondary treatment of sewage, the sewage is a stabilized and a harmless one.
- However, the primary and secondary treatments remove only conventional constituents like TSS, BOD, COD, Organic carbon. Nitrogen, phosphorus etc.
- The non conventional compounds and other emerging compounds may still be present in sewage.
- Also sewage contains some roundworms and bacterial pathogens that are difficult to control.
- All these factors affect the public health and therefore, the sewage needs to undergo tertiary treatment before disposal or reuse for industrial, agricultural and municipal purposes.
- The tertiary treatment required will be always based on the type of water reuse and degree of quality of the reclaimed water.
- **OBJECTIVES OF TERTIARY TREATMENT PROCESS:**

✓ Removal of suspended solids

✓ Removal of dissolved solids like salts

✓ Removal of nitrate and phosphate

✓ Killing of microorganisms

- **REMOVAL OF SUSPENDED SOLIDS:**

Suspended solids are removed by two methods:

✓ Microstraining:

- In this method, sewage is placed in rotating drum filter of pore size 25-35 µm and then drum is rotated.
- During rotation, clear water comes out of drum and suspended solids remains inside drum.

✓ Chemical coagulation and filtration:

- In this method, precipitating agents such as alum is added in sewage.
- Fine suspended solids adsorbs to the surface of Al(OC)3 precipitate, finally precipitate with adsorbed solids are separated by filtration.

- **REMOVAL OF DISSOLVED SOLIDS LIKE SALTS:**

✓ Adsorption by activated carbon:

- Dissolved solids can be removed by filtering the water through filter containing activated carbon particle.

✓ Reverse osmosis:

- Reverse osmosis removes dissolved solids like NaCl and microbial cells.

- **REMOVAL OF NITRATE AND PHOSPHATE:**

- ✓ If sewage after treatment is to be discharge into river, nitrate and phosphate should be removed from sewage before disposal.
- ✓ It is because nitrate and phosphate causes eutrophication.
- ✓ These plant nutrients are removed by biological process.
- ✓ At first sewage is placed in a tank containing nitrifying bacteria.
- ✓ These bacteria converts ammonium salt and nitrite into nitrate.
- ✓ Then the sewage is placed into second tank containing denitrifying bacteria.
- ✓ These bacteria converts nitrate into Nitrogen gas that leaves the sewage.
- ✓ Phosphate is also removed by bacteria by microbial assimilation process.

- **KILLING OF MICRO-ORGANISMS:**

- ✓ Finally microorganisms in sewage are killed by disinfection like chlorination.

CHLORINATION OF SEWAGE:

- The process of killing the pathogenic bacteria present in the waste water is called disinfection of sewage.
- Chlorination is the process of treating the sewage with chlorine in order to disinfect the pathogens, either before or after the treatment.
- Chlorine is added to the sewage for the following purposes,

- ✓ To remove the odours.
- ✓ To break down the sulphur compounds.
- ✓ To kill the bacteria cells.
- ✓ To prevent the flies in trickling filters.
- ✓ To remove the grease.

- When chlorine is added to the treated sewage as a final step in the treatment is called post-chlorination.
- The post chlorination is carried out for the sewage having low bacterial count and will reduce the bacteria and BOD of the treated sewage.
- When chlorine is added to the raw or partially treated sewage in order to control the bacterial growth is called pre-chlorination.
- Pre chlorination is used to control the odour of sewage before it enters to the sedimentation tank, prevent the flies in trickling filter and helps to remove the grease in skimming units.

- ➢ Chlorine may be added to the sewage at the beginning and end of the treatment process is called split chlorination.

ADVANCES IN SEWAGE TREATMENT

- ➢ Advanced treatment of waste water is defined as the additional treatment needed to remove the suspended, colloidal and dissolved constituents remaining after conventional secondary treatment.
- ➢ **NEED FOR ADVANCED WASTEWATER TREATMENT:**

- ✓ To remove the organic matter and TSS beyond what can be removed by secondary treatment.
- ✓ To remove nutrients, organic and inorganic constituents for re-use purposes.

TECHNOLOGIES USED FOR ADVANCED TREATMENT:

- ➢ Depth Filtration
- ➢ Adsorption
- ➢ Gas-stripping
- ➢ Ion-exchange
- ➢ Advanced oxidation process
- ➢ Distillation
- ➢ **DEPTH FILTRATION:**

- ✓ Depth filtration is an advanced wastewater treatment method, which involves the removal of particulate material suspended in sewage and also used to remove chemically precipitated phosphorous.
- ✓ The various techniques available in depth filtration are,

- Deep bed down flow filters
- Deep bed up flow continuous backflow filters.
- Pulsed bed filters
- Travelling bridge filters
- Synthetic medium filters

- ➢ **ADSORPTION:**

- ✓ Adsorption is defined as the process of accumulating substances that are in solution on a suitable interface.
- ✓ Adsorption is a mass transfer operation, in that a constituent in the liquid phase is transferred into solid phase.

- ✓ The adsorbate is the substance that is being removed from the liquid phase at the interface.
- ✓ The adsorbent is the solid, liquid or gas phase onto which adsorbate accumulates.
- ✓ Activated carbon process is an example for the adsorption of advanced sewage treatment method.

➢ **GAS-STRIPPING:**

- ✓ Gas stripping involves the mass transfer of a gas from the liquid phase to the gas phase.
- ✓ The transfer is completed by contacting the liquid containing the gas that is to be stripped with a gas that does not containing any gas initially.

➢ **ION-EXCHANGE:**

- ✓ Ion-exchange is a unit process in which ions of a given species are displaced from an insoluble exchange material by ions of a different species in solution.
- ✓ The most widely used method of ion-exchange is domestic water softening method.
- ✓ Ion exchange method has been used in waste water application for the removal of nitrogen, heavy metals and TSS.
- ✓ Ion exchange process can be operated in a batch or continuous mode.
- ✓ In a batch process, the resin is stirred with water to be treated in a reactor, until the reaction is complete.
- ✓ The used resin is removed by settling and simultaneously regenerated and reused.
- ✓ In a continuous process, the exchange material is placed in a bed or a packed column and the water to be treated is passed through it.

➢ **ADVANCED OXIDATION PROCESS:**

- ✓ Advanced oxidation processes are used to oxidize the complex organic constituents found in wastewater, that are difficult to de-grade biologically into simpler end products.
- ✓ When chemical oxidation is used, it may not be necessary to oxidize completely a given compound or group of compounds.

➢ **DISTILLATION:**

- ✓ Distillation is a unit operation in which the components of a liquid solution are separated by vaporization and condensation.
- ✓ Along with reverse osmosis, distillation can be used to control the formation of salts in critical reuse applications.

- ✓ The method of distillation for wastewater reclamation is a recent development, the current development must be consulted for the results of efficient operations and more recent applications.

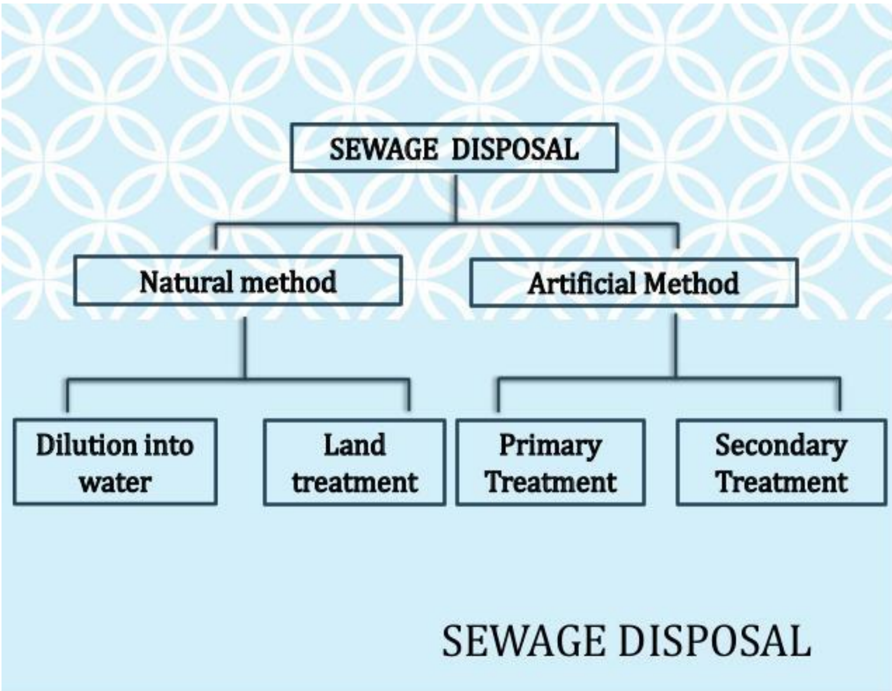
SEWAGE DISPOSAL

- Sewage disposal is defined as the process of disposing the sewage, without affecting the environment or the place of disposal.
- Scientific method of disposal of sewage will protect the health of the community and the humans from bad smell.
- Mosquitoes, gases and other foul conditions.
- Disposal of sewage by proper method will also reduce the danger of spread of disease like typhoid, dysentery, diarrhea etc.
- It also prevents the destruction of fish or other aquatic life by letting the untreated or partially treated sewage discharge into the water bodies.

OBJECTIVES OF SEWAGE DISPOSAL

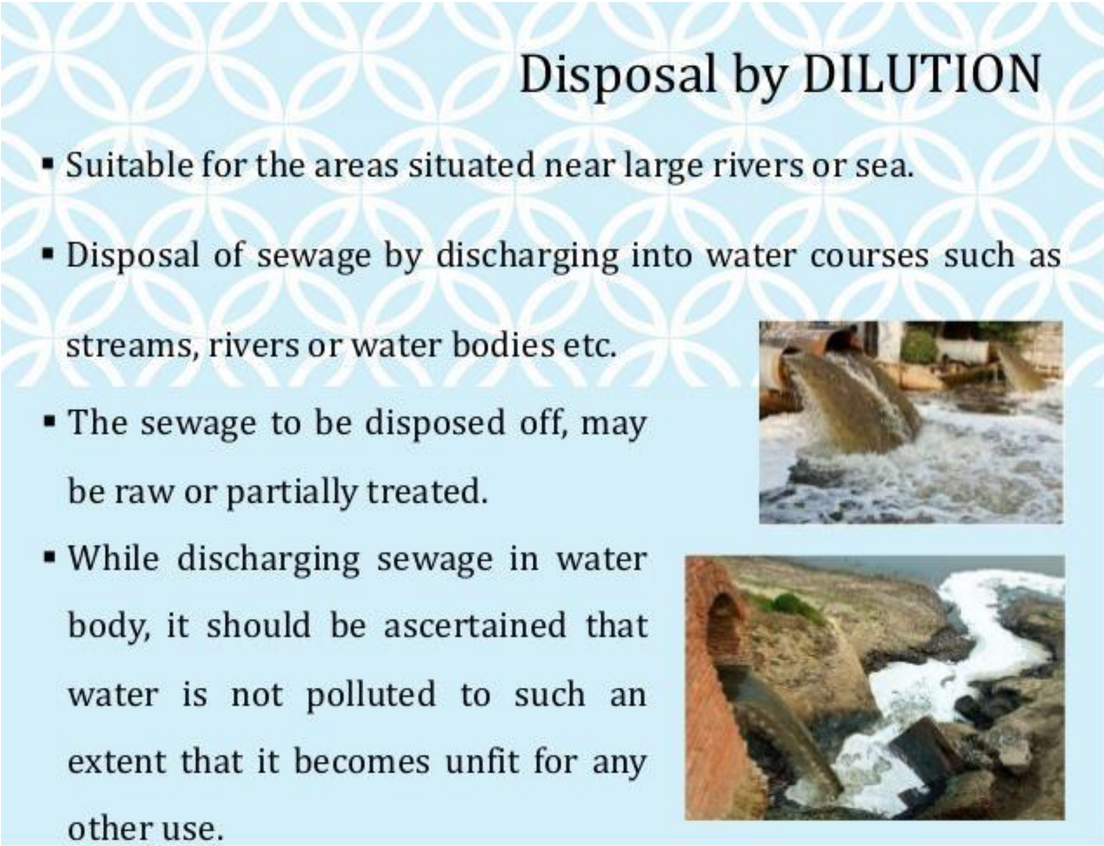
- To eliminate or reduce danger to the public health by possible contamination of water supplies.
- To render the sewage inoffensive without causing odour or nuisance.
- To prevent the life of fish or other aquatic life by allowing raw sewage into bodies of water as such.
- The destruction of fish & other Aquatic life can be prevented by the sewage disposal methods.
- With proper sewage disposal the environment or the areas does not become polluted.
- Sanitary conditions are maintained in the area.

METHODS OF SEWAGE DISPOSAL



- In natural method of disposal, the sewage or wastewater is disposed into either receiving water bodies and disposal of sewage into land for irrigation.
- In artificial method of sewage disposal, before discharging the effluent into natural water bodies, the sewage is treated for primary or secondary treatment.

NATURAL METHOD OF DISPOSAL BY DILUTION



- The sewage, in due course of time, gets purified automatically by the self purification capacity of water.
- The quantity of pure natural water required for the process of self purification should be about 6-14 times the volume of the sewage disposed.
- Diluting water must be rich in oxygen content for Dilution.
- Diluting waters are not become a source of water supply for at least some distance from the point of disposal.

CONDITIONS FOR DILUTION:

- The city should be situated near the river, sea or lake.
- The sewage is comparatively fresh (4 to 5 hours old).
- The sewage should be free from all floating and settleable solids.
- The diluting water should not become a source of water supply.
- The area of point of disposal should not provide facilities for settling of solids and formation of sludge deposits.
- Diluting water should have high oxygen content.
- Completing mixing of the sewage with diluting water should be possible.
- The diluting waters should not be used for navigational purposes.
- **DILUTION FACTOR:**

- ✓ The ratio of the quantity of the diluting water to that of the quantity of sewage is called Dilution Factor.
- ✓ If the dilution factor is less than 8, the sewage has to be completely purified under the following circumstances.

- The diluting water has more than 20 ppm of D.O in 5 days.
- The river is being used as a source of water supply on the downstream side.

- The effluent has to be used disposed of into tidal waters which may be in the form of river or sea.

Standards of Dilution Based on Royal commission Report

Dilution Factor	Standards of purification required
Above 500	No treatment is required .Raw sewage can be directly discharged into the volume of dilution water
Between 300 to 500	Primary treatment such as plain sedimentation should be given to the sewage
Between 150 to 300	Treatments such a sedimentation, screening and essentially chemical precipitation are required
Less than 150	Complete thorough treatment should be given to sewage

PRELIMINARY INVESTIGATIONS:

- When the method of disposal of dilution is to be adopted, a study of the effluent to be discharged and nature of the receiving body of water should be made.
- ✓ Analysis of diluting water with special reference to the available D.O.
- ✓ Effect of sewage disposal on water used for aquatic life.
- ✓ Hydrographic survey to determine the intensity and direction of winds, currents and tides.
- ✓ Minimum quantity of diluting water available at all time of the year.
- ✓ The degree of treatment given to sewage etc.

TYPES OF NATURAL WATERS:

- Creeks
- Estuaries
- Ground water
- Lakes
- Ocean or sea
- Perennial rivers and streams

- **CREEKS:**

- ✓ A creek is in the form of an inlet on sea coast and it may not have dry weather flow during some period of the year.

- **ESTUARIES:**

- ✓ The wide lower tidal part of a river is known as estuary.
- ✓ The dilution of sewage in estuaries is affected by ocean water in addition to the river water.
- ✓ Hence the process of dilution of sewage in estuaries is generally satisfactory.

- **GROUND WATER:**

- ✓ The sewage when applied on land ultimately filters out through different layers of solids and it meets ground water at higher depths.
- ✓ If ground water flows through favourable strata of soil, the dilution of water is satisfactory.

- **LAKES:**

- ✓ A lake is an enclosed water space and it may be used for the purpose of dilution of sewage.
- ✓ In some areas, the larger lakes are used for both water supplies and disposal of sewage.
- ✓ In such cases, the location of sewage disposal point should be carefully located, so as not to affect the water supply intake.
- ✓ The various characteristics of lake like its size, shape, nature of the surrounding area, volume of fresh water flowing in it etc. should be carefully decided before deciding its self-purifying capacity.

- **OCEAN OR SEA:**

- ✓ The ocean or sea has water in abundance and hence its capacity to dilute sewage is practically unlimited.
- ✓ The sewage of any quality can be diluted into sea.
- ✓ It is observed that the sewage reacts with sea water and forms precipitates giving milky colour to the sea water and this is known as sludge banks.
- ✓ These sludge banks are undesirable as they produce hydrogen sulphide gas by reacting with sulphate resulting in bad odour.
- ✓ The dissolved oxygen in sea water is 20 % less as compared to the stream water or fresh water and also its re-aeration is slower.
- ✓ However, these deficiencies are removed by large volumes or sea water.

Following points should be noted while discharging sewage into the sea.

- ✓ There should be sufficient depth of water near the point of swage discharge into the sea.
- ✓ The sea outfall for sewage should be carried sufficiently deep into the sea to a distance of about 1.5 Km, so as not to cause any nuisance to the baths or recreation centres on the sea shore.
- ✓ The sea outfall for sewage should be placed on firm rocky foundations.
- ✓ The sewage should be discharged below low water level at the time of lowest tides.

➢ **PERENNIAL RIVERS AND STREAMS:**

- ✓ The perennial rivers and streams flow throughout the year, with maximum and minimum limits.
- ✓ The minimum limit generally occurs in summer.
- ✓ The dilution in summer becomes difficult due to the fact that in summer, the high temperature of water results in low solubility of oxygen.
- ✓ The sewage under such circumstances should be properly treated before allowing dilution with perennial rivers and streams.

SELF PURIFICATION OF NATURAL WATERS:

- ➢ When sewage is discharged into natural waters. Its organic matter gets oxidized by the dissolved oxygen content in water, and the receiving water gets polluted due to the waste products, present in the sewage effluents.
- ➢ But this is not happening always due to the natural forces of purification.
- ➢ The oxidation of organic matter converts the organic matter to simple harmless substances. The deficiency of dissolved oxygen is filled by the absorption of atmospheric oxygen.
- ➢ Thus, the oxygen of water is consumed by the sewage and at the same time, the oxygen is taken from the atmosphere.
- ➢ This procedure occurs in all-natural waters is called Self-purification of natural waters.
- ➢ The rate of self-purification will depend on various factors such as rate of re=aeration, type of organic matter present in the sewage, temperature, velocity of flow, presence of available oxygen in receiving waters, sedimentation etc.
- ➢ The self-purification of process of streams polluted by sewage can be grouped in the following four zones or divisions.
- ➢ Degradation Zone
- ➢ Active-Decomposition Zone
- ➢ Recovery Zone

- Clear water Zone

ZONES OF POLLUTION IN THE STREAM

1.Zone Of Degradation:

- Situated just below outfall sewer.
- Water is dark and turbid with sludge at the bottom.
- DO reduces upto 40% of saturation level.
- CO_2 content increases.
- Conditions are unfavorable for aquatic life.

2.ZONE OF ACTIVE DECOMPOSITION:

- Water in this zone becomes grayish and darker than previous zone.
- DO concentration falls to zero.
- Fish life is absent and bacteria is present.
- At the end of this zone DO rises to 40% of saturation.
- Aquatic life starts to reappear.

3.ZONE OF RECOVERY;

- Process of recovery starts.
- Stabilization of organic matter takes place into this zone.
- BOD falls and DO content increase above 40% value.
- NO2 , SO4 and CO3 are formed.
- Near the end of this zone entire aquatic life reappears.

4.Clear Water Zone:

- Water becomes clearer and attractive in appearance.
- DO rises to saturation level.
- Oxygen balance is attained.
- Recovery is complete.

SOURCES OF GETTING OXYGEN:

- ✓ The oxygen required for the self-purification is obtained by natural waters from the atmosphere in the following three ways.
- ➢ **RAIN:**
- ✓ The rain water is saturated with oxygen and when combines with natural water results in increase of oxygen content.

- **SURFACE LEVEL:**

✓ The surface in natural water is in contact with the atmosphere.

✓ This surface absorbs oxygen from the atmosphere and passes it to the body of natural waters.

- **WAVES:**

✓ Some portion of air absorbed by waves and eddies of natural waters.

✓ The diffusion and dispersion due to the movement of fish in water will also encourage absorption of oxygen from the atmosphere.

FACTORS AFFECTING SELF PURIFICATION:

- DILUTION
- CURRENT
- TEMPERATURE
- SUNLIGHT

RATE OF OXIDATION

- **DILUTION:**

✓ When sufficient dilution water is available in the receiving water body, where the waste water is discharged, the DO level in the receiving stream may not reach to zero or critical DO due to availability of sufficient DO initially in the river water before receiving discharge of wastewater.

- **CURRENT:**

✓ When strong water current is available, the discharged wastewater will be thoroughly mixed with stream water preventing deposition of solids.

✓ In small current, the solid matter from the wastewater will get deposited at the bed following decomposition and reduction in DO.

- **TEMPERATURE:**

✓ The quantity of DO available in stream water is more in cold temperature than in hot temperature.

✓ Also, as the activity of microorganisms is more at the higher temperature, hence, the self- purification will take less time at hot temperature than in winter.

- **SUNLIGHT:**

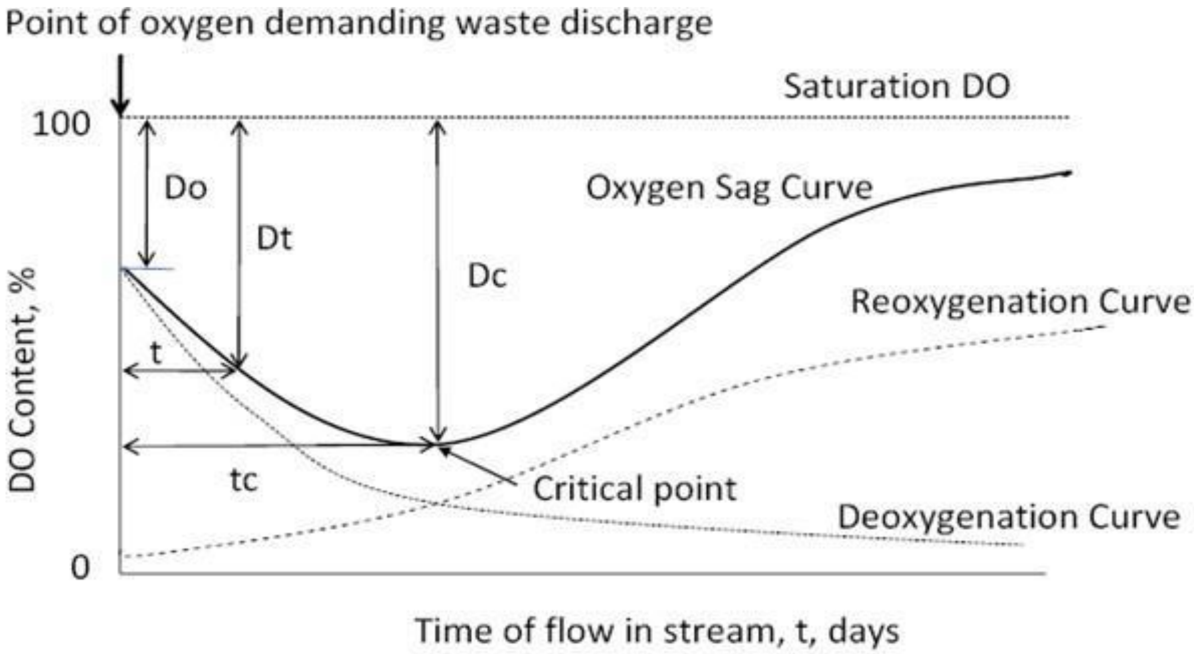
✓ Algae produces oxygen in presence of sunlight due to photosynthesis.

✓ Therefore, sunlight helps in purification of stream by adding oxygen through photosynthesis.

- **RATE OF OXIDATION:**

- ✓ Due to oxidation of organic matter discharged in the river DO depletion occurs.
- ✓ This rate is faster at higher temperature and low at lower temperature.
- ✓ The rate of oxidation of organic matter depends on the chemical composition of organic matter.

OXYGEN DEFICIENCY OF A POLLUTED RIVER



Deoxygenation, reoxygenation and oxygen sag curve

- ➢ **DE-OXYGENATION CURVE:**
- ✓ The curve which represents (or) showing the depletion of D.O with time at the given temperature.
- ➢ **RE-OXYGENATION CURVE:**
- ✓ In order to counter balance, the consumption of D.O due to the de – oxygenation, atmosphere supplies oxygen to the water and the process is called the re – oxygenation.
- ✓ When wastewater is discharged in to the stream, the DO level in the stream goes on depleting.
- ✓ This depletion of DO content is known as deoxygenation.
- ✓ The rate of deoxygenation depends upon the amount of organic matter remaining (Lt), to be oxidized at any time t, as well as temperature (T) at which reaction occurs.

- ✓ The variation of depletion of DO content of the stream with time is depicted by the deoxygenation curve in the absence of aeration.
- ✓ When the DO content of the stream is gradually consumed due to BOD load, atmosphere supplies oxygen continuously to the water, through the process of re-aeration or reoxygenation, i.e., along with deoxygenation, re-aeration is continuous process.
- ✓ The rate of reoxygenation depends upon:
  - ✓ Depth of water in the stream: more for shallow depth.
  - ✓ Velocity of flow in the stream: less for stagnant water.

    Oxygen deficit below saturation DO: since solubility rate depends on difference between saturation concentration and existing concentration of DO.

    Temperature of water: solubility is lower at higher temperature and also saturation concentration is less at higher temperature.
- ✓ When sewage is discharged into the river, the oxygen demand by the organic matter of sewage is satisfied.
- ✓ This is presented by the de-oxygenation curve.
- ✓ The ordinates below the de-oxygenation curve indicate the oxygen remaining in natural waters, after satisfying the oxygen demand.
- ✓ When de-oxygenation takes place, the deficiency or deficit of oxygen is filled up by the process of re-aeration. This is represented by the re-oxygenation curve.
- ✓ The rate of de-oxygenation becomes equal to the rate of re-oxygenation and the rate of re-aeration depends on the deficiency of oxygen developed by the sewage.
- ✓ The rate of re-oxygenation increases and the natural waters become saturated with D.O content as before.
- ✓ By using the above two curves, the quantity of net oxygen balance can be calculated at any stage of the self-purification process.
- ✓ This is represented by Oxygen sag curve or Oxygen deficit curve.
- ✓ When the rate of de-oxygenation is equal to the rate of re-oxygenation, the critical point of maximum deficit is reached.
- ✓ This point is shown on the oxygen sag curve and after this point is reached, the rate of re-oxygenation rapidly increases.
- ✓ The oxygen sag curve indicates the net oxygen balance and the ordinates above the curve represent the balance of oxygen contained in the natural waters.
- ✓ The saturated DO content of the natural water is about 9.1 mg/l at 20 C.

- ✓ But due to the presence of algae, organic matter or rise in temperature of water. The initial DO concentration is about 8 mg/l instead of 9.1 mg/l. Thus, initial DO deficit is (9.1 – 8) = 1.1 mg/l.
- ✓ The reoxygenation of natural water is a continuous process.
- ✓ It is Carried out by turbulence, diffusion, wind velocity, movement of fishes etc.
- ✓ The entire analysis of super – imposing rates of de-oxygenation and re-oxygenation have been carried out mathematically and given in the form of Streeter Phelps Equation.
- ✓ Oxygen Deficit, D = Saturation D.O – Actual D.O

➢ **FACTORS EFFECTING NATURAL FORCES:**

- ✓ TEMPERATURE
- ✓ TURBULENCE
- ✓ HYDROGRAPHY
- ✓ DISSOLVED OXYGEN
- ✓ RATE OF REAERATION

➢ **TEMPERATURE:**

- ✓ At higher temperature concentration of dissolved oxygen is low while the rate of biological and chemical activities is high.
- ✓ This is likely to lead to anaerobic condition, the pollution is heavy.

➢ **TURBULENCE:**

- ✓ The turbulence in the body of water helps in breaking the surface of the stream or lake and helps in rapid reaeration from the atmosphere.
- ✓ Too much of turbulence scours the bottom sediment and stops algae growth.

➢ **HYDROGRAPHY:**

- ✓ Hydrography affects the velocity and surface expanse of the river-stream.
- ✓ High velocity cause turbulence and rapid aeration, while surface expanse will also have the same effect.

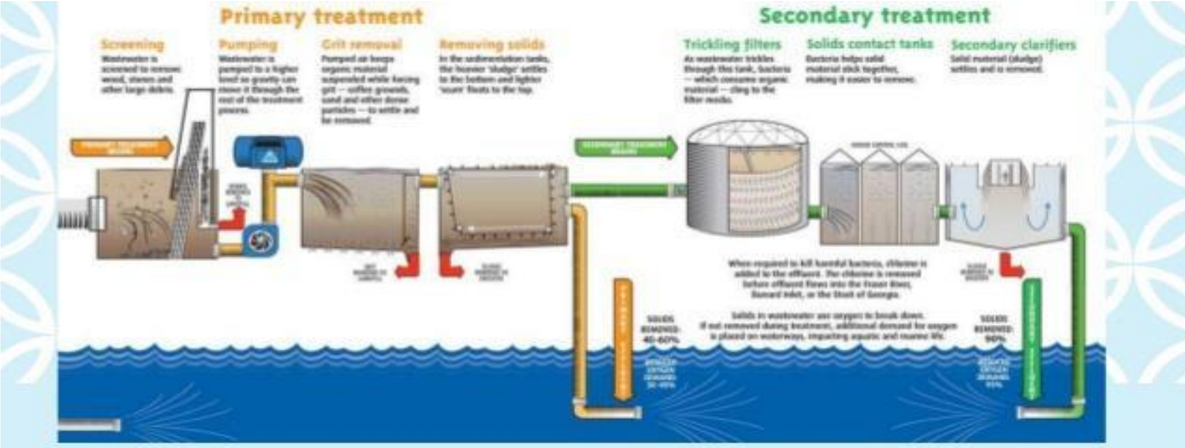
➢ **DISSOLVED OXYGEN:**

- ✓ The larger the amount of dissolved oxygen present in water the better and earlier is the self-purification process.

➢ **RATE OF REAERATION:**

- ✓ The rate at which dissolved oxygen is restored will considerably govern the self-purification process.

✓ The greater is this rate, the quicker will self-purification.



DISADVANTAGES

- Additional land is required.
- If land is made up of heavy, sticky and fine grained soils, its voids get chocked and may create nuisance.
- Sanitary reasons may not permit growing of crops on sewage farms.

- The process in which wastewater is evenly distributed over the ground surface which acts as a low rate filter.
- Suspended particles are strained out colloids and organic matter are absorbed by the soil particles.
- Nutrients are utilized by vegetation and more complex organic materials are decomposed to simpler inorganic compounds by soil bacteria.

QUALITY STANDARDS FOR WASTE WATER EFFLUENTS TO BE DISCHARGED ON LAND FOR IRRIGATION

- The bureau of Indian standards previously known as Indian standard institution, has vide his code no. 3307-1965 laid down the tolerance limits for various polluting characteristics of Waste water effluents for their discharge on land irrigation.

- In order to make them legally enforceable , GOI has notified the standards polluted effluents For discharge on land under environment rules 1986.

- These standards are based upon the quality of irrigation water required by the crops, thus limit the concentration of pollutants contained in sewage.

THESE PRESCRIBE BIS STANDARDS ARE SHOWN IN TABLE

SL. NO.	POLLUTANT OF WASTE WATER	RULES (1986)
1.	COLOUR AND ODOUR	REMOVE COLOUR AND ODOUR AS FAR AS PARTICABLE
2.	BOD	100mg/l
3.	SUSPENDED SOLIDS	200mg/l
4.	pH value	5.5 to 9
5.	OIL AND GREASE	10mg/l
6.	ARSENIC	0.2mg/l
7.	CYANIDE	0.2mg/l
8.	RADIOACTIVE MATERIALS alpha emitters	$10^{-8}\mu c/ml$

FACTS ABOUT LAND DISPOSAL METHOD FOR DISPOSAL OF SEWAGE

- For land disposal, large area of land, preferably with sandy soils.
- This method is generally found to be better choice in hot climatic areas.
- Land disposal saves the inland rivers from getting polluted by sewage

CONDITIONS FAVOURABLE FOR LAND TREATMENT

- The area of land treatment is composed of sandy, loamy or alluvial soils.
- Such soils are easily aerated and it is easy to maintain aerobic conditions in them.
- The depth of water table is more even in rainy season so that there are no chances of pollution of underground water sources by land treatment.
- The rainfall in the area is low as it will assist in maintaining good absorption capacity of soil.

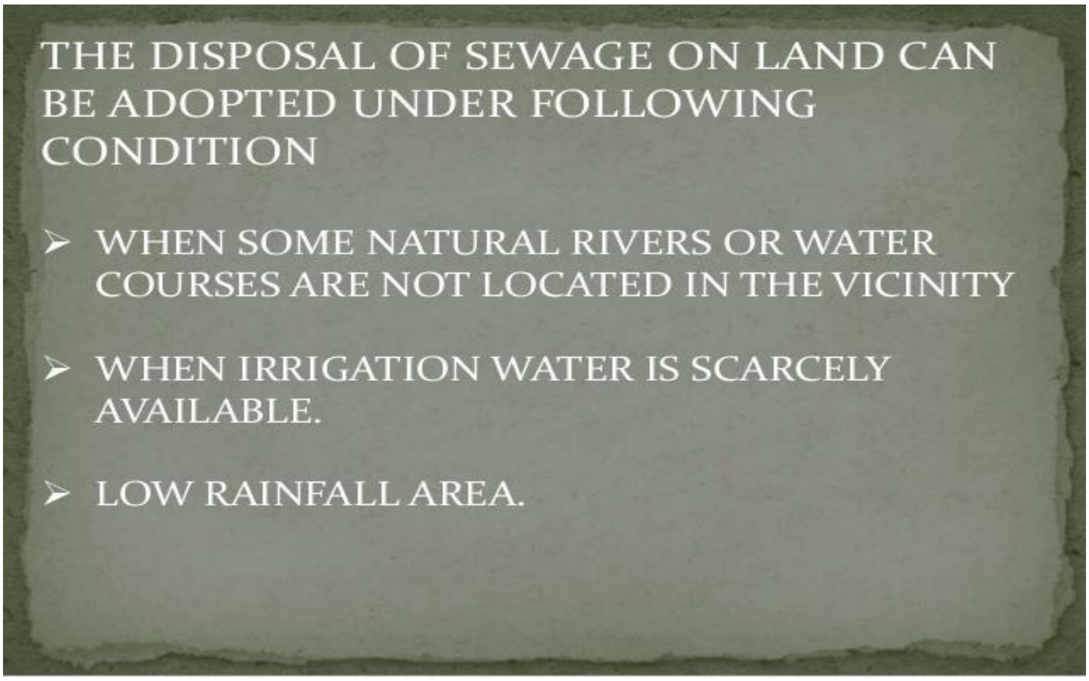
- ➢ There is absence of river or other natural water sources in the vicinity of disposal of sewage.
- ➢ There is demand for cash crops which can be easily grown on sewage farms.
- ➢ There is availability of large open areas in the surrounding locality for practicing broad irrigation by sewage.
- ➢ **ADVANTAGES OF LAND TREATMENT:**

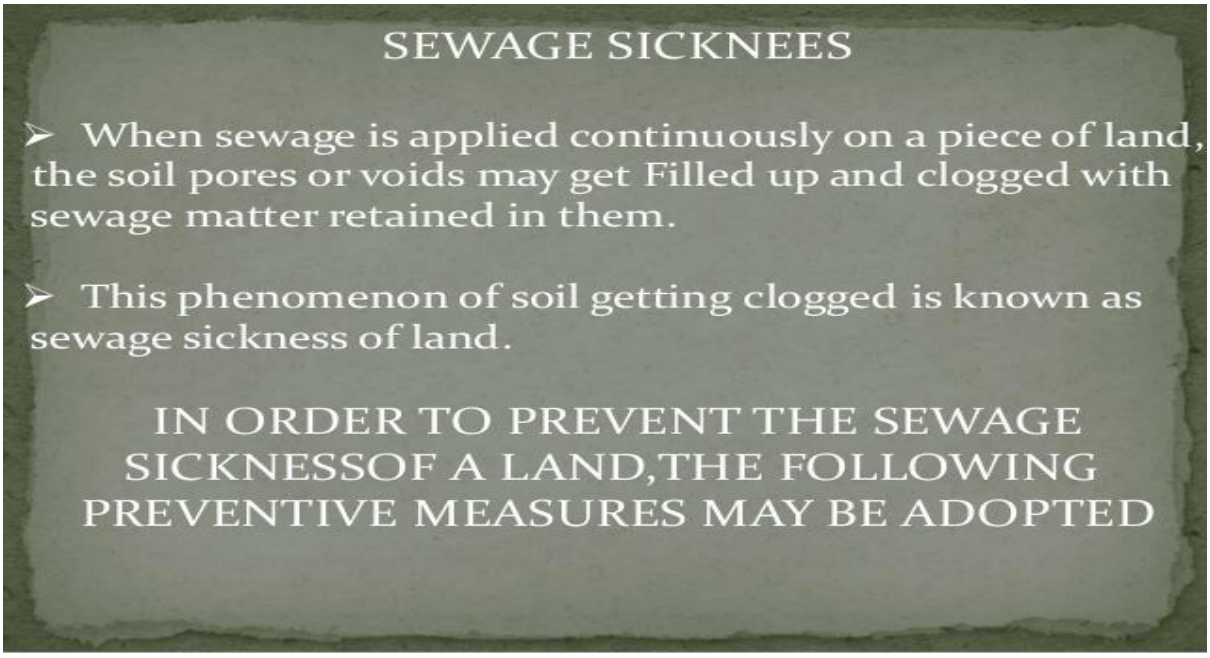
- ✓ Increased fertility of land results in profitable returns of crops.
- ✓ It is cheap where land is available in plenty.
- ✓ Application of sewage on land is the best method of supplying manure to the soil.
- ✓ Crops grown on land treated with sewage possess high calorific value and more vitamins.
- ✓ The method becomes very much useful at places where disposal of sewage by dilution is not possible.
- ✓ The method does not require costly equipment for its working.
- ✓ The method proves economical and safe where available irrigation water is scarce in quantity.
- ✓ The method to some extent charges the underground aquifers.
- ✓ Water of irrigation canal is saved when this method is practised.
- ✓ Adds manure to land
- ✓ Pollution of natural water courses is minimized.
- ✓ Does not require any installation of equipment involving high initial cost.
- ✓ Crops could be grown and hence a return value is always possible to obtain.
- ✓ Method especially suitable where large quantity of river water is not available at all times of the year.

- ➢ **DISADVANTAGES OF LAND TREATMENT:**

- ✓ If proper precautions are not taken, nuisance developed by sewage farming may lead to possible dangers to the health of men.
- ✓ It is therefore, necessary that the sewage farms should be operated under skilled technical supervision.
- ✓ Crops grown on sewage farms are generally not liked by ordinary public.
- ✓ The method is not applicable for all the seasons of year.
- ✓ In monsoon, some other arrangement of sewage disposal has to be found out.
- ✓ The method requires large area of land which may not be available in some cases.

- ✓ Types of crops grown on sewage treated land are limited in number.
- ✓ Difficult to get land during rainy and harvest seasons.
- ✓ Additional land is required for reserve.
- ✓ Sanitary reasons may not permit growing of crops on sewage farms.
- ✓ More land area is required is sewage volume is greater since land capacity is limited.
- ✓ If all precautions are not taken, sewage farming results in sewage sickness to land and health to life.





BROAD IRRIGATION:

- ✓ In this method, sewage is allowed to flow over cultivated lands, from which a part of the sewage evaporates, some percolates and the rest escape into surface drainage channels.
- ✓ Sewage waters the land and adds to its fertilizing value, due to the presence of nitrogen, phosphorus, potash etc.
- ✓ These fertilizing elements of sewage are consumed by the roots of crops.
- ✓ Crops like cotton, potatoes, sugarcane, grass etc, can be profitably grown. This is also called sewage farming.

SEWAGE FARMING:

The process in which sewage is used for growing crops is known as sewage farming.

- ✓ The fertilizing elements of sewage i. e nitrates, sulphates, & phosphates are used by the roots of crops.
- ✓ The nutrients of sewage make the fields fertile.
- ✓ It is a profitable business & a good income can be generated by sewage farming.

SEWAGE SICKNESS:

- ✓ If sewage is applied continuously on a piece of land, pores or voids of soil are filled up or clogged.
- ✓ Free circulation of air is thereby prevented and anaerobic conditions develop.
- ✓ At this stage, the land is unable to take any further sewage load.
- ✓ Organic matter decomposes and foul-smelling gases are produced.
- ✓ The phenomena of soil are known as sewage sickness of land.

PREVENTIVE MEASURES:

In order to prevent sewage sickness of land, the following preventive measures may be adopted

ALTERNATIVE ARRANGEMENT:

- ✓ There should be ample provision of extra land so that land with sewage sickness can be given the desired rest.
- ✓ Alternatively, sewage should be disposed of by some other method when sewage farms are taking rest.

DEPTH OF SEWAGE:

- ✓ If sewage is applied in excess, the chances of sewage sickness are increased.
- ✓ The land is unable to receive the excess sewage in a satisfactory way and it ultimately clogs up.
- ✓ Depth of sewage on land should be carefully decided by keeping in view the climatic conditions, drainage facilities, nature of crops and characteristics of soil.

DRAINAGE OF SOIL:

- ✓ Subsoil drain pipes should be laid in sufficient number to collect the percolated effluent.

INTERMITTENT APPLICATION:

- ✓ Sewage should be applied on land at intervals.

- ✓ The period between successive applications depends on general working of sewage farm and the permeability of soil.
- ✓ Depending on the nature of the soil, this period between successive applications varies from few hours to few weeks.

PRETREATMENT OF SEWAGE:

- ✓ sewage should be given some pre-treatment before it is applied on land.

ROTATION OF CROPS:

- ✓ It is desirable to grow different types of crops on a piece of land instead of one single crop.
- ✓ Rotation of crops minimizes the chances of sewage sickness.

TREATMENT TO LAND:

- ✓ The land affected by sewage sickness should be properly treated before it is put up in use again.
- ✓ Clogged surfaces should be broken by suitable equipment.

PREVENTION OF SEWAGE SICKNESS:

Primary treatment like screening & sedimentation should be given to sewage before its application to land so that suspended solids are removed & the pores of soil will not be clogged.

The sewage should be applied intermittently on land i.e by giving rest to the land for some time.

The land should be ploughed during non-supply period of sewage so that soil gets aerated.

Keeping some portion of land reserved in order to use the same in resting period.

Enough area will be required for this purpose.

By planting different crops on the same land by rotation system of crops.

The soil will be aerated & will utilize the fertilizing elements of sewage.

By providing sufficient under drainage system to collect the excessive sewage quantity.

By frequent ploughing & rotation of soil.

By not applying the sewage in excess quantity.

SOIL DISPERSION SYSTEM

A mound system for wastewater treatment is a soil absorption system placed above the natural surface of the ground.

In pressure-dosed mounds, primary treated effluent is dispersed into carefully chosen fill of permeable, well-drained sands which contain a high volume of free air within the pore space.

A proprietary dispersal system is available that treats effluent from a septic tank, releasing much cleaner water into the soil than standard dispersal systems.

CHARACTERISTICS OF SLUDGE

The sludge has an objectionable odour and it may pollute the environment.

It is bulky and contains large amount of water.

Its specific gravity may be taken as very nearly equal to that of water.

In 100 parts of sludge, about 98 % of water and remaining 2 % only the solid matter present in the sludge.

In the moisture content of the sludge is reduced to about 70 % to 80 %, the sludge become viscous.

If the moisture content is reduced to 10 %, the sludge becomes dry and assumes powder form.

The water is so firmly held in the sludge and it requires special treatment for water removal from the sludge.

SLUDGE TREATMENT

- Before disposing the sludge, it should undergo various unit processes are:
- ✓ Sludge Thickening
- ✓ Sludge Digestion
- ✓ Elutriation
- ✓ Sludge Dewatering

OBJECTIVES OF SLUDGE TREATMENT:

- The sludge from primary sedimentation tank and sludge from secondary sedimentation units contains 96 % to 99 % of moisture content in its volume.
- Before disposing the sludge, the moisture should be removed in order to reduce the volume of sludge disposal.
- To reduce the cost of transport for heavy volume of disposal.
- To minimize the land requirement.
- To save the additional fuel required for incineration method of sewage disposal.

SLUDGE DIGESTION

Sludge digestion is a biological process in which organic solids are decomposed into stable substances.

Digestion reduces the total mass of solids, destroys pathogens, and makes it easier to dewater or dry the sludge.

Digested sludge is inoffensive, having the appearance and characteristics of a rich potting soil.

Sludge, the by-product of biological wastewater treatment is also considered as biomass.

Energy recovery from sludge is possible through sludge incineration (biomass-to-energy) or by means of sludge digestion (biomass-to-biogas).

The methane generation is a key advantage of the anaerobic process.

The methane can be used to generate heat and electric power in cogeneration units while reducing the carbon footprint and greenhouse emissions of the wastewater treatment plant.

After sludge digestion, the digestate can be stabilized for landfill or used as fertilizer, depending on its composition and local legislation.

An alternative is to further mechanically dewater the sludge prior to thermal drying and incineration.

Most large sewage treatment plants use a two-stage digestion system in which organics are metabolized by bacteria anaerobically (in the absence of oxygen).

In the first stage, the sludge, thickened to a dry solids (DS) content of about 5 percent, is heated and mixed in a closed tank for several days.

Acid-forming bacteria hydrolyze large molecules such as proteins and lipids, breaking them into smaller water-soluble molecules, and then ferment those smaller molecules into various fatty acids.

The sludge then flows into a second tank, where the dissolved matter is converted by other bacteria into biogas, a mixture of carbon dioxide and methane.

Methane is combustible and is used as a fuel to heat the first digestion tank as well as to generate electricity for the plant.

Anaerobic digestion is very sensitive to temperature, acidity, and other factors.

It requires careful monitoring and control.

In some cases, the sludge is inoculated with extra hydrolytic enzymes at the beginning of the first digestion stage in order to supplement the action of the bacteria.

It has been found that this enzymatic treatment can destroy more unwanted pathogens in the sludge and also can result in the generation of more biogas in the second stage of digestion.

Another enhancement of the traditional two-stage anaerobic digestion process is thermal hydrolysis, or the breaking down of the large molecules by heat.

This is done in a separate step before digestion.

In a typical case, the process begins with a sludge that has been dewatered to a DS content of some 15 percent.

The sludge is mixed with steam in a pulper, and this hot homogenized mixture is fed to a reactor, where it is held under pressure at approximately 165 °C (about 330 °F) for about 30 minutes.

At that point, with the hydrolytic reactions complete, some of the steam is bled off (to be fed to the pulper), and the sludge, still under some pressure, is released suddenly into a “flash tank,” where the sudded drop in pressure bursts the cell walls of much of the solid matter.

The hydrolyzed sludge is cooled, diluted slightly with water, and then sent directly to the second stage of anaerobic digestion.

Sludge digestion may also take place aerobically—that is, in the presence of oxygen.

The sludge is vigorously aerated in an open tank for about 20 days.

Methane gas is not formed in this process.

Although aerobic systems are easier to operate than anaerobic systems, they usually cost more to operate because of the power needed for aeration.

Aerobic digestion is often combined with small extended aeration or contact stabilization systems.

Aerobic and conventional anaerobic digestion convert about half of the organic sludge solids to liquids and gases.

Thermal hydrolysis followed by anaerobic digestion can convert some 60 to 70 percent of the solid matter to liquids and gases.

Not only is the volume of solids produced smaller than in conventional digestion, but the greater production of biogas can make some wastewater treatment plants self-sufficient in energy.

ADVANTAGES:

- Reduction of sludge volume.
- Production of biogas available for heat and electric power generation.
- Reduction of greenhouse gases.

SLUDGE DIGESTER

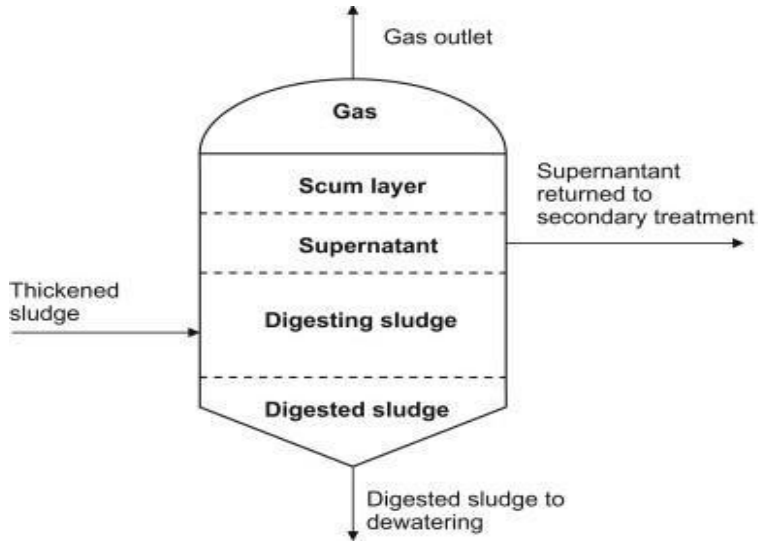


Figure No.1

The digesters are closed circular tanks 30 m in diameter and up to 12 m deep.

The digestion uses the naturally-occurring anaerobic (i.e. living without oxygen) microorganisms to break down organic materials into methane and carbon dioxide.

The sludge is heated to 37 degrees C in the primary digester to improve the rate of digestion.

The sludge then enters the secondary digester.

Anaerobic digestion is a biological process which breaks down a significant number of organic solids in the sludge and at the same time produces methane gas that is used as a boiler fuel for plant heating.

Consequently, the volume of final sludge is significantly reduced. So is the cost for sludge disposal.

The mixture of sludge and liquid in the secondary digester is hauled by truck to Edmonton's Clover Bar Sludge Lagoons for disposal.

The digesters are equipped with gas compressors and sludge recirculation pumps to provide adequate mixing capability for better digestion of sludge and production of methane gas.

SLUDGE CONDITIONING

Sludge conditioning is a process whereby sludge solids are treated with chemicals or various other means to prepare the sludge for dewatering processes, in other words, to improve dewatering characteristics of the sludge.

MECHANISMS TO CONDITION THE SLUDGE:

There are two mechanisms involved in sludge conditioning:

1. Neutralization of charge (double layer theory)
2. Bridging of individual particles into a floc structure (polymer bridge formation)

SLUDGE DEWATERING

Digested sewage sludge is usually dewatered before disposal.

Dewatered sludge still contains a significant amount of water—often as much as 70 percent—but, even with that moisture content, sludge no longer behaves as a liquid and can be handled as a solid material.

Sludge-drying beds provide the simplest method of dewatering.

A digested sludge slurry is spread on an open bed of sand and allowed to remain until dry.

Drying takes place by a combination of evaporation and gravity drainage through the sand.

A piping network built under the sand collects the water, which is pumped back to the head of the plant.

After about six weeks of drying, the sludge cake, as it is called, may have a solids content of about 40 percent.

It can then be removed from the sand with a pitchfork or a front-end loader.

In order to reduce drying time in wet or cold weather, a glass enclosure may be built over the sand beds.

Since a good deal of land area is needed for drying beds, this method of dewatering is commonly used in rural or suburban towns rather than in densely populated cities.

SLUDGE DISPOSAL

The final destination of treated sewage sludge usually is the land.

Dewatered sludge can be buried underground in a sanitary landfill.

It also may be spread on agricultural land in order to make use of its value as a soil conditioner and fertilizer.

The suspended solids that accumulate at the bottom of the clarifiers or settling tank is called sludge.

There are different types of sludge based on the sources are:

Chemically precipitated sludge

Trickling filter sludge

Digested sludge

Sludge from settling tank

Sludge from activated sludge process.

The sewage after treatment is separated into two different parts:

Effluent

Sludge

The effluent is clear sparkling liquid and sludge is a combination of suspended solids with different proportions of water.

The disposal of effluent is not a problem whereas the disposal of sludge should be carefully done in order to avoid the pollutions.

The effluent can be used for various purposes such as street washing, fish culture, growing crops, industrial supply, watering for public park etc.