Study Materials

Municipal Wastewater Engineering

18CV55

As per VTU syllabus

CBCS – OBE

2018 Scheme

Study Material Compiled by

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Vision Statement To be an Exemplary Centre, disseminating quality education and developing technically competent civil engineers with professional integrity for the betterment of society

Mission Statements

1. Impart technical proficiency through quality education.
2. Motivate entrepreneurship through enhanced industry -interaction and skill based training.
3. Inculcate human resource values through outreach activities.
4.

Program Educational Objectives (PEOs)

1. Lead a successful career by analyzing, designing and solving various problems in the field of Civil Engineering.
2. Execute projects through team building, communication and professionalism
3. Excel through higher education and research for endured learning.
4. Provide effective solution for sustainable environmental development.

Program Specific Outcomes (PSO)

1. Identify & address the challenges in transportation, sanitation, waste management, and urban flooding in metropolitan cities.
2. Provide solutions related to Civil Engineering built-environment through multidisciplinary approach.

DISCLAIMER

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B. E. CIVIL ENGINEERING
Choice Based Credit System (CBCS)and Outcome Based Education (OBE)
SEMESTER - V

MUNICIPAL WASTEWATER ENGINEERING

Course Code	**18CV55**	CIE Marks	40
Teaching Hours/Week (L:T:P)	(3:0:0)	SEE Marks	60
Credits	03	Exam Hours	03

Course Learning Objectives: This course will enable students to;
1. Understand the various water demands and population forecasting methods.
2. Understand and design different unit operations and unit process in involved in wastewater treatment process
3.Understand the concept and design of various physicochemical treatment units
4. Understand the concept and design of various biological treatment units
5. Understand the concept of various advance waste water and low cost treatment processes for rural areas.

Module-1

Introduction: Need for sanitation, methods of sewage disposal, types of sewerage systems, dry weather flow, wet weather flow, factors effecting dry and wet weather flow on design of sewerage system, estimation of storm water flow, time of concentration flow, numericals.
Sewer appurtenances: Manholes, catch basins, oil and grease traps. P, Q and S traps. Material of sewers, shape of sewers, laying and testing of sewers, ventilation of sewers basic principles of house drainage.

Module-2

Design of sewers: Hydraulic formula to determine velocity and discharge. Self cleansing and non scouring velocity. Design of hydraulic elements for circular sewers for full flow and half flow conditions.
Waste water characteristics: sampling, significance and techniques, physical, chemical and biological characteristics, flow diagram for municipal waste water
Treatment unit operations and process. Estimation of BOD. Reaction kinetics (zero order, 1st order and 2nd order).

Module-3

Treatment of municipal waste water: Screens: types, disposal. Grit chamber, oil and grease removal. primary and secondary settling tanks.
Disposal of effluents: Dilution, self-purification phenomenon, oxygen sag curve, zones of purification, sewage farming, sewage sickness, numerical problems on disposal of effluents. Streeter-Phelps equation.

Module-4

Biological Treatment Process: Suspended growth system - conventional activated sludge process and its modifications. Attached growth system – trickling filter, bio-towers and rotating biological contactors.
Principle of stabilization ponds, oxidation ditch, Sludge digesters(aerobic and anaerobic), Equalization., thickeners and drying beds.

Module-5

Advanced Wastewater Treatment: Need and technologies used. Nitrification and Denitrification Processes, Phosphorous removal. Advance oxidation processes (AOPs), Electro coagulation.
Rural sanitation: Low cost treatment process: Working principal and design of septic tanks for small community in rural and urban areas, two-pit latrines, eco-toilet and soak pits.

Course outcomes: After studying this course, the students will be able to:
1. Select the appropriate sewer appurtenances and materials in sewer network.
2. Design the sewers network and understand the self purification process in flowing water.
3.Deisgn the varies physic- chemical treatment units
4. Design the various biological treatment units
5. Design various AOPs and low cost treatment units.

Question paper pattern:
- The question paper will have ten full questions carrying equal marks.
- Each full question will be for 20 marks.
- There will be two full questions (with a maximum of four sub- questions) from each module.
- Each full question will have sub- question covering all the topics under a module.
- The students will have to answer five full questions, selecting one full question from each module.

Textbooks

1. Howard S. Peavy, Donald R. Rowe, George T, "Environmental Engineering" - Tata McGraw Hill, New York, Indian Edition, 2013
2. B C Punmia, "Environmental Engineering vol-II", Laxmi Publications 2nd, 2016
3. Karia G.L., and Christian R.A, "Wastewater Treatment Concepts and Design Approach", Prentice Hall of India Pvt. Ltd., New Delhi. 3rd Edition, 2017
4. S.K.Garg, "Environmental Engineering vol-II, Water supply Engineering", Khanna Publishers, – New Delhi, 28th edition and 2017

Preamble

Environmental engineering is concerned with the control of all those which exercise or may exercise deleterious effect on his development, health and sundial with the consideration of the physical, economic and social impact of the control measures applied. Environmental engineering deals with the application of engineering principles to the control, modification and adaption of the physical, chemical and biological factors of the environment in the interest of man's health, comfort and social wellbeing. In this textbook, some aspects of environmental engineering, such as ecology, water supply systems, waste water treatment and disposal, rural sanitation and air pollution are presented.

If proper arrangements for the collection, treatment and disposal of all the wastes produced from the town or city such as water from bathroom, kitchens, lavatory basins, house and street washings, from various industrial processes semi liquid wastes of human and animal excreta, dry refuse of house and street sweepings, broken furniture, crockery, wastes from Industries etc. are not made, they will go on accumulating and create

(i) Buildings and roads will be in danger due to accumulation of spent water in their foundation
(ii) Disease causing bacteria will bread up in the stagnate water
(iii) Drinking water will be polluted.

Total insanitary conditions will be developed in the town or city and it will become impossible for the public to live in the town or city. Therefore in the interest of the community of the town or city it is most essential to collect, treat and dispose of all the waste products of city in such a way that it may not cause any problem to the people residing in the town.

MODULE 1

OBJECTIVE OF PROVIDING SEWERAGE WORKS

The following are the aims and objects of sewage disposal.

1. Proper disposal of human excreta to a safe place, before its starts decomposition and may cause insanitary conditions in the locality
2. To take out all kinds of wastewater from the locality immediately after its use, so that mosquitos, files, bacteria etc. may not breed in it and cause nuisance.
3. Final disposal of sewage on land or in nearby watercourses after some treatment so that receiving land or water may not get polluted and unsafe for its further use.
4. As far as possible the fertilizing elements of sewage may be used in growing crops through farming and getting some income in addition to the disposal of sewage
5. In un-sewered areas, the treatment of sewage from individual houses, should be done by septic tank or other suitable means and the effluent should be disposed of.
6. If the sewage is disposed of on land, it should have such s degree of treatment that it may not affect the sub-soil in anyway.

DEFINITIONS OF TERMS-SULLAGE, SEWAGE, SEWER AND SEWERAGE

Sullage The liquid waste from latrines, Urinals stable etc. is known as sullage.

Sewage The term sewage is used to indicate the liquid waste from the community and it includes sullage, discharge from latrines, urinals, stable etc. industrial waste and storm water.

Sewer The underground conducts or drains through which is conveyed are known as the sewers.

Sewerage The entire science of collecting and carrying sewage by water carriage system through sewers is known as sewerage.

Garbage The term indicates dry refuse which includes decayed fruits, grass, leaves, paper pieces, sweepings, vegetables etc.

Refuse The term refuse is used to indicate all kinds of dry wastes of the community (i.e.,) street and house sweepings, garbage etc.

CLASSIFICATION OF SEWAGE

1. Storm Sewage Which includes surface runoff developed during and immediately after rainfall over the concerned area.

2. Sanitary Sewage Which includes the liquid wastes of domestic and industrial places. This sewage is extremely foul in nature and required to be disposed of very carefully.

SYSTEMS OF SEWERAGE METHODS

1. CONSERVANCY SYSTEM

In this system various types of refuse and storm water are collected, conveyed and disposed off separately by different methods in this system. This method is also called dry system and is in practice from very ancient times. This is method is adopting in small towns, villages and undeveloped portions of large city even it is out of date system.

In this method garbage or dry refuse is collected from the dustbins and conveyed by trucks or covered carts once or twice in a day. All the incombustible portions such as sand, dust, clay, ashes etc. are used for filling low lying areas and combustible portions such as dry leaves, waste paper, broken furniture etc.… are burnt. The decaying fruits, vegetables, grass are first dried and then disposed of by burning or in the manufacture of manure. Human excreta or night soil is collected in separate liquid and semi-liquid wastes by animal drawn carts, trucks or tractor trailors and buried in trenches. After 2-3 years the buried night soil is converted into an excellent manure which can be used for growing crops. In this system sullage and storm water are also carried separately in closed or open drains upto the point of disposal, where they are allowed to mix up with streams, rivers or sea.

ADVANTAGES AND DISADVANTAGES

ADVANTAGES

1. Initial cost is low, because storm water can pass through open drains.
2. The quantity of sewage reaching at the treatment plant before disposal is low.
3. The sewer section is small and no deposit of silting because storm water goes in open drains

DISADVANTAGES

1. Possibility of storm water may mix with sewers causing heavy load on treatment plant.
2. In crowded lanes it is difficult lay two sewers or construct drains roadside causing great inconvenience to the traffic.
3. More land is required for human excreta.
4. Liquid refuse may get on access in the sub soil and pollute the underground water.
5. Aesthetic appearance of city cannot be increased.
6. Decomposition of sewage causes insanitary conditions which are dangerous to the public health.
7. This system is completely depends upon the mercy of sweepers at every time and may possibility of spreading of diseases in the town if they are on strike.

2. WATER CARRIAGE SYSTEM

In this system, the excremental matters are mixed up in the large quantity of water and are taken out from the city through properly designed sewerage systems where they are disposed off after necessary treatment in a satisfactory manner. The sewage so formed in water carriage system consists of 99.9 percentage of water and 0.1 percentage of solid matters. All the solid matters remain in suspension in the sewage and do not change the specific gravity of water. So all the hydraulic formulae can be directly used in the design of sewerage system and treatment plants.
This system is universally used nowadays because of the following advantages.

MERITS AND DEMERITS OF WATER CARRIAGE SYSTEM

MERITS

1. It is hygienic method because all the excremental matters are collected and conveyed by water only.
2. There is no nuisance in the streets of town and risk of epidemics reduced because of underground sewerage system.
3. Less space is occupied in crowded lane as only one sewer is laid
4. Self-cleaning velocity can be obtained even at less gradients due to more quantity of sewage.
5. The land required for the disposal work is less as compared to conservancy system.
6. This system does not depend on manual labor at every time except when sewers get choked.
7. The usual water supply is sufficient and no additional water is required in water carriage system.
8. Sewer after proper treatment can be used for various purposes.

DEMERITS

The main disadvantage of this system is the wastage of water (99.9% of water).
1. This system is very costly in initial cost.
2. The maintenance of this system is also costly.
3. During monsoon large volume of sewage is to be treated compared to remaining period of year.

COMPARISION OF CONSERVANCY AND WATER-CARRIAGE SYSTEMS

CONSERVANCY SYSTEM	WATER-CARRIAGE SYSTEM
1. Very cheap in initial Cost	1. It involves high initial cost
2. Due to foul smell from latrines, they are to be constructed away from the living room	2. As there is no foul smell, latrines remain clean and neat and hence are constructed with room.
3. The aesthetic appearance of the city cannot be increased	3. Good aesthetic appearance of the city can be obtained.
4. Storm water is carried in usually surface drains, hence no problem of pumping the storm water	4. Sewage is treated before disposing of ,it may or may not require pumping it depends on the topography of the town.
5. The quantity of waste liquid reaching the disposed point is less, hence it can be disposed of without any treatment.	5. Large quantity of sewage highly polluted in nature, it requires its treatment before disposal so it is costly process.
6. This system is fully dependent on the human agency	6. This system is not dependent on the human agency
7. As sewage is disposed of without any treatment it may pollute the natural water courses	7. Sewage is treated upto required degree of sanitation.
8. For burying of excremental matter, large area is required.	8. Less area is required as compared to conservancy system.

TYPES OF SEWERAGE SYSTEM AND THEIR SUITABILITY

The sewerage system are classified as follows

(a) Combined system

(b) Separate system

(c) Partially separate system

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(a) COMBINED SYSTEM

This system is best suited in areas having small rainfall, which is distributed, throughout the area, because at such places self-cleaning velocity will be available in every season. As only one sewer is laid in this system, it is best suited for crowded area because of traffic problems.
The combined system can also be used in area having less sewage, to obtain the self-cleaning velocity.

MERITS AND DEMERITS OF COMBINED SYSTEM

The following are the merits of combined system
1. There is no need of flushing because self-cleaning velocity is available at every place due to more quantity of sewage.
2. The sewage can be treated easily and economically because rainwater dilutes the sewage.
3. House plumbing can be done easily only one set of pipes will be required.

DEMERITS

The following are the demerits of the combined system 1. The initial cost is high as compared to separate system
2. It is not suitable for areas having rainfall for smaller period of year because resulting in the silting up of the sewers due to self-velocity is not available
3. During heavy rainfall, the overflowing of sewers will endanger the public health
4. If whole sewage is to be disposed of by pumping, it is uneconomical

(b) SEPERATE SYSTEM

When domestic and industrial sewage are taken in onset of sewers, whereas storm and surface water are taken in another set of sewers, it is called separate system.

MERITS AND DEMERITS OF COMBINED SYSTEM

The following are the merits of the separate system
1. Since the sewage flows in separate sewer, the quantity to be treated is small which results in economical design of treatment works.
2. Separate system is cheaper than combined system, because only sanitary sewage flows in closed sewer and storm water which is unfoul in nature can be taken through open channel or drains, whereas both types of sewage is to be carried in closed sewer in combined system
3. During disposal if the sewage is to be pumped, the separate system is cheaper
4. There is no fear of steam pollution.

DEMERITS

1. Flushing is required at various points because self-cleaning velocity is not available due to less quantity of sewage
2. There is always risk that the storm water may enter the sanitary sewage sewer and cause over-flowing of sewer and heavy load in the treatment plant
3. Maintenance cost is more because of two sewers
4. In busy lanes laying of two sewers is difficult which also causes great inconvenience to the traffic during repairs

(C) PARTIALLY SEPERATE SYSTEM

In the separate system, if a portion of storm water is allowed to enter in the sewers carrying sewage and the remaining storm water flows in separate set of sewers, it is called partially separate system

MERITS AND DEMERITS OF PARTIALLY SEPERATE SYSTEM

MERITS

1. It is economical and reasonable size sewers are required because as it is an improvement over separate system.
2. The work of house-plumbing is reduced because the rain water from roof, sullage from bath and kitchen, can be taken in the same pipe carrying the discharge from the water closets. The water from all other places can be taken in separate sewer or drain.
3. No flushing is required because small portion of storm water is allowed to enter in sanitary sewage.

DEMERITS

1. Cost of pumping is more than separate system when pumping is required because portion of storm water is mixed.
2. There are possibilities of over-flow.
3. In dry weather, the self-cleaning velocity may not develop.

QUANTITY OF SEWAGE

In order to find out suitable section of sewer, it is necessary to determine the quantity of sewage that will flow through the sewer. The sewage consists of dry weather flow and storm water.

QUANTITY OF DISCHARGE IN SEWERS

The quantity of discharge in sewers is mainly affected by the following factors.
(i) Rate of water supply
(ii) Population
(iii) Type of area served as residential, industrial or commercial
(iv) Ground water infiltration

(i) 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.

(ii) POPULATION

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

(iii) TYPE OF AREA SERVED

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

(iv) GROUND WATER INFILTRATION

When sewers laid below the water table in the ground, the ground water may percolate in the sewer from the faulty joints and cracks in the pipelines. The quantity of infiltration water in the sewer depends upon the height of the water table about the sewer invert, permeability of soil, size and nature of the faults or cracks in the sewer line. As per the U.S.A. reports
(i) 4.5 to 45 cum/hectare area/day
(ii) 11 to 225 cum/hectare area/km length of the sewer line
(iii) 0.7 to 7.2 cum/day/cm of dia of the sewer.

DRY WEATHER FLOW

The sanitary sewage, which includes wastewater from residences and industries, is known as Dry Weather Flow (D.W.F)

VARIABILITY OF FLOW

Practically the average sewage never flows in the sewer; it continuously varies from hour to hour of the day and season to season. The consumption of water in summer is more than in winter or rainy season and this change in consumption of water directly affects the quantity of sewage. Practically it has been seen that the maximum to average flow of sewage is between 1.5 to 1.0 and average to minimum is between 1.2 to 1.0

DETERMINATION OF STORM WATER FLOW

The quantity of storm water, which is known as the wet weather flow (W.W.F), that will enter the sewer is to be carefully determined. The following are the factors mainly affect the quantity of storm sewage.

(i) Intensity of rainfall
(ii) Characteristics of catchment area
(iii) Duration of storm
(iv) Atmospheric temperature, wind and humidity
Generally two methods are used to calculate the quantity of storm water.
(i) Rational method
(ii) Empirical formulae method

(i) RATIONAL METHOD

In this method , the storm water quantity is determined by the rational formula

$$Q = \frac{C.i.A}{360}$$

where Q=quantity of storm water in m^3/sec

C=Coefficient of runoff from table

I=intensity of rainfall in mm/hour

A=drainage area in hectares

* The runoff coefficient 'C' is calculated (overall)

$$= \frac{A1C1 + A2C2 + \text{---------} + AnCn}{A1 + A2 + \text{--------------} + An} = \frac{\sum AC}{\sum A}$$

Where A1, A2, A3 ------- An are the different types of areas

And C1, C2, C3 ------- Cn are their runoff coeff. respectively from table.

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(ii) EMPIRICAL FORMULAE METHOD

For determining runoff from very large areas under specific conditions such as slope of land, imperviousness, rate of rainfall etc. These formulae are derived after long practical experience and collection of field data.

(A) Burkli – Zeighar formula (used in switzerland)

$$Q = \frac{C.I.A}{141.58} \cdot \sqrt[4]{\frac{S}{A}}$$

(B) Mc.Math Formula (used in U.S.A)

$$Q = \frac{C.i.A}{148.35} \cdot \sqrt[5]{\frac{S}{A}}$$

(C) Fuller's Formula

$$Q = \frac{C.\ M^{0.8}}{13.23}$$

(D) Funnig's Formula

$$Q = 12.8\ M^{5/8}$$

(E) Tallbot's Formula

$$Q = 22.4\ M^{1/4}$$

Where Q = runoff in cum/sec

C = runoff coefficient

i = intensity of rainfall in cm/hour

S = slope of the area in metre per thousand metre

A = drainage area in hectare

M = drainage area in square km

SHAPES OF SURFACE DRAINS

The following are the four shapes, which are commonly adopted in the construction of surface drains.

1. Rectangular surface drains
2. Semi-circular surface drains
3. U-shaped surface drains
4. V-shaped surface drains

1. RECTANGULAR SURFACE DRAINS

These drains are suitable for carrying heavy discharge. They however do not develop the required velocity when depth of flow is small and they get easily deposited.

2. SEMI-CIRCULAR SURFACE DRAINS

These are suitable for streets where the discharge to be accommodated is of small quantity. These drains are readymade semi-circular sections of stoneware or concrete or asbestos cement pipes.

3. U-SHAPED SURFACE DRAINS

These drains are easy to construct and they combine the advantages of semi-circular drains and rectangular surface drains.

4. V-SHAPED SURFACE DRAINS

These drains possess better hydraulic properties but they are difficult to construct. These drains will carry fluctuating to construct. These drains will carry fluctuating discharge without depositing solids at any point and capable of producing a good velocity. These drains are constructed either in brick masonry or stone masonry in cement mortar. The inside surface is smoothly plastered with rich cement mortar. The drains are provided with suitable gradients to maintain the velocity within the range so as to avoid either silting or scouring.

DIFFERENT SHAPES OF CROSS-SECTIONS FOR SEWERS CIRCULAR AND NON CIRCULAR

Generally the sewers of circular shape are adopted because of following facts
1. Circular shape affords least perimeter and hence construction cost is minimum for the same area of other shape
2. Deposition of organic matter are reduced to minimum because of no corners
3. They are easy to manufacture or construct and handle
4. Because of circular shape, these are subjected to hoop compression hence the concrete required is minimum and no reinforcement is required
5. They possess excellent hydraulic properties because they provide the maximum hydraulic mean depth when running full or half full.

The circular sewers prove to be best when the discharge does not vary too much and the chances of sewers running with very low depths (less than half) are less.
However the sewers of non-circular shapes are also used for the following reasons
1. To bring down the cost of construction
2. to improve the velocity of flow when the depth of sewage is low
3. to secure more structural strength
4. to simplify the process of construction
5. to make them large enough for a man to enter for cleaning or repairing

SHAPES OF NON-CIRCULAR SHAPES:

The following are the non-circular shapes, which are commonly, used for sewers.

1. BASKET HANDLE SECTION: In this type of sewer, the upper portion of sewer has got the shape of a basket-handle. The bottom portion is narrower and carries small discharges during monsoon and combined sewage is carried through the full section. This shape of sewer is not generally used at present

2. CATENARY-SHAPED SECTION: In this type of sewer, the shape of sewer is in the form of a catenary and only gravity force is acted upon this sewer. This is suitable for tunneling work.

3. EGG-SHAPED OR OVOID SECTION: This type of sewer is suitable for carrying combined flow. The main advantage of this type of sewer is that it gives slightly higher velocity during low flow than a circular sewer of the same capacity. But construction of this section is difficult and less stable than circular section. Inverted egg-shaped sewer gives better stability and carries heavy discharges.

4. HORSE-SHOE SECTION: This type of sewers are used for the construction in tunnel to carry heavy discharges, such as truck and outfall sewers. This is also suitable when the available headroom for the construction of sewer is limited. The invert of the sewer may be flat, circular or paraboloid and top is semicircular with sides vertical or inclined.

5. PARABOLIC SECTION: This type of sewers are suitable for carrying comparatively small quantities of sewage and economical in construction. The invert of sewer may be flat or parabolic and upper arch of the sewer takes the form of parabola.

6. RECTANGULAR OR BOX TYPE SECTION: The rectangular or box type section of sewer is stable and it is easy to construct. It is sometimes used to work as a storage tank during the tide it becomes necessary to store the sewage for some period.

7. SEMI-CIRCULAR: This type of sewers are suitable for constructing large sewers with less available headroom and it possess better hydraulic properties.

8. SEMI-ELLIPTICAL SECTION: This type of the section is suitable to carry heavy discharges and adopted for soft soil, as it is more stable. The dia of sewer may be more than 1.8m and possess good hydraulic properties except at low depths.

9. U-SHAPED SECTION: The shape of this section is the true shape of letter. Or small trench of U shape can be setup in the larger section of sewer. The trench is known as the cunette and adopted for a combined sewer having predominant flow of storm water.

BRIEF DESCRIPTION AND CHOICE OF TYPES OF SEWERS

The following factors are to be carefully considered while making selection for the materials of sewer.

1. Cost: The cost should be moderate and reasonable
2. Durability: The material should be durable
3. Imperviousness: The material of sewer should be impervious nature

4. Resistance to Abrasion: The material should possess enough resistance to abrasion caused due to grit moving with high velocity.
5. Resistance to corrosion: The material should be capable of offering resistance to the corrosion because the sewage possesses corrosive qualities
6. Weight: The material should possess moderate weight so as to make easy handling and transportation.

The following are the various materials, which are used for sewers (i) Asbestos cement sewers

(ii) Brick sewers

(iii) Cast-Iron sewers

(iv) Cement concrete sewers

(v) Corrugated iron sewers

(vi) Plastic sewers

(vii) Steel sewers

(viii) Stoneware sewers

(ix) Wood sewers

STONEWARE SEWERS:

The stoneware sewers are also known as the vitrified clay sewers or salt-glazed sewers and they are prepared from various clays and shapes in required proportion, allowed to dry and then burnt in a kiln. A small quantity of salt is added to kiln get glass like glaze on the surface of pipes.

ADVANTAGES:

1. These pipes are strong enough to take backfilling and traffic
2. The interior surface of sewers are smooth and impervious
3. The overall performance is very good
4. These sewers are cheap and easily available
5. These sewers are durable and better resistance to corrosion & erosion
6. These sewers are capable of withstand hydraulic pressure upto 0.15N/mm^2 and bear a load of soil of about 4.5 m depth

DISADVANTAGES:

1. These are brittle in nature and may damage in handling or transport.
2. These are not strong enough to allow sewage under pressure.
3. These are difficult to handle or transport because of heavy weight.

CAST IRON SEWERS:

The cast sewers possess high strength and they are durable. These are available in sizes from 150mm to 750mm diameter. These sewers can resists the action of acids in sewage if the inner surface is coated with paint or cement concrete. The cast-Iron sewers are used for following special purpose

1. Danger of contamination against leakages.
2. Expensive road surface like C.C. can be avoided.
3. Heavy external loads under railway lane, foundation.
4. Under high pressure.
5. The places subjected to considerable differences in temperature.
6. Where the ground is likely to subject to heavy movements and vibrations.
7. Where wet ground required to reduce infiltration

DISADVANTAGES:

1. Cost is high
2. Transportation and handling is difficult

CEMENT CONCRETE SEWERS:

The cement concrete sewers may be plain or reinforced. The plain cement concrete sewers are used upto the diameter of 600mm and beyond 600mm reinforcement is provided.

ADVANTAGES:

1. These are strong and impervious.
2. Larger diameter can be made.
3. Inner surface of sewer is smooth.
4. For attack of chemical and erosive actions the inner surface should be lined with vitrified clay.

DISADVANTAGES:

1. Heavy weight transportation and handling is difficult.
2. Joints should be carefully filled.

A.C.PIPES: These sewers are made from a mixture of asbestos fibres and cement. They are available upto sizes of 900mm.

ADVANTAGES:

1. Easy to cut and join.
2. Durable and good resistance to corrosion.
3. The inside surface is smooth.
4. Light in weight and hence easy to handle.

DISADVANTAGES:

1. Brittle and cannot stand impact forces during handling operations.
2. The structural strength is poor and hence cannot be laid to resist heavy external loads.

LAYING OF SEWERS:

The construction of sewer consists of the following works

a) Marking center lines of sewers.

b) Excavation of trenches.

c) Checking the gradient.

d) Preparation of bedding.

e) Laying of sewers.

f) Jointing.

g) Back filling.

MARKING CENTER LINE OF SEWER:

The centre line of a sewers are marked on the streets and roads from the plans starting from the lowest point or outfall of the main proceeding upwards. The setting out of work is done by means of chain and theodolite or compass. For checking the centre line during the construction generally wooden pegs or steel spikes are driven at 10 meters intervals on a line parallel to the centre where while laying sewers, they will not disturb them. For checking the levels of sewer pipes and their alignment temporary benchmarks are established at 200-400 metres intervals. The reduced level (R.L) of these benchmarks should be calculated with respect to G.T.S benchmarks. On the centre line position of sewer appurtenances are also marked

EXCAVATION TRENCHES:

After marking the layout of the sewer lines on the ground, the first step is the removal of pavement, which starts from the lower end of the sewers and proceeds upwards. Pickaxes, spade or pneumatic drills can be used in case of removing concrete pavements. After removing pavements, the excavation of trenches is done manually or machinery. The width of trench depends upon the dia of sewer and depth of sewer line below the ground level. The width of sewer line is 15cm more than external diameter of sewer for easiness in lowering and adjusting the sewer pipe. The minimum trench width of 60 to 100cm is necessary for conveniently laying and jointing of even very small size sewers. The excavation of trench sides require shoring and shuttering and also dewatering is done by gravity method or pumping method

PREPARATION OF BEDDING:

Trenches are excavated with proper grade so that sewage may flow in sewer due to gravitational flow only. The centre line of sewers and their grades are transferred from the ground by means of sight rail and boning rod. When a sewer has to be laid in a soil underground strata or in a reclaimed land, the trench shall be excavated deeper than what is ordinarily required trench bottom or rock. In the case of very bad soil the trench bottom shall be filled in with cement concrete of appropriate grade. In areas subject to subsidence the pipe sewer shall be laid on a timber platform or concrete cradle supported on piles. In the case of casting-site sewers and R.C.C section with reinforcement, bearing capacity is encountered and soil stabilization shall be done either by rubber, concrete or wooden crib.

LAYING:

Smaller size pipes can be laid by the pipe-layers directly by hand only. But heavier and larger size pipes are lowered in the trenches by passing ropes around them and supporting through hock. It is the common practice to lay the pipes with their socket end upgrade for easiness in joining. After lowering the pipes these are brought near and spigot end of one pipe is placed in the socketed end of the other after properly placing and arranging the pipes they are suitably joined. The joints are carefully cured for sufficient time.

JOINTING OF SEWERS:

The C.I.Pipes shall be examined for line and level and the space left in the socket shall be filled in by pouring molten piglead of best quality as for IS:782 and IS 3114. For concrete pipes, the collars shall be placed symmetrically over the end of two pipes and the annual space between the inside of the collar and the outside of the pipe shall be filled with hemp yarn soaked in tar or cement slurry tamped with just-sufficient quantity of water to have consistency of semi-dry condition, well packed and thoroughly rammed with caulking tools and then filled with cement mortar 1:2. The joints shall be finished off with a fillet slopping at 45° to the surface of the pipe and cured for 24 hours. Any plastic solution or cement mortar that may have squeezed in the pipe shall be removed to leave the inside of the pipe perfectly clean.

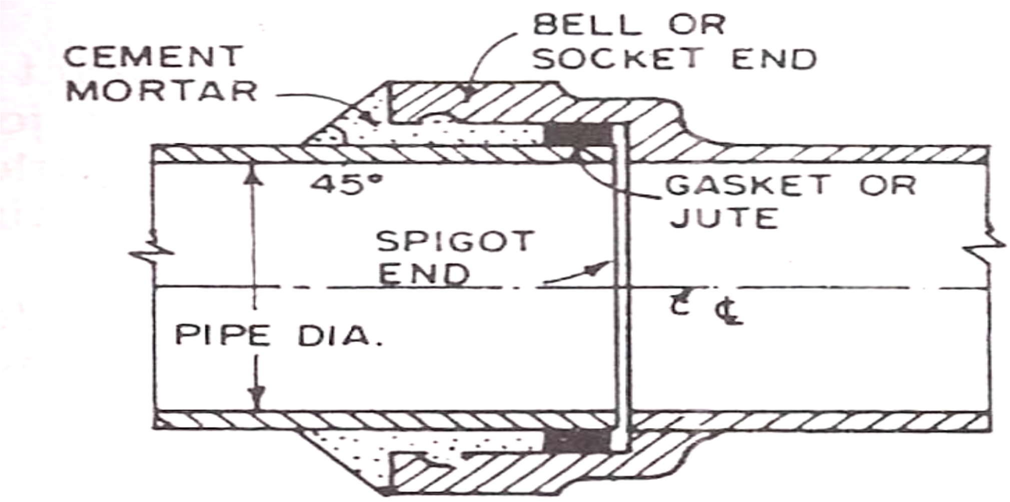
For stoneware pipes, all the joints shall be caulked with tarred gasket in one length for each joint and sufficiently long to entirely surround the spigot end of the pipe. The gasket shall then be filled with 1:2 cement sand mortar in a semi-dry condition and a fillet shall be formed round the joint with trowel forming an angle of 45° with the barrel of the pipe as per IS 4217. Rubber gasket may also be used for jointing.

JOINTS IN SEWERS

Sewer joints can be of the following types:

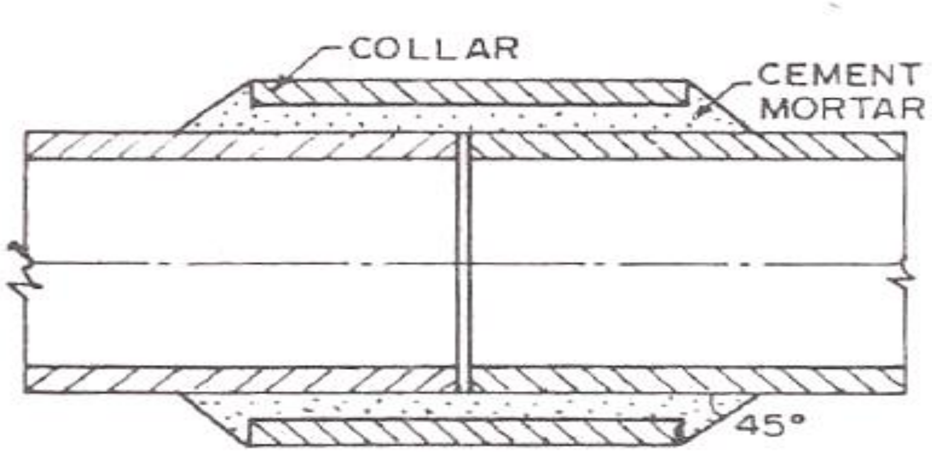
Bell and spigot joint.
Collar joints
Simplex joints.
Flexible or bituminous joints.
Mechanical joints.
Open joints.

1. **Bell and spigot joint.** Such joints are quite common in plain or reinforced concrete pipes. Each pip has a spigot end and a bell or socket end. Cement mortar of proportion 1:1 or 1: 2 is inserted between the space of the bell end and spigot end. Gasket or jute packing may be placed in the inner side, to maintain the alignment of the sewer. The mortar caulked joint is finished at about 45^{o} on the outer face.



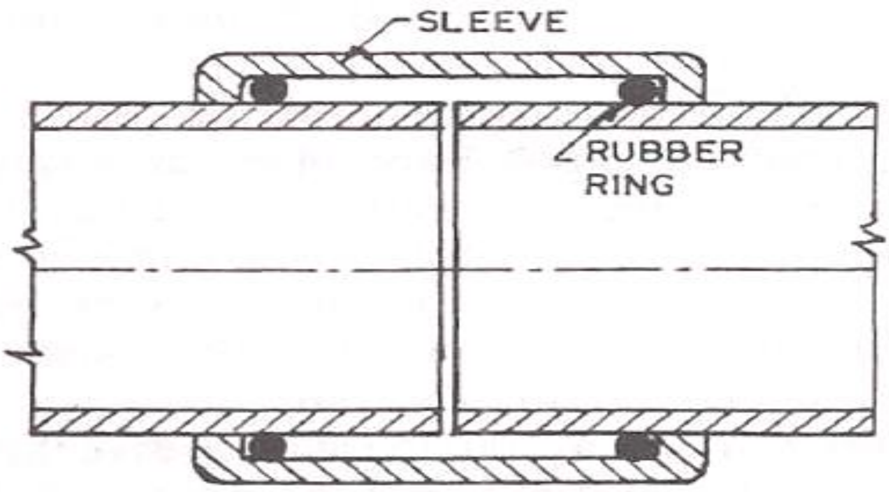
BELL AND SPIGOT JOINT

2. **Collar joints.** For such a joint, the plain ends of the consecutive lengths of pipes are kept near each other and a collar of slightly bigger diameter is placed around. The annular space between the collar and the ends of the pipes is then filled with cement mortar of 1:1 proportion. Such joints are used for concrete pipes of larger diameters.



COLLAR JOINT

3. **Simplex joint.** Simplex joint, also known as ring tie coupling, is similar to collar joints, and are used for asbestos cement pipes. The joint, consists of a pip sleeve or coupling of asbestos cement and tow rubber rings which are compressed between the exterior of the pipes and the interior of the sleeve. Such a joint is quite flexible.



SIMPLE JOINT FOR A.C. PIPES

4. **Flexible or bituminous joint.** The collar joint using cement mortars is relatively rigid. Such joints crack. These joints are made flexible by using bitumen or bituminous compounds instead of cement mortar.

5. **Mechanical joints.** Such joints use mechanical devices like flanged rings, bolts, screwed ends etc. to keep the two ends together. They are used for metallic sewers made of cast iron, steel etc.

6. **Open joints.** If there is no objection to infiltration, open joints are adopted. The bell and spigot ends are simply placed together, without inserting filling material in the annular space. Gasket may however be inserted, to maintain alignment. The joint is merely covered with tar paper, to prevent entry of subsoil into the sewer.

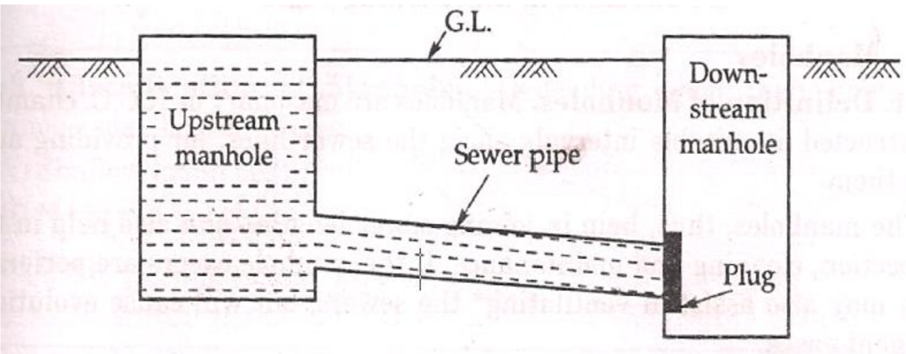
TESTING OF SEWER PIPES

The sewer after being laid and jointed, are tested for watertight joints, and also for correct straight alignment. As described below.

(A) Test for leakage, called water test

- The sewers are tested, so as to ensure 'no leakages' through their joints after giving a sufficient time to these joints to set in. For this purpose, the sewer pipe sections are tested between manholes under a test pressure of about 1.5m of water head.

- In order to carry-out this test on a sewer line between two manholes, the lower end of the sewer is, first of all, plugged, as shown in the fig. The water is now filled in the manhole at the upper end, and is allowed to flow through the sewer line. The depth of water in the manhole is maintained to the testing head of about 1.5m. The sewer line is watched by moving along the trench, and the joints which leak or sweat, are repaired. The leaking pipes, if any, will also be replaced.



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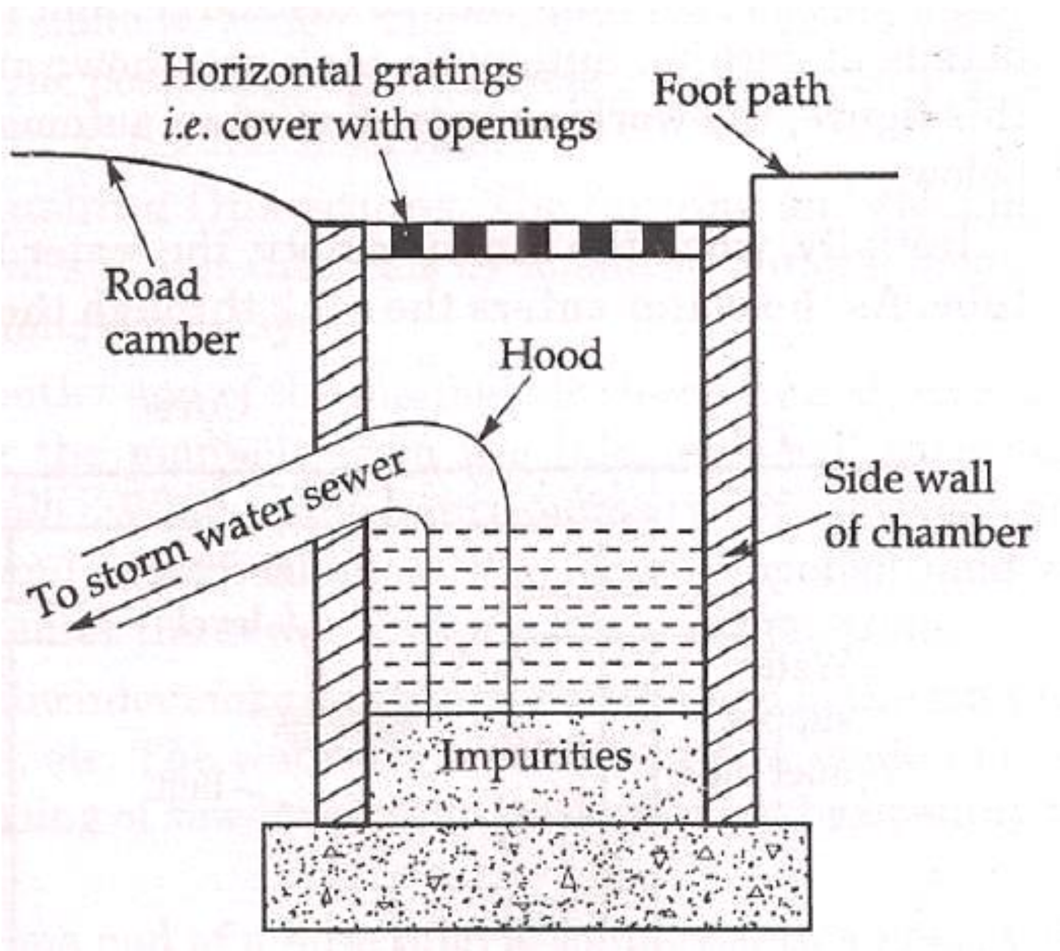
(B)Testing for straightness of alignment and obstruction

- The straightness of the sewer pipe can be tested by placed a mirror at one end of the sewer line and lamp at the other end. If the pipeline is straight, the full circle of the light will be observed.
- However, if the pipeline is not straight it would be apparent; the mirror will also indicate any obstruction in the pipe barrel. Any observation present in the pipe can also be tested by inserting at the upper end of the sewer.
- A smooth of ball of diameter 13mm less than internal diameter of the sewer pipe. In the absence of any obstruction, such as yarn or motor projecting through the joint, etc. the ball shall roll down the invert of the sewer pipe and emerge at the lower.

SEWER APPURTENANCES

CATCH BASINS OR CATCH PITS.



Catch basins or Catch pits.

- Catch basins are nothing but street inlets provided with additional small settling basins, as shown in **Fig.3.1**. Grit, sand, debris, etc., do settle in these basins, and their entry into the sewer is thus prevented. In addition to this, a hood, as shown, is also provide, which prevents the escape of foul gases, which may find its way through the sewer line.
- Catch basins need periodical cleaning, as otherwise, the settled organic matter may decompose, producing foul odors, and may also become a breeding place for mosquitoes.
- Catch basins were considered necessary in old combined sewerage systems, but, however, in modern days, they are not considered as very essential, because the modern well paved streets offer very less grit and debris with storm runoff, and the same can be conveyed easily in storm water sewers (drains) laid at suitable gradients to provide self-cleansing velocities.
- Moreover, the problem of eruption of foul gases from S.W. sewers (drains) is very less; and as such, there is not much necessity of providing such basins in the modern separate sewerage systems.

MANHOLES

Definition of Manholes: Manholes are masonry or R.C.C. chambers, constructed at suitable intervals along the sewer lines, for providing access into them.

The manholes, thus, help in joining sewer lengths, and also help in their inspection, cleaning and maintenance. If the manhole covers are perforated, they may also assist in ventilating the sewers, but will cause evolution of pungent gases.

Location and Spacing of Manholes.

- The manholes are generally provided at regular intervals in a straight sewer line, and also at points of every bend, junction, change of gradient, or change of sewer dia.

- Unless there are practical difficulties, the sewer line between two manholes is laid straight with even gradient. Even when the sewer line runs straight, the manholes are provide at regular intervals.

- The spacing between the manholes, in such a case however, depends mainly upon the size of the sewer line. The larger is the diameter of sewer, the greater will be the spacing between the manholes.

- The manhole spacing’s generally adopted, on straight sewer reaches, are given below:

Classification of Man holes

FLUSHING TANKS

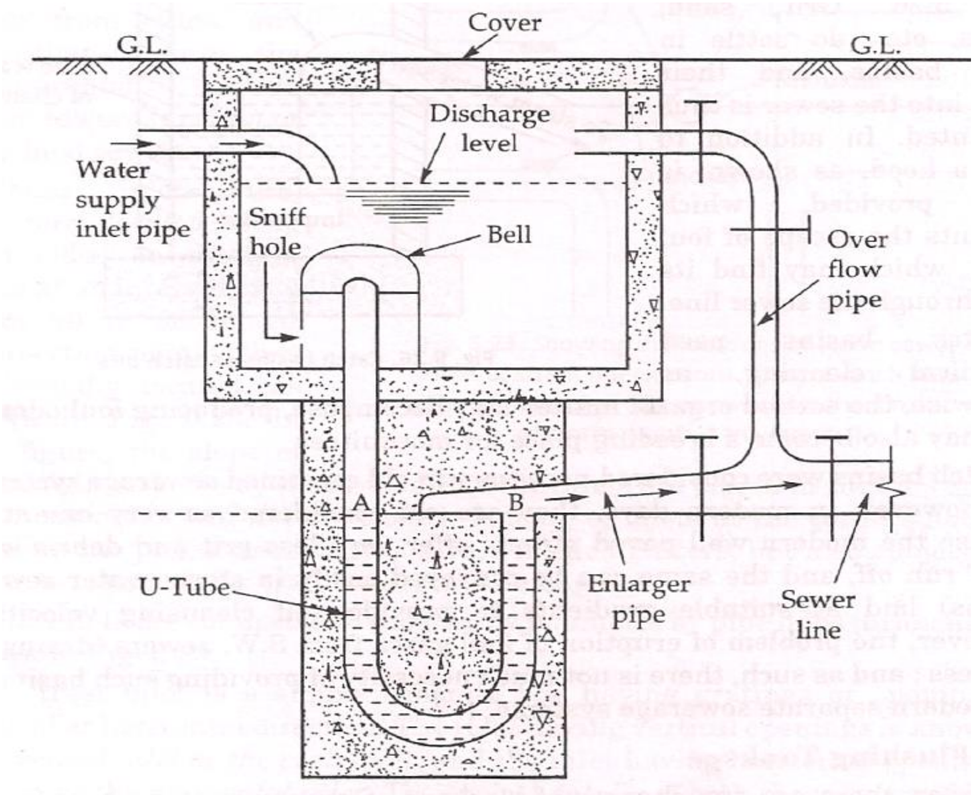
- Wherever, there are any chances of blockage of sewer pipes, such as in the case of sewers laid on flat gradients not producing self-cleansing velocities, or near the dead end points of sewers, flushing devices are installed.
- These devices store water temporarily, and throw it into the sewer for the purpose of flushing and cleaning the sewer. Such devices are called flushing tanks.
- Flushing tanks should have a capacity to store enough water, which may prove to be sufficient for cleaning the sewer line. This capacity is generally depth equal to about one-tenth of the cubical contents of the sewer line served by it.

Two types of flushing operations are normally used; viz.

(1) Flushing operation using automatic flushing tank
(2) Hand operated flushing operation.

The automatic types of flushing tanks are being used more commonly in modern days.

(1) **Automatic Flushing Tanks.**



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- In this type of a flushing tank, the flushing operation is carried out automatically at regular intervals. The entry of water is so regulated as to fill the tank up to the discharge point in a period equal to the flushing interval.

- An overflow pipe is also provided to drain away water in case the tank fails to discharge, and thereby overflows. The working operation of an automatic flushing tank is explained below:
- Initially, when the tank is empty, the water level stands at A – B in the U-tube. As the water enters the tank through the inlet pipe, the water level in the tank slowly goes on rising.
- The water level in the U-tube remains to this level, i.e. A-B till the water level in the tank remains below the level of sniff hole. But, however, as the water in the tank goes above the level of the sniff hole, the air is caught and compressed in the bell portion. This compressed air exerts pressure on the surface A, and hence the water level gets depressed in this along arm of U-tube.
- The water level goes on depressing more and more as the tank goes on filling more and more. Ultimately, a stage is reached when this happens, some compressed air gets released through the shorter arm of u-tube and a corresponding quantity of water enters the bell. It is so adjusted that the discharge line is just reached at this stage, and the head of water above the bell becomes greater than that in the shorter arm of U-tube.
- The compressed air is suddenly removed from the longer arm of U-tube, and a siphoning action starts, which releases the water from the tank into the sewer through the enlarger pipe. The siphonic action continues till the water in the tank falls up to the sniff hole. The air then enters the bell portion through the sniff hole and it breaks the siphonic action.
- The water level in the tow arms of the U-tube again assumes the position A-B. the cycle goes on repeating, thus releasing water in the sewer at regular intervals.

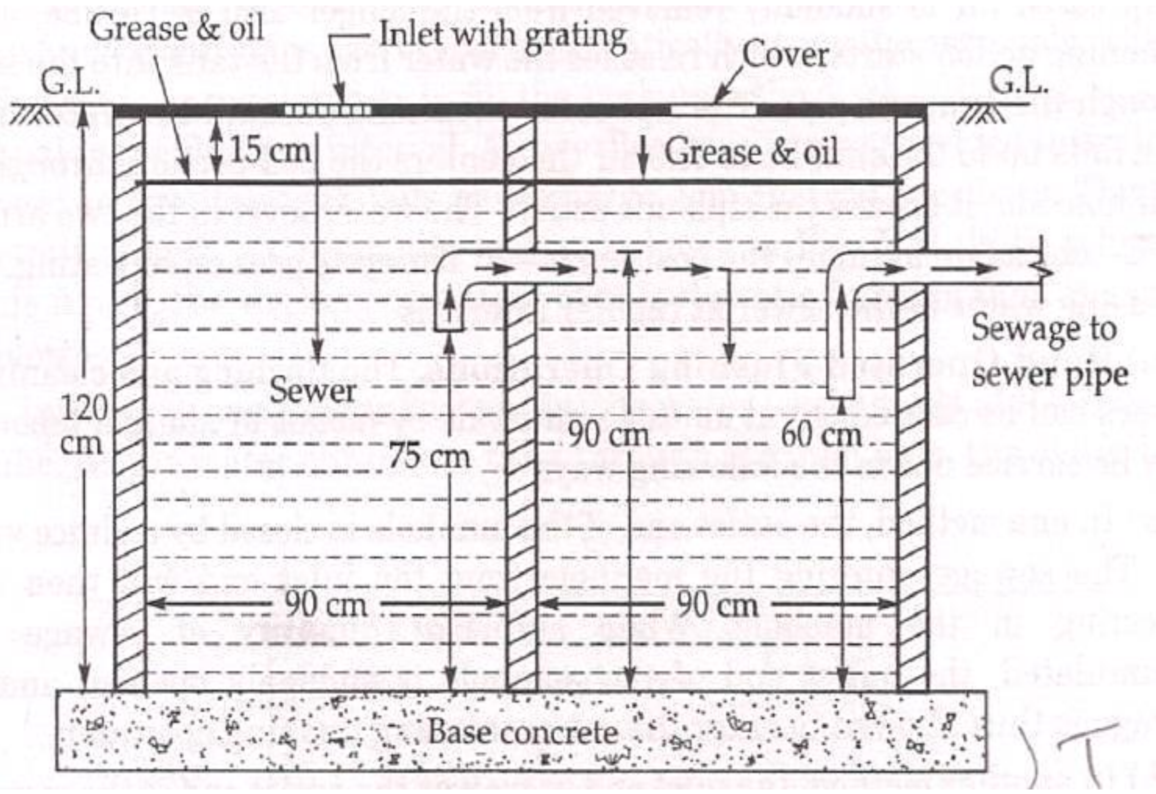
(ii) <u>Hand Operated Flushing Operations.</u>

The flushing and cleansing of sewers can be carried out at suitable intervals by means of manual labor. It may be carried out in the following ways:

(a) In one method, the outlet end of the manhole is closed by a sluice valve, etc. the sewage entering the manhole from the inlet end will then start collecting in the manhole. When sufficient quantity of sewage gets accumulated, the outlet end of the manhole is suddenly opened, and the sewage is thus allowed to enter the sewer, causing flushing operation.

(b) In another method, the inlet end as well as the outlet end of the manhole is closed by sluice valves, etc. the water from outside is now made to enter into the manhole. The flushing of sewer can then be carried out by opening the outlets and the inlet ends.
(c) In another method, one end of a hose pipe is connected to a nearby fire hydrant, and the other end may be placed in the manhole to obtain the flushing operation.

GREASE AND OIL TRAPS.



- Grease and oil traps are those trap chambers which are constructed in a sewerage system to remove oil and grease from the sewage before it enters into the sewer line. Such traps are located near the sources contributing grease and oil to the sewage.

- They are, therefore, generally located at places, such as, automobile repair work-shops, garages, kitchens of hotels, oil and grease industries, etc.

  (i) The grease and oil, of allowed to enter the sewer, will stick to the sewer sides, and thus reducing the sewer capacity.

  (ii) The suspended matter which would have, otherwise, flown along with the sewage, also sticks to the sides of the sewer, due to sticky nature of oil and grease ; thus further reducing sewer capacity.

(iii) The presence of oil and grease in the sewage adds to the possibilities of explosion in the sewers.

(iv) The presence of oil and grease traps work is simple: the grease and oil being lighter in weight float on the top surface of the sewage. Hence, if an outlet draws the sewage from lower level, grease and oil will get excluded. Based on this principle, the grease and oil trap chambers are designed in such a way that the outlet level is located near the bottom of the chamber, and the inlet level is kept near the top of the chamber.

MODULE 2

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
= (0.75-1 m/s)

MAXIMUM VELOCITY CRITERIA

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
Note Manning's formula is generally used for finding velocity in sewer. Commercially available sizes (diameter) of sewers are
9" = 225 mm
12" = 305 mm
15"=380mm
18"=460 mm.

SURFACE DRAINAGE

The sullage from kitchens, bathrooms and storm water, which passes through the surface drains, is called surface drainage. They are less hygienic as they are open and exposed to atmosphere

REQUIREMENTS

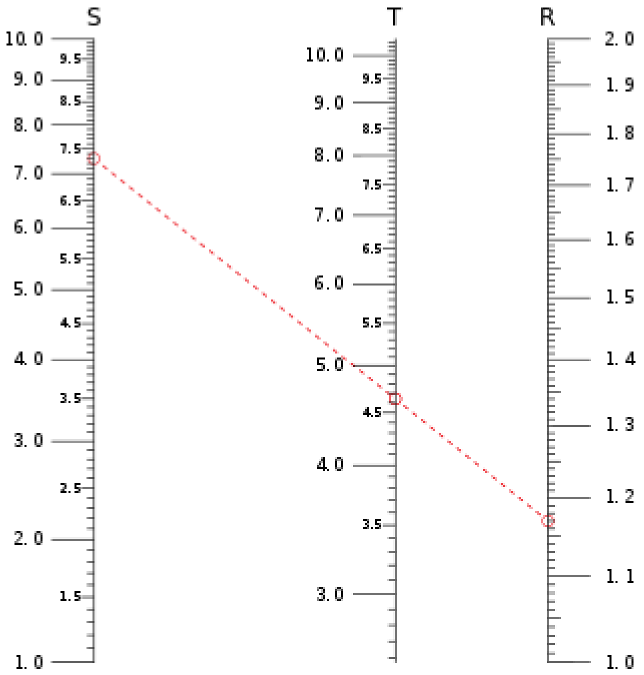
1. The inner surface of surface should be plastered
2. The joints of drains should be properly and neatly finished
3. The drain should be laid such a gradient that self-cleansing velocity is developed
4. They should be laid on easy curves
5. They should be properly designed with reasonable provision of free board

NOMOGRAMS

Use of nomograms as per IS 1742 to determine the unknown values of gradient, diameter, discharge and velocity.

In the design of sewerage scheme for a town, the calculations have to be done for every sewer line to obtain the necessary gradients, the given self-cleansing velocities and estimated discharge use of the formula for every calculation and thus number of calculations flow whole scheme becomes a cumbersome job. This work is simplified by adopting tables, nomograms, partial flow diagrams etc. prepared on the basis of the appropriate formula.

Nomogram is very commonly used in the design of sewers. This nomogram is based on manning's formula in which value of 'n' is taken as 0.013. The values given in the Nomogram are for sewers running full. As per IS 1742, the Nomogram can be used conveniently. For example if the required discharge of a sewer for which n=0.013 is 224 lit/sec, and the grade is 0.00125, a line is drawn through these two values. The intersection of this line on velocity scale and diameter scale gives the corresponding values. Thus for this example diameter of sewer is found to be 600mm and the velocity to be maintained is 0.765 m/sec. Hence if two values are known, the remaining two values can be easily got from the nomogram.



$$T = (1.84S + 4.66)^{0.37} (1.21R)^{4/3}$$

Sewerage are closed conducts are called sewers and are laid underground for conveying foul discharges from water-closets of public and domestic buildings, chemical mixed water from industries without creating any nuisance outside the town. Sewers should have such cross-section

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that self-cleaning velocity should be developed even during dry weather flow. No deposit should settle down in the bed of sewers under any circumstances. These should be laid in the town at such a slope that water in case of flood in river at the outlet should not come out from manholes and cause insanitary conditions

Sewers

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Sewage flow variations- Minimum daily, hourly flow variations

The quantity of sewage produced depends upon the quantity of water use.
Generally;

Average daily flow = (70 – 80) % average water consumption i.e.
Average Daily Flow (ADF) of Sewage = 75%
Average Daily Demand (ADD) of water consumption = 0.75 ADD

The flows in sanitary sewers vary seasonably monthly, daily, hourly. For areas of moderate sizes be expressed as;
Maximum Daily Flow = 1.5 x ADF
Where
1.5 varies from place to place
Maximum hourly flow = (2 – 4) ADF
This is actually the peak flow
Sewers are designed on peak flow basis, however the minimum flow passing through the sewer is also important in the design of a particular sewer because at low flow the velocity will be reduced considerably which may cause silting.
So the sewers must be checked for minimum velocities at their minimum hourly flows. Generally for a moderate area the following minimum flows may be assumed.
Minimum Daily Flow = 2/3 ADF
Minimum Hourly Flow = 1/3 ADF

The sewers should be laid of such a gradient as to have minimum self-cleansing velocity.
PROBLEMS

A population of 30,000 is residing in a town having an area of 60 hectares. If the average coefficient of runoff for this area is 0.60 and the time of concentration of the design rain is 30min. calculate the discharge for which the sewers of a proposed combined system will be designed for the town in the question. Make suitable assumptions where needed

Solution First assume per capita water supply= 120l/person/day.
Assume 80% of water supplied will be reaching sewers as sanitary sewage.
Quantity of sanitary sewage produced per day= (80/100)*120*30,000 litres
=2880cu.m
Quantity of sanitary sewage produced per second=2880/ (24*60*60)= 0.033cumecs
Average sewage discharge=0.033cumecs
Assume max sewage discharge to be three times the average sewage discharge ,
Max sewage discharge=3*0.033=0.1 cumecs
The storm water discharge $=Q_P=1/36*K*p_c*A$
Pc=100/T+20=100/(30+20)=2cm/hr
Qp= 1/36*0.6*2*60=2cumecs
Total peak discharge for which the sewers of the combined system should be designed
= Max sewage discharge + max storm runoff
=0.1+2=2.1 cumecs

Assuming that the surface on which the rain falls in a district is classified as follows
20% of the area consists of roofs for which the runoff ratio is 0.9, 20% of the area consists of pavements for which the runoff ratio is 0.85, 5% of the area consists of paved yards of houses for which runoff ration is 0.8., 15% of area consists of macadam roads for which runoff ratio is 0.40, 35% of the area consists of lawns, gardens and vegetable plants for which the runoff ratio is 0.10 and the remaining 5% of the area is wooded for which the runoff ratio is 0.05, determine the co-efficient of runoff for the area. If the total area of the district is 36 hectares and the max rain intensity is taken as 5cm/hr, what is the total runoff for the district?

Solution

$K_1A_1=20/100*A*0.9=0.18A$
$K_2A_2=20/100*A*0.85=0.17A$
$K_3A_3=5/100*A*0.8=0.04A$
$K_4A_4=15/100*A*0.4=0.06A$
$K_5A_5=35/100*A*0.1=0.035A$
$K_6A_6=5/100*A*0.05=0.0025A$
$K=K_1A_1+K_2A_2+K_3A_3+K_4A_4+K_5A_5+K_6A_6/(A)$
K= 0.18A+0.17A+0.04A+0.06A+0.034A+0.0025A/(A)
K=0.4875

The runoff factor for the entire area=0.4875
Peak discharge$=Q_p=1/36*K*pc*A$
$Q_p=1/36*0.4875*5*36=2.55$cumecs

Sampling

Types of Samples

Introduction

There are two main types of samples which are used in water and wastewater treatment - grab samples and composite samples. The type of sample taken in a given instance will depend on the type of test to be performed, the frequency of testing, and on permit requirements. We will explain each test procedure below.

Grab Samples

A **grab sample**, also known as a **catch sample**, consists of a single sample taken at a specific time. This is the most common type of sample and is the sampling technique you will use for most of your labs. For example, you took a grab sample when you collected a beaker of raw water and tested it for pH.

A grab sample has certain limitations. In essence, a grab sample takes a snapshot of the characteristics of the water at a specific point and time, so it may not be completely representative of the entire flow. Grab samples are most appropriate to small plants with low flows and limited staffs that cannot perform continual sampling.
On the other hand, grab samples do provide an immediate sample, and are thus to be preferred for some tests. Specifically, pH, dissolved oxygen, and total residual chlorine can change very rapidly in water once the sample is removed from the flow, so grab samples are preferred for these tests.

Grab samples must be collected carefully to make them as representative as possible of the water

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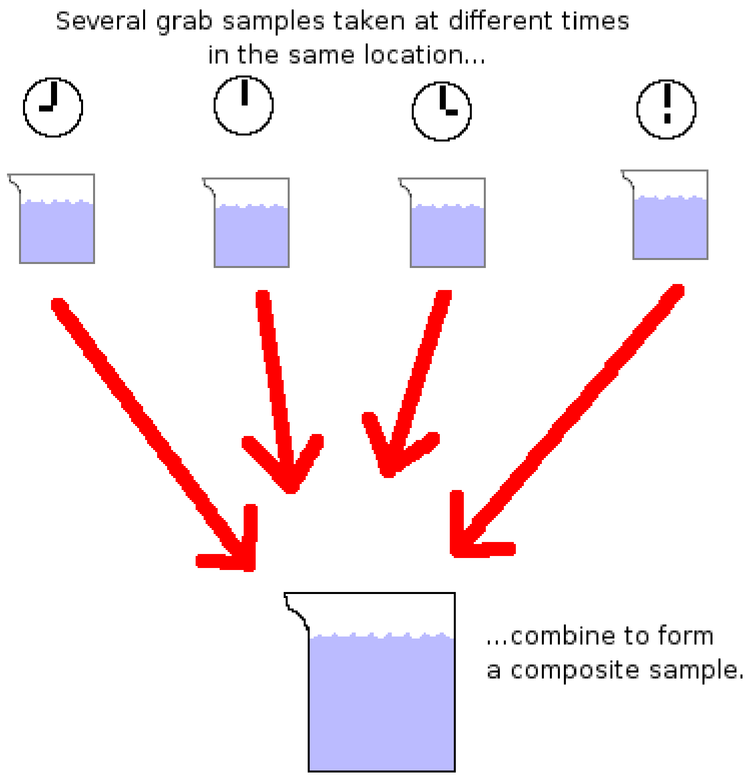
as a whole. They should be taken at a time of day when the plant is operating near its average daily flow rate. If grab samples are used to determine plant efficiency by collecting a raw water sample and a treated water sample, then the collection of the effluent should be delayed long enough after collection of the influent sample to allow for the raw water to pass completely through the treatment process.

Finally, be aware that mixing two or more grab samples may not result in a result which averages the characteristics of the samples. Chemical reactions can take place in mixed samples which alter pH and chlorine residual values. The next section will give you more information on combining samples.

Composite Samples



A **composite sample**, also known as an **integrated sample**, is a sample which consists of a mixture of several individual grab samples collected at regular and specified time periods, each sample taken in proportion to the amount of flow at that time. Composite samples give a more representative sample of the characteristics of water at the plant over a longer period of time.

Like grab samples, composite samples have both strengths and weaknesses and are not acceptable for all tests. The greatest strength of composite samples is their ability to take into account changes in flow and other characteristics of the water over time. This helps the operator gain an overall picture of the total effects that the influent will have on the treatment process and that the effluent will have on the receiving water. However, composite samples cannot be used for tests of water characteristics which change during storage (such as dissolved gases) or of water characteristics which change when samples are mixed together (such as pH.) Table 1060: I in *Standard Methods* lists whether grab or composite samples are most appropriate for a variety of tests.

Composite samples are often taken using automatic sampling devices. These may be set to take a sample every 8, 12, or 24 hours, with the frequency depending on test requirements, on the size of the treatment plant, and on permit requirements.

Sample Volumes for Composite Samples

One of the most important aspects of a composite sample is that each individual grab sample must be proportional to the amount of flow at the time the sample was collected. Most automatic equipment used to take composite samples will make these calculations for you and will collect a correctly sized grab sample during each time period. This section presents a calculation you can use to determine the size of the grab sample at a given time when producing a composite sample manually.

The volume of sample collected at any given time depends on the volume of flow at that time, the total flow for the day, the total composite sample volume, and the number of individual grab samples to be taken. The following equation can be used to calculate a grab sample's volume:

$$\text{Grab sample volume, mL} = \frac{(\text{Flow rate at sample time, MGD}) \times (\text{Composite sample volume, mL})}{(\text{Number of grab samples}) \times (\text{Average daily flow, MGD})}$$

For example, the average daily flow at your plant is 11.3 MGD and the total volume of your composite sample is to be 4,000 mL made up of 24 grab samples. At the time you take your first sample, the plant's flow is 5.2 MGD, so you can calculate the volume of the grab sample to take as follows:

$$\text{Grab sample volume, mL} = \frac{5.2 \text{ MGD} \times 4{,}000 \text{ mL}}{24 \times 11.3 \text{ MGD}}$$

$$\text{Grab sample volume, mL} = 77 \text{ mL}$$

So you should take a 77 mL grab sample during your first sampling of the day.

Characteristics of wastewater

The characteristics of wastewater can be classified as

1. Physical characteristics
2. Chemical characteristics
3. Biological characteristics

Physical characteristics of wastewater

1. **Color:** Fresh domestic sewage is grey, with the passage of time as putrefaction starts, it begins to get black.

2. **Odor:** Normal fresh sewage has a musty odor which is normally not offensive, but as it starts to get stale, it begins to give offensive odor. Within 3-4hrs, all the oxygen present in the sewage gets exhausted and it starts emitting offensive odor of hydrogen sulphide gas & other sulphur compounds produced by anaerobic micro-organisms.

3. **Temperature:** Generally the temperature of wastewater is higher than that of the water supply due to addition of warm water from the households & from industries. When the wastewater flows in closed circuits, its temperature rises further. Average temperature of wastewater in India is around 200c, which is quite close to the ideal temperature for the biological activities.

4. **Turbidity:** It is a measure of light-emitting properties of wastewater & turbidity test is used to indicate the quality of waste discharges w.r.t colloidal matters. The turbidity depends upon the strength of the sewage.

5. **Solid content:** Sewage normally contains 99.9% of water & 0.1% of solids. Total solids in wastewater exist in 3 forms:
   1. Suspended solids
   2. Dissolved solids
   3. Colloidal Solids

Chemical Characteristics of Wastewater

1. **pH value:** The test for pH value of wastewater is carried out to determine whether it is acidic or alkaline. A high concentration of either an acid or alkali in wastewater is indicative of industrial wastes.

2. **Chloride content:** Chloride in natural waster result from the leaching of chloride-containing rocks & soils with which the water comes in contact. Chlorides found in domestic sewage are derived from kitchen wastes, human faeces & urinary discharges.

3. **Nitrogen Contents:** Nitrogen appears as
   1. Ammonia Nitrogen or Free Ammonia: It is the very first stage of decomposition of organic matter. It exists in aqueous solution as either ammonium ion or ammonia depending upon the pH.
   2. Organic Nitrogen: It is determined by Kjeldahl method. The sum of organic & ammonia nitrogen is called Total Kjeldahl nitrogen
   3. Albuminoid Nitrogen: The quantity of nitrogen present in wastewater before the decomposition of organic matter is started. It indicates the amount of undecomposed nitrogenous material in the wastewater.
   4. Nitrites Nitrogen: Nitrites indicate the presence of partly decomposed organic matter.
   5. Nitrates Nitrogen: Nitrates indicate the presence of fully oxidized organic matter.

4. **Fats, grease & oils:** It is mainly contributed from kitchen wastes like butter, vegetable oils & fats. It is also discharge from industries like garages, workshops, factories etc. They interfere with biological action & cause maintenance problems.

5. **Surfactants:** It comes primarily from synthetic detergents. They are discharge from bathrooms, kitchens, washing machines etc.

6. **Phenols, pesticides & agricultural chemicals**: Phenols are found in industrial wastewater, if it is directly discharged into the rivers it causes serious taste problems in drinking water. Pesticides, agricultural chemicals result from surface runoff from agricultural, vacant, park lands.

7. **Toxic Compounds:** Copper, lead, silver, chromium, arsenic, boron (Toxic cations), Cyanides, chromates (Toxic anions) etc. results from industrial wastewaters.

8. **Sulphates, Sulphides and H_2S gas:** Sulphates & sulphides are formed due to decomposition of various sulphur containing substances present in wastewater. Anaerobic bacteria chemically reduce sulphates to sulphides and to H_2S.

9. **Other gases:** carbon-di-oxide, methane, Hydrogen sulphide, ammonia, nitrogen, oxygen are the common gases found in untreated wastewater.

10. **Oxygen Consumed:** It is the oxygen required for the oxidation of carbonaceous matter.

11. **Dissolved Oxygen:** It is the amount of oxygen in the dissolved state in the wastewater. Wastewater generally does not have DO, its presence in untreated wastewater indicated that the wastewater is fresh.

BIOLOGICAL CHARACTERISTICS

The biological characteristics of sewage are related to the presence of micro-organisms.

1. Aquatic plant
2. Aquatic animals
3. Aquatic molds, bacteria and viruses

Anaerobic processes

Decomposition of organic matter is called putrefaction & the result is called liquefaction as the solid organic matter is dissolved by enzymes. Anaerobic bacteria oxidize organic matter utilizing electron acceptors other than oxygen. In carrying out their metabolic process they produce CO_2, H_2O, H_2S, CH_4, NH_3, N_2, reduced organics & more bacteria. Treatment units which work on putrefaction alone are septic tanks, imhoff tanks and sludge digestion tanks.

Aerobic Processes

The work of the aerobic bacteria i.e. combination with oxygen is called oxidation. Aerobic bacteria utilize free oxygen as an electron acceptor. The end products of aerobic activity are CO_2, H_2O, SO_4, NO_3, NH_3 and more bacteria. Though each of the above two processes work in opposite direction the former by splitting up & the latter by building up, there is co-ordination between two. In the first stage, the anaerobic bacteria decompose complex organic matter into simple organic compounds while in the second stage; the aerobic bacteria oxidize them to form stable compounds.

OXYGEN DEMAND

The oxygen is demanded in wastewater for the oxidation of both inorganic & organic matter. It is expressed in following ways.

1. Biochemical oxygen demand (BOD)
2. Chemical Oxygen Demand (COD)
3. Total Oxygen Demand (TOC)
4. Theoretical Oxygen Demand (Th.OD)

Biochemical oxygen demand (BOD)

BOD is defined as the oxygen required for the micro-organisms to carry out biological decomposition of dissolved solids or organic matter in the wastewater under aerobic condition at standard temperature.

The BOD test results are used for the following purposes:

1. Determination of approximate quantity of oxygen required for the biological stabilization of organic matter present in the wastewater.
2. Determination of size of wastewater treatment facilities
3. Measurement of efficiency of some treatment processes.
4. Determination of strength of sewage
5. Determination of amount of clear water required for the efficient disposal of wastewater by dilution.

Chemical Oxygen Demand (COD)

COD can be determined only in 3 hours in contrast to 5 days of BOD test. In COD test, a strong chemical oxidizing agent is used in an acidic medium to measure the oxygen equivalent of organic matter that can be oxidized.

Total Organic Carbon (TOC)

It is used to evaluate the amount of organic matter present in the wastewater. The error in the analyses due to the presence of inorganic carbon can be eliminated by acidification & aeration of the sample prior to the analysis.

Total Oxygen Demand (TOD)

The TOD method is based on the quantitative measurement of the amount of oxygen used to burn the organic substances & to a minor extent, inorganic substances. It is thus the direct measure of the oxygen demand of the sample.

Theoretical Oxygen Demand (ThOD)

This is a theoretical method of computing the oxygen demand of various constituents of the organic matter present in wastewater. If we know the chemical formulae of the constituents of organic matter are known, ThOD can be easily computes.

Relative Stability

It is the ratio of available oxygen to the required oxygen satisfying first stage BOD.

Population Equivalent

P_E= (Total BOD5 of the industrial wastewater) / (BOD_5 value per capita/day)

PROBLEMS

1. Calculate the population equivalent of a city, given
   1. The average sewage from the city is $80*10^6$ l/day
   2. The average 5 day BOD is 250mg/l.

Solution: Average BOD_5=250mg/L

Average Sewage flow=$80*10^6$ l/day.

Total BOD5 load in daily sewage=250*80*106=$20000*10^6$ mg/day

= 20000kg/day

Assuming domestic sewage quantity=0.08kg/capita/day

Population equivalent=20000/0.08=250000 persons

2. Determine the ultimate BOD for a sewage having 5-day BOD at 200C as 160ppm. Assume the deoxygenation constant as 0.2 per day.

Solution: $BOD_5=Y_5=L_0-L_5= L_0(1-10^{-5K})$

BOD_5=160ppm

K=0.2 per day

$160= L_0(1-10^{-5K})$

$L_{0=}$213.7ppm

3. Find the rate constant (to base 10) at a temperature of 30^0C, if its value at 20^0C is 0.12 per day.

Solution: $K_T=K_{20}\theta^{T-20C}$

Since the temperature range is 20^0 to 30^0C, then

θ=1.056

$K_{30}=K_{20}\ (1.056)^{T-20}$

$K_{30}=0.12(1.056)^{30-20}$=0.207 per day

4. A 15 solution of sewage sample is incubated for 5 days at 20^0C. The depletion of oxygen was found to be 3ppm, determine the BOD of the raw sewage.

Solution: Dilution Ratio= 100/(% of solution)= 100/1=100

BOD_5= 3*100=300ppm

5. During BOD test conducted on a 5% dilution of waste, the following observations were taken.
   a. DO of aerated water used for dilution=3.6mg/l
   b. DO of original sample= 0.8mg/l
   c. DO of diluted sample after 5 day incubation=0.7mg/l. Assume deoxygenation constant at test temperature as 0.12.

Compute: 1. 5day BOD and 2. Ultimate BOD

Solution: The diluted sample contains 5% wastewater and 95% aerated water.

DO of test specimen = [DO of wastewater * its content]+ [DO of aerated water* its c content]

= (0.8*0.05) + (3.6*0.95)

= 3.46 mg/l

DO of incubated sample after 5 day = 0.7 mg/l

DO consumed = 3.46-0.7 = 2.76 mg/l

Dilution factor =100/5 = 20

BOD_5 = (DO consumed)*(Dilution Factor)

=2.76*20 = 55.2 mg/l

$y_t = L_0(1-10^{-5K})$

$y_5 = L_0(1-10^{-0.12*5})$

$= 0.7488L_0$

$L_0 = y_5/0.7488$

=55.2/0.7488 = 73.72 mg/l

MODULE 3

Disposal by dilution

The dilution method for disposing of the sewage can be favorable

1. When sewage is comparatively fresh
2. When the diluting water has a high DO content
3. Where diluting waters are not used for the purpose of navigation

4. Where the flow of currents of the diluting water are favorable, causing no deposition, nuisance or destruction of aquatic life
5. When the outfall sewer of the city or the treatment plant is situated near natural waters.

Dilution in Rivers and self-purification of natural streams

1. Physical forces
   a. Dilution and dispersion
   b. Sedimentation
   c. Sunlight
2. Chemical forces
   a. Oxidation
   b. Reduction

Dilution and Dispersion

When the putrescible organic matter is discharged into a large volume of water contained in the river stream, it gets rapidly dispersed and diluted. The action thus results in diminishing the concentration of organic matter and thus reduces potential nuisance of sewage.

Sedimentation

The Settleable solids if present in sewage effluents will settle down into the bed of the river, near the outfall of sewage thus helping in the self-purification process.

Sunlight

The sunlight has a bleaching and stabilizing effect of bacteria. It also helps certain microorganisms to derive energy from it and convert themselves into food for other forms of life through photosynthesis.

Oxidation

The oxidation of organic matter present in sewage effluents, will start as soon as the sewage outfalls into the river water containing DO. The process of oxidation will continue till the organic matter has been completely oxidized. This is the most important action responsible for affecting self-purification of rivers.

Reduction

The various factors on which these natural forces of purification depend are:

- Temperature
- Turbulence

- Hydrography

Zones of pollution in a River-Stream

1. **Zone of degradation:** This zone is characterized by water becoming dark and turbid with formation of sludge deposits at the bottom.
2. **Zone of active decomposition:** This is characterized by heavy pollution by water becoming grayish and darker than in the previous zone.
3. **Zone of Recovery:** In this zone the river stream tries to recover from its degraded condition to its former appearance.
4. **Zone of cleaner water:** In this zone river attains original conditions with DO rising up to the saturation value.

Indices of self-purification

Oxygen deficit (D) = Saturation D.O. – Actual D.O.
De-oxygenation curve: In a polluted stream, the DO content goes on reducing due to decomposition of volatile organic matter. The rate of de-oxygenation depends upon the amount of the organic matter remaining to be oxidized at the given time as well as on the temperature of reaction.

Re-oxygenation curve: In order to counter balance the consumption of DO due to deoxygenation atmosphere supplies oxygen to the water and the process is called reoxygenation.
Oxygen deficit curve: In a running polluted stream exposed to the atmosphere, the deoxygenation as well as the reoxygenation goes hand in hand. If deoxygenation exceeds reoxygenation then oxygen deficit will result.

Stratification in Lakes

Biological zones in lakes

1. Euphotic zone: The upper layer of lake water through which sunlight can penetrate is called Euphotic zone
2. Littoral zone: The shallow water near the shore, in which rooted plants grow is called littoral zone.
3. Benthic zone: The bottom sediments in a lake comprise what is called benthic zone.

Productivity of a lake

1. Oligotrophic lakes
2. Mesotrophic lakes
3. Eutrophic Lakes

4. Senescent Lakes

DISPOSAL ON LAND

The method will help in increasing crop yields as the sewage generally contains a lot of fertilizing minerals and other elements.
The effluent irrigation method for disposal of sewage can be favorably adopted under the following conditions

1. When some natural rivers are not located in the vicinity.
2. When irrigation water is scarcely available broad irrigation may be practiced over it with the help of sewage effluents.
3. In areas of low rainfall
4. When sandy, loamy or alluvial soils are present.
5. When areas of low water table

Effluent irrigation

The chief consideration is the successful disposal of sewage.

Sewage Farming

The stress is laid upon the use of sewage effluents for irrigating crops and increasing the fertility of the fertility of soil.

Methods of applying sewage effluents to farms

1. Surface irrigation called broad irrigation
2. Sub surface irrigation
3. Sprinkler or spray irrigation

Sewage sickness

When sewage is applied continuously on a piece of land, the soil pores or voids may get filled up and clogged with the sewage matter retained in them. The time taken for such a clogging will of course depend upon the type of soil.

Preventive measures

1. Primary treatment of sewage
2. Choice of land
3. Under-drainage of soil
4. Giving rest to the land

5. Rotation of crops
6. Applying shallow depths

PROBLEM

1. A stream, saturated with DO has a flow of 1.2m3/s, BOD of 4mg/l & rate constant of 0.3 per day. It receives an effluent discharge of 0.25m3/s having BOD 20mg/l, DO 5mg/l & rate constant 0.13 per day. The average velocity of flow of the stream is 0.18 m/s. Calculate the DO deficit at point 20km & 40km downstream. Assume that the temperature is 200C throughout & BOD is measured at 5 days. Take saturation DO at 200C as 9.17mg/l.

Solution: y_5=BOD of the mix

Q_s= Stream Flow=1.2m^3/s

y_s=BOD of stream=4mg/l

Q_e=Effluent discharge=0.25m^3/s

y_e=BOD of effluent=20mg/l

$y_5=(Q_s y_s+Q_e y_e)/(Q_s+Q_e)$

=(1.2*4)+(0.25*20)/(1.2*0.25)

=6.759 mg/l

$y_5=L_0(1-10^{-Kt})$

$6.759=L_0(1-10^{-0.13*5})$

L_0=8.71mg/l

$(DO)_s$=Saturation DO of stream at 200C

$(DO)_e$= Do of effluent = 5mg/l

$(DO)_{mix}=(DO)_S*Q_s + (DO)_e*Q_e / (Q_s+Q_e)$

= (9.17*1.2) + (5*0.25) / (1.2+0.25)

= 8.45 mg/l

1. DO deficit at a point 20km downstream

t=distance/velocity= (20*1000)/(0.18*60*60*24)

=1.286days

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Using streeter-phelps equation

$D_t=KL_0/(R-K)[10^{-Kt}-10^{-Rt}] + D_0 10^{-Rt}$

$=0.13*8.71/(0.3-0.13)[10^{-0.13*1.286}-10^{-0.3*1.286}] + 0.72*10^{-0.3*1.286}$

=2.089mg/l

2. DO deficit at a point 40km downstream

t=40*1000/(0.18*60*60*24)=2.572 days

$D_t=0.13*8.71/(0.3-0.13)[10^{-0.13*2.572}-10^{-0.3*2.572}] + 0.72*10^{-0.3*2.572}$

=2.079 mg/l

2.A town discharges 80cumecs of sewage into a stream having a rate of flow of 1200 cumecs during lean days, at a 5-day BOD of sewage at the given temperature is 250mg/l. Find the amount of critical DO deficit & its location in the downstream portion of the stream. Assume deoxygenation coefficient K as 0.1 & coefficient of self-purification (fs) as 3.5. Assume saturation DO at given temperature as 9.2mg/l.

Solution: (DO)stream=9.2mg/l

$(DO)_{effluent}=0$

$(DO)_{mix}=(9.2*1200)+(0*80)/(1200+80)$ =8.625 mg/l

Initial DO deficit=D_0=9.2-8.625=0.575mg/l

5day BOD of the mix y_s =(0*1200)+(250*80)/(1200+80)=15.625mg/l.

$y_s=L_0[1-(10^{)-K*5]}$

$15.626=L_0[1-(10^{)-0.1*5}]$

L_0=22.85mg/l

$t_c=1/(K(f_s-1)\log_{10}[f_s\{1-(f_s-1)D_0/L_0\}]$

=2.063days

$D_c=L_0/f_s(10^{)-Ktc}$

=22.85/3.5(10)-0.1*2.063=4.06mg/l

$X_c=v*t_c=0.12(2.063*24*60*60)*10^{-3}$

21.39km

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Sewage treatment or **Municipal wastewater treatment** is the combination of **physical** and **biological process** with chemical process occasionally applied additionally to bring the sewage to such a quality that it is not harmful to human health and environment.

Purpose of Sewage Treatment

The sewage is treated before its final disposal because of the following reasons:

1. To kill the pathogenic bacteria present in the sewage which may result in water borne diseases like cholera, typhoid, dysentery etc.
2. To avoid unhygienic condition in the area because of highly fouled sewage.
3. To protect aquatic life from harmful effects of sewage directly discharged into the water body (river or sea).
4. The stagnant sewage may percolate into the soil and pollute the ground water reservoir which may lead to epidemics.
5. Treatment makes the possibility of reuse of valuable fresh water for agriculture purposes.
6. The treated sewage may be used for reclamation of land.

Classification of Sewage Treatment

1. Preliminary Treatment (Physical)
2. Primary Treatment (Physical)
3. Secondary (Biological)
4. Trickling Filter (Biological)
5. Advance Treatment Activated Sludge Process (Physical, Chemical and Biological)

Preliminary Treatment

It consists of removal of floating material (like dead animals, tree branches, papers, plastics, wood pieces, vegetables peels etc.) and also the heavy Settleable inorganic solids (grit etc.). Preliminary treatment includes: *Screening*, *Comminutors*, *Grit Chamber*, *Detritus Chamber* and *Skimming Tank* **Preliminary Treatment**

Primary Treatment

It is a plain sedimentation process to remove suspended organic solids from the sewage. Chemical are sometimes used to remove finely divided and colloidal solids. **Primary Treatment**

Secondary Treatment

The secondary treatment is required to remove the soluble and colloidal organic matters which remain after primary treatment. As it is mostly biological process also called biological treatment.

Trickling Filter

Trickling Filter also known **as percolating** or **sprinkling** filter is like a well having depth up to about 2m and filled with some granular media. The **sewage** is sprinkled over the media which percolates through filter media and is collected through the under-drainage system. **Trickling Filter**

Sludge Treatment /Advanced Treatment

It may be defined as the sludge which settles down after the sewage has been agitated freely in the presence of abundant atmospheric oxygen. It contains a large number of aerobic bacteria and other organisms and acts a fertilizing constituent (agent).

Preliminary treatment

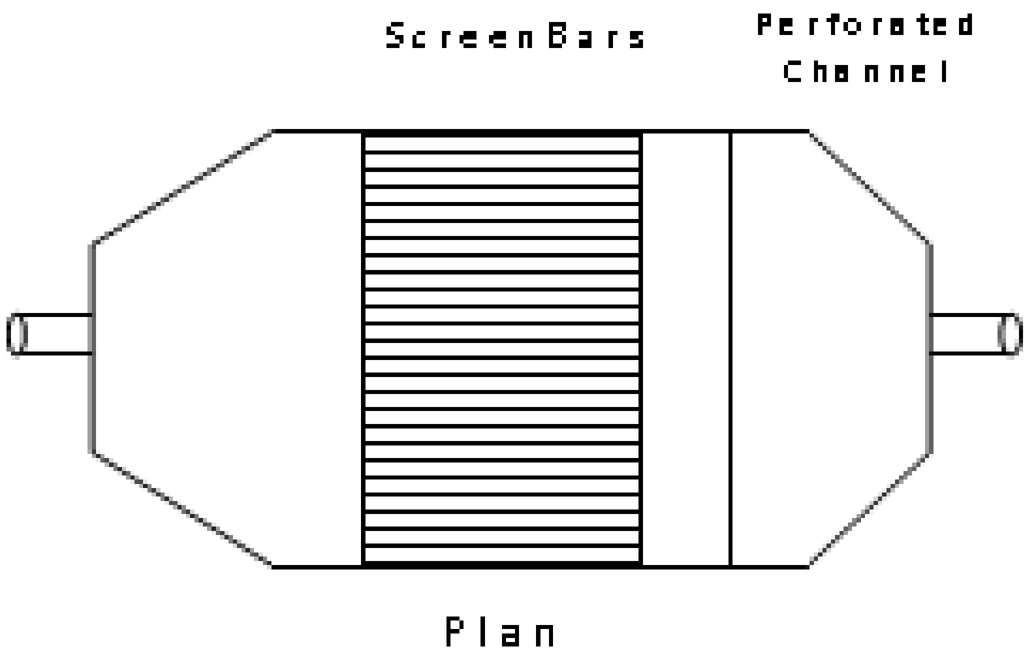
It consists of removal of floating material (like dead animals, tree branches, papers, plastics, wood pieces, vegetables peels etc.) and also the heavy Settleable inorganic solids (grit etc.). Preliminary treatment includes:

1. Screening
2. Comminutors
3. Grit Chamber
4. Detritus Chamber
5. Skimming Tank

Screening

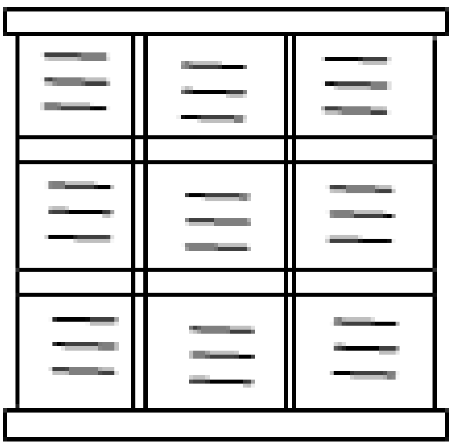
Screening is the removal of large size floating matters by a series of closely spaced bars placed across the flow inclined at $30^o – 60^o$. These floating materials, if not removed, will choke the pipes or adversely affect the working of the sewage pumps.

Screens should preferably be placed before the grit chambers, however, if the quality of grit is not important, as in the case of land sliding. Screens may be placed after the grit chamber or something within the body of the grit chamber.
The screens may be cleaned manually or mechanically, the waste accumulated is removed periodically which can be disposed of by burial, disintegration or used as fertilizers.



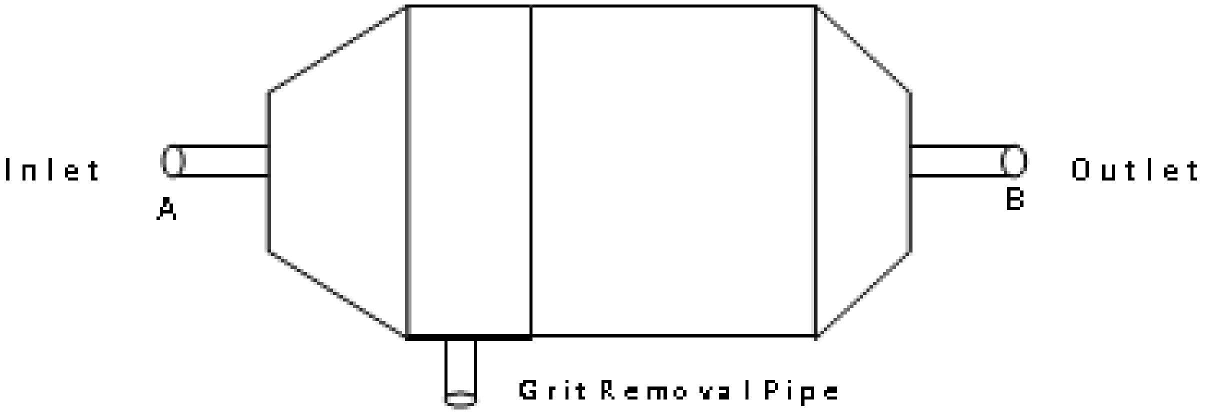
Comminutors

The larger suspended solids are reduced to smaller size by comminutors rather than removing by screens. The comminutors are usually provided in large plants. Comminutor consists of a fixed screen and a moving cuter or curved screen with rotating or oscillating cutter. A typical comminutor shown in the figure consists of rotating hollow cast iron drum about its vertical axis. Comminutors should be installed on the d/s end of grit chamber to avoid its excessive wear.



Grit Removal

Grits are heavy inorganic solids such as sand, metal fragments, egg shells of specific gravity ranging from 2 -2.65. They cause excessive wear during different treatment stages and therefore must be removed. A grit chamber may be horizontal flow or vertical flow and is manually or mechanically cleaned. Grit of a properly designed and operated chamber is free from organic matters which may be used as land fill. If grit contains organics in high proportion, it is disposed of by burial or used as manure.

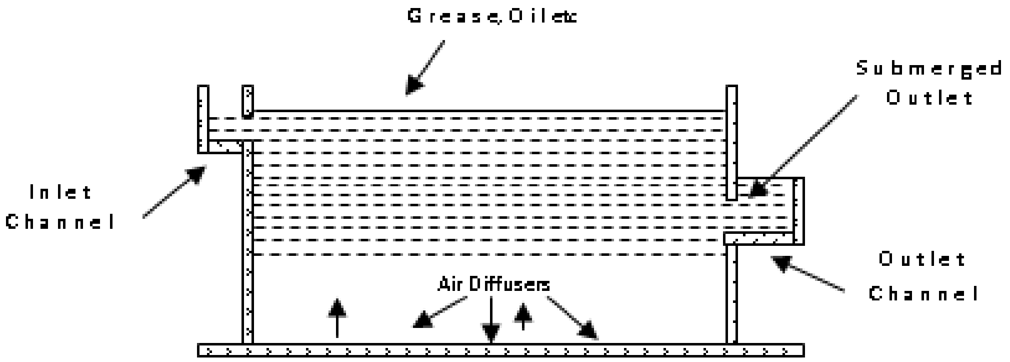


Detritus Chamber

They are installed to remove finer particles which are left from grit chamber.

Skimming Tank

It is used to separate grease and oil and other floating matters which may adversely affect the efficiency of the treatment facilities. Grease may tend to trap trickling filter and coat the biological flock in the activated sludge process. The floating matters may be collected by continuous mechanical process or by hand manually. They have baffled entrance and outlet.



Skimming Tank

Designing criteria
Horizontal velocity = 5 – 25 cm/sec
Retention / detention time ≤ 15 min
Depth of tank = 1 m

Primary Treatment of Wastewater

Primary Treatment of Wastewater is a plain sedimentation process to remove suspended organic solids from the sewage. Chemical are sometimes used to remove finely divided and colloidal solids.

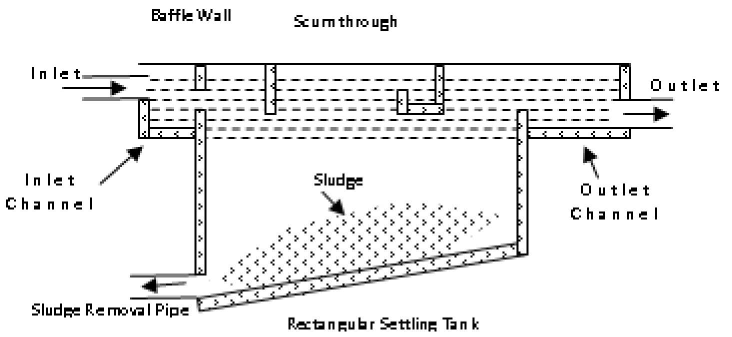
Objectives of Primary Treatment

The main objectives of primary treatment of wastewater are:

1. To reduce the strength of sewage to the extent of 30% to 50%.
2. To remove Settleable solids by 80% to 90%.
3. To reduce BOD by 30% to 35%.
4. To make the sewage fit for further treatment process.
5.

Primary Sedimentation Tank

Primary sedimentation tank is also known as primary clarifier and is located just after grit chamber. It may be rectangular, circular or square shape. The principle and construction details are same as that of plain sedimentation tank of W.T.P.



Design Specifications of Primary Sedimentation Tank

1. Hydraulic loading rate (surface overflow rate)/settling velocity V_s = (0.3 – 0.7) mm/sec (1 – 2.5 m/hr)
2. Detention time / retention time T_d = 1 – 2 hrs
3. Depth of Tank = (1 – 5) m
4. BOD removal (20 – 40) %
5. Suspended solids removal (30 – 60) %

6. Minimum number of tanks = 2
7. Sludge accumulated = 2.5 Kg of wet solids / m^3 of flow.

Types of Primary Sedimentation Tanks

1. Typical primary sedimentation tank
2. Circular Radial Flow Tank
3. Up Flow Tanks

PROBLEMS

1. Design a primary sedimentation settling tank of rectangular shape for a town having a population of 50000 with a water supply of 180litres per capita per day.

Solution: Assume 80% water supplied to the city is converted into sewage.

$$=(80/100)*50000*180=7200*10^3 \text{ l/day.}$$

Capacity required=7200/24*2=600m^3

Let us assume an overflow rate of 30m^3/d/m^2 for average flow

Surface area=7200/30=240m2

Effective depth=600/240=2.5m

B*L=240

L=4B

B*4B=240

B=7.5m & L=30m

Provide 4m for inlet & outlet arrangements

Total length=30+4=34m

Provide 1m depth for sludge accumulation & 0.5m as free board.

Total Depth=2.5+1+0.5=4m

Dimensions of the tank will be 34m*7.5m*4m.

2. Design a circular primary settling tank for a town having a population of 50000 with a water supply of 180litres per capita per day.

Solution: Sewage flow=7200m^3/day

Capacity required=7200*2/24=600m^3

Let us provide an overflow rate of 30m3/d/m2

Surface area required=7200/30=240m2

Diameter of the tank=$\sqrt{(240*4)/\pi}$=17.5m

Effective depth of tank=capacity/surface area=600/240=2.5m

Provide 1m extra depth of sludge accumulation & 0.5m depth as free board.

MODULE 4

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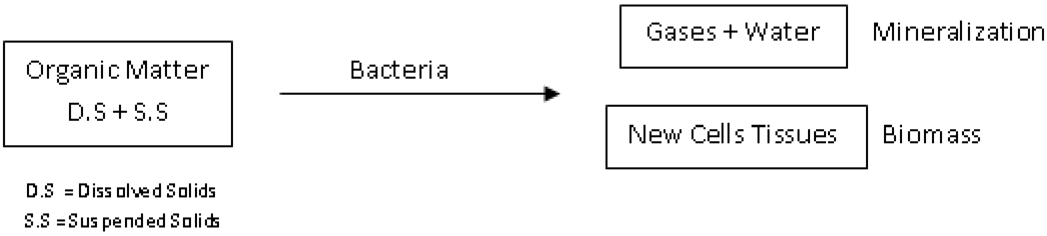
Secondary Treatment

The **secondary wastewater** treatment is required to remove the soluble and colloidal organic matters which remain after primary treatment. As it is mostly biological process also called biological treatment.

In the treatment the bacteria present in sewage and other micro-organisms are allowed to use the organic matters as their food and oxidize them to stable compounds like water gases (Co_2, NH_3, CH_4, $H_2$5 etc.) and new cells. The process may occur naturally at slow rate or biological treatment is done to increase the rate of reaction by having large number of organisms in a small container.



Types of Biological Waste Water Treatments

1. Attached Growth Process
2. Suspended Growth Process

Attached Growth Process

They are biological treatment process in which micro-organisms, responsible for the conversion of organic matters in waste water to gasses and new cells are attached to some inert medium such as rocks or some specially designed plastic materials e etc. They are also called fixed film process. The efficiency of these processes depends on the area of inert material available for growth. Some of the processes are:

- Contact Beds
- Intermittent Filter
- Trickling Filter
- Rotating Biological Contractor

Suspended Growth Process

They are biological treatment process in which the microorganisms responsible for the conversion of organic matters to gases and new cells are kept in suspension naturally or mechanically. Examples are

- Activated Sludge Process
- Aerated Lagoon
- Oxidation Ponds
- Sludge Digestion System

Trickling Filter

Trickling Filter also known **as percolating** or **sprinkling** filter is like a well having depth up to about 2m and filled with some granular media. The **sewage** is sprinkled over the media which percolates through filter media and is collected through the under-drainage system.

A modern trickling filter consists of a bed of highly permeable media to which micro-organism are attached and sewage percolates or trickle down and hence the name **"Trickling Filter"**. The filter media consists of rocks varying in size from 25-100mm. The depth of rock varies from 0.9-2.5m averaging 1.8m. A rotating arm (distributor arm) is provided to evenly distribute sewage. The air is also provided through under-drainage system from ventilation of filter.

Working Mechanism of Trickling Filter

The settled sewage from primary sedimentation tank is sprinkled intermittently over the filter bed when sewage trickles down, a microbial layer develops on the surface of rock which is called slime layer which is mostly consist of bacteria. (Oxidation of the organic matter is carried out under aerobic conditions. A bacterial film is formed around the particles of the filtering media and for the existence of this film oxygen is supplied by the intermittent working of the filter and by the provision of the suitable ventilation facilities in the body of the filter). The sewage is oxidized by the bacteria producing effluent in the form of water, gases and new cells.

Classification of Trickling Filters

1. Conventional trickling filter or ordinary trickling filter or standard rate or low rates trickling filter.
2. High rate or high capacity trickling filters

1. Low Rate Filters

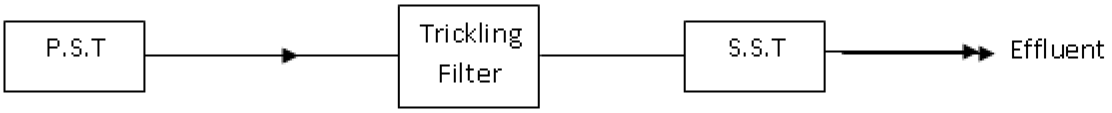
They are also known as standard rate or conventional rate filters. The settled sewage is applied to the filter bed and after trickling through it, passes through the final sedimentation tank for removal of most of the stabilized solids.

2. High Rate Filters

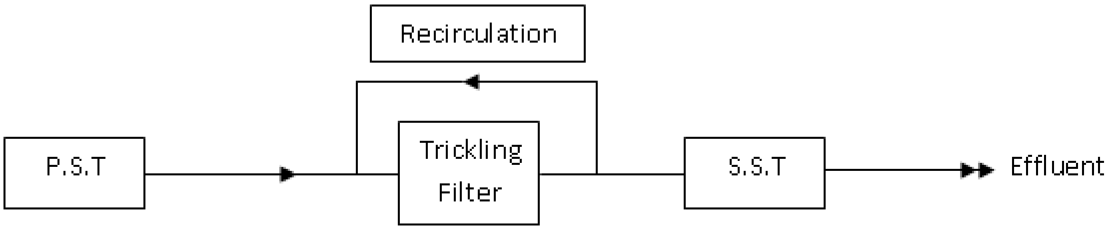
In case of high rate trickling filters the settled sewage is applied at much higher rate than for the low rate filter. The high rate filters of modern advancements also function on the same lines and having the same construction detail but with the difference that provision is made in them for recirculation of sewage through the filter by pumping a part of the filter effluent to the primary settling tank (or the dosing tank of trickling filter) and re-passing it through filter.

Recirculation of High Rate Trickling Filters

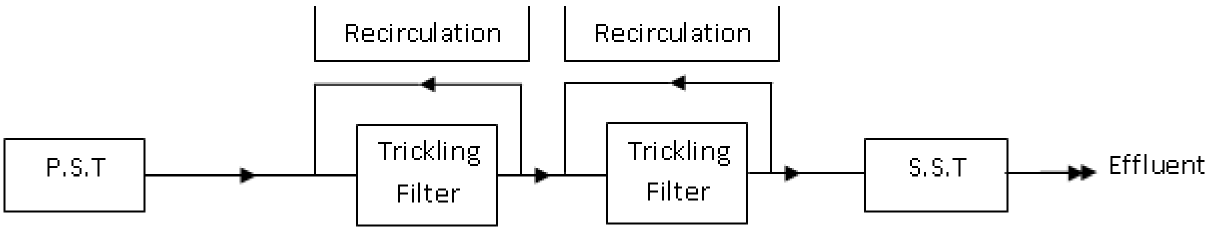
To increase the load rate of trickling filter the sewage is an essential and important feature of high rate filters. The recirculation consists in returning portion of the treated or partly treated sewage to the treatment process (i.e. filter).



Low Rate/Standard Trickling Filter (No Recirculation)



Single Stage High Rate Trickling Filter



Two Stage High Rate Trickling Filter

Comparison of Standard Rate Trickling Filter SRTF and High Rate Trickling Filter HRTF

S. No	Parameters	S R T F	H R T F
1	Hydraulic loading rate (m^3/m^3-day)	1-4	10-40
2	Organic loading rate (kg of 80D/m^3-day)	0.08-0.32	0.32-1
3	Depth of filter	1.5-3m	1-2m
4	Recirculation ratio	Generally zero	1-2
5	Dosing Interval	3-10 minutes Intermittent	> 15 seconds Continuous
6	Cost of operation	More	Less
7	Effluent quality	Highly nitrified	Nitrified up to nitrate stage
8	Water requirements	Less	More
9	Land requirement	More	Less
10	Size of filter media	25-100 mm	30-60 mm

Advantages of Recirculation

1. It allows contains dosage regardless of fluctuating in sewage flow and thus keeps the bed working.
2. It dilutes the influent with better quality water and this making it fresh and reduces odor.
3. It maintains a uniform rate of organic and hydraulic loading.
4. It provides longer contact of the applied sewage with the bacterial film on the contact media and accelerating the biological oxidation process.
5. It increases the efficiency by reducing the BOD load generally.

Advantages and Disadvantages of Trickling Filter

Advantages of Trickling Filter

- Rate of Filter loading is high as required less land areas and smaller quantities of filter media for their installations.
- Effluent obtained from the trickling filter is sufficient stabilized.
- Working of Trickling filter is simple and does not require any skilled supervision.
- They are flexible in operation.
- They are self-cleaning
- Mechanical wear and tear is small as they contain less mechanical equipment.

Disadvantages of Trickling Filter

- The beds loss through these filters is high.
- Construction cost is high
- These filters cannot treat raw sewage and primary sedimentation is must.
- Fly nuisance and odor nuisance may prevail.

PROBLEMS

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

a. Sewage flow = 4.5mld

b. Recirculation ratio = 1.5;

c. BOD of raw sewage = 250mg/l

d. BOD removal in primary tank = 30%

d. Final effluent BOD desired = 30mg/l

Solution: Quantity of sewage flowing into the filter per day = 4.5 M.l/day

BOD concentration in raw sewage = 250mg/l

Total BOD present in raw sewage = 4.5Ml*250mg/l

=1125kg

BOD removed in primary tank = 30%

BOD left in the sewage entering per day in the filter unit = (1125)*0.7

=787.5 kg

BOD concentration desired in final effluent = 30mg/l.

Total BOD left in the effluent per day = 4.5 * 30 kg

=135 kg

BOD removed by the filter = 787.5 – 135

= 652.5 kg

Efficiency of the filter = BOD removed/ Total BOD*100

= 652.5/787.5 *(100) = 82.85%

$\eta=100/(1+0.0044\sqrt{Y/V.F})$

$\eta=82.85\%$

Y= Total BOD in kg=787.5kg

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$F=(1+(R/I)/(1+0.1(R/I))^2$ Here R/I= 1.5

$F=1+1.5/[1+0.1*1.5]^2$

$=2.5/(1.15)^2=2.5/1.322=1.89$

$82.85=1000/(1+0.0044\sqrt{787.5/V*1.89})$

$1+0.0044*\sqrt{416.6/V}=1.2$

OR $\sqrt{416.6/V}=0.2/0.0044$

$=45.45$

$416.6/V=2066.1$

V=0.2 hectare-m.

$= 2000m^3$

Assuming the depth of the filter as 1.5m, we have

The surface area required=2000/1.5 m2

$=1333.3m^2$

Diameter of the circular filter required = $\sqrt{1333.3*4/\pi}$

=41.2m

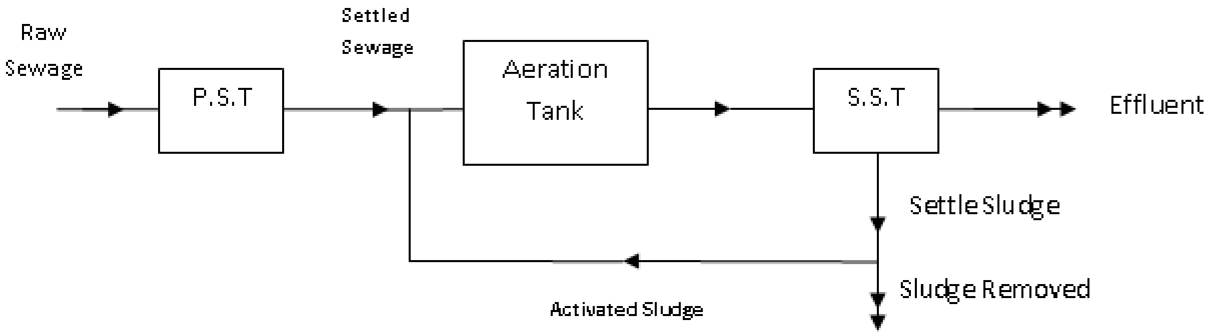
Hence, use a high rate trickling filter with 41.2m diameter., 1.5m deep filter media and with recirculation (single stage) ratio of 1.5.

Activated Sludge

Activated sludge may be defined as the sludge which settled down after the sewage has been agitated freely in the presence of abundant atmospheric oxygen. Activated sludge contains a large number of aerobic bacteria and other organism and acts as a fertilizing constituent (agent) when it is mixed with raw sewage containing sufficient O_2 , the bacteria perform two functions.

1. It oxidizes organic solids.
2. Promotes coagulation and flocculation and converts colloidal and dissolved solids into Settleable solids.

The flow diagram of activated sludge process is shown in the figure below:



The **settled sewage** from P.S.T is mixed with required amount of activated sludge coming from S.S.T. The resultant mixture is called "Mixed Liquor Suspended Solid (MLSS)".

MLSS is passed through aeration tank where it is mixed with air for 4-8 hours. The sewage is oxidized by bacteria in the presence of O_2 due to which BOD of sewage is reduced. The aerated MLSS is then sent to S.S.T where is allowed to settle. The effluent is discharged off and some of the settled sludge is recirculated as activated sludge and the rest is disposed of after treatment.

The effluent of S.S.T is sparkling clear water and contain very small amount of organic matters and can be disposed of without any further treatment except chlorination which is employed occasionally.

Design Criteria of Activated Sludge

Mixed Liquor Suspended Solid (MLSS) It represents the strength of mixed liquor suspended solid in term of conc of microorganism in aeration tank. Its value in A.T varies from 1500-3000 mg/l and the permissible limit being 2100-2500 mg/l. MLSS above (75000-10000) mg/l is too much.

F/M Ratio. It represents the food to microorganism ratio and is given by

F/M = BOD/MLSS*(V/Q) = BOD/MLSS*td (day^{-1})
V = Volume of AT (m^3)
Q = flow rate (m^3/day)
T_d = detention time (day)
BOD (mg/l) and MLSS (mg/l)
Its allowable value is (0.2 – 0.5) day^{-1}

A great value means more food which is wasted and less value means less food and death of bacteria.

Sludge Volume Index (S.V.I)

It is the volume in ml occupied by 1gm of settled suspended solid. It is used to indicate the degree of concentration of sludge reflecting the physical state of sludge and also shows the settleability of sewage. It is found with the help of Imhoff. One liter of sample collected at the outlet of A.T is placed at rest for about 30 minutes in Imhoff tank. The volume of settled sludge (V_s) is found and Sludge Volume Index (SVI) is calculated from

S.V.I = (V_s x 1000)/MLSS (ml/g)

The value of SVI ranges from 50-150 ml/g means good settleability.

Sludge Recirculation Ratio (r). It is the ratio of return sludge to sewage flow. It is also called **return sludge ratio**.

Return sludge ratio = Qr/Q = V_s/ (1000-V_s)

Where

V_s = volume of settled sludge in Imhoff cone. Its value varies from 0.25 to .5 ml/l.

Detention time = td = 4 – 8 hrs (in A.T)

Air supply = 10 m^3/m^3 of sewage treated / day

L : B = 5 : 1

Depth of A.T = 3.5 m

Dissolved oxygen level (D.O) < 2mg/l

Minimum number of A.T = 2

Aeration and Methods of Aeration in Activated Sludge Process

The process of absorbing oxygen from air is known as aeration. High amount of O^2 is provided in the aeration tank because of high BOD in sewage. This cannot be provided naturally therefore aerators are used to provide O^2 artificially. When the dissolved oxygen level (D.O) falls below 2mg/l anaerobic activities starts.

There are three methods for aeration in activated sludge process.

1. Diffused air aeration
2. Mechanical aeration
3. Combine aerator

Advantages of Activated Sludge Process

1. Low installation cost
2. Good quality effluent
3. Low land requirement
4. Loss of head is small
5. Freedom from fly and odor nuisance high degree of treatment

Disadvantages of Activated Sludge Process

1. Not very flexible method (If there is sudden increase in the volume of sewage or if there is sudden change in the character of sewage, there are adverse effects on the working of the process and consequently the effluent of bad quality is obtained).
2. Operation cost is high
3. Sludge disposal is required on large scale
4. This process is sensitive to certain industrial wastes
5. Skilled supervision is required to check that the returned sludge remains active

Aeration

The **process** of **absorbing oxygen** from air is **known as aeration**. High amount of O^2 is provided in the aeration tank because of high BOD in sewage. This cannot be provided naturally therefore aerators are used to provide O^2 artificially. When the dissolved oxygen level (D.O) falls below 2mg/l anaerobic activities starts.

Aeration Methods in Activated Sludge Process

There are three **methods for aeration** in activated sludge process.
1. Diffused air aeration
2. Mechanical aeration
3. Combine aerator

1. Diffused Air Aeration

In diffused air aeration method compressed air is blown through the sewage and air is diffused in sewage by diffuser. Diffusers are of two types: ***Plate diffuser*** and ***Tube diffuser***

Plate Diffuser

They are rectangular/square plates made of crystalline alumina or high silica sand. In this method the compressed air is blown through a perforated plate diffuser. The air comes out through the holes of the diffuser plate and rises upward in the form of bubbles. Thus the sewage absorbs oxygen from the air.

Tube Diffuser

It consists of a perforated tube suspended in the waste water near the bottom and can be taken out while cleaning. The compressed air is dent through the tube. The air comes out through the holes with great force and agitates the sewage.

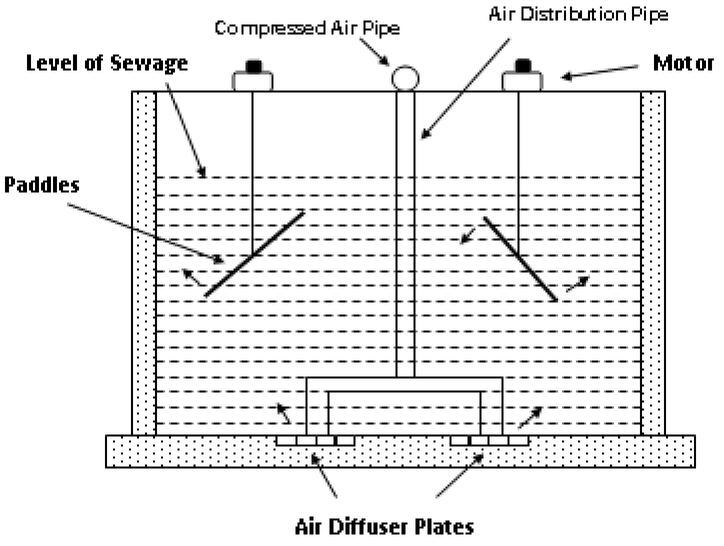
2. Mechanical Aeration

In this method the surface of sewage is agitated violently with the help of some mechanical equipment to encourage absorption of oxygen from atmosphere. There are two well-known forms of mechanical aerator. ***Vertical surface aerator*** and ***Horizontal surface aerator***

They consist of electrically driven propellers (vanes) mounted in either a floating or fixed supports. They throw the bulk liquid (sewage) through air and oxygen transfer occurs both at the surface of the droplets and at the surface of the bulk liquid and is then mixed by the currents produced by agitation. In this method the performance is seriously affected by ice formation in winter.

3. Combine Aerator

In this system, diffused air aeration and mechanical aeration are combined in a single unit. The well-known type of such combination is **Dorroco aerator.** The aeration of sewage is done by air diffusers as well as mechanical aerators. Air diffuser plates are located at the bottom of tank and the submerged paddles rotate in the direction opposite to that in which the compressed air rises up from the air diffusers. Paddles are rotated by a motor on a horizontal shaft with a speed of 10-12 rpm.



Dorroco Aerator

Advantages of Combine Aerator

1. **Aeration** is very efficient
2. Detention period is reduced (3-4 hrs)
3. Quantity of compressed air required is less as compared to the diffused air aeration.

Sludge treatment and disposal

The treatment and final disposal of the produced primary and secondary excess sludge takes up a significant part of the material- and financial resources of the waste water treatment plant. The excess sludge from an activated sludge process has three undesirable aspects:

- Biological instability: the excess sludge is putrescible due to the high fraction of biodegradable organic matter and enters into decomposition within hours after the interruption of aeration
- The hygienic quality of the excess sludge is very poor: a very large variety of viruses, bacteria and other pathogens (protozoa, amoebae, helminth eggs) are present
- The suspended solids concentration in the excess sludge is low: in the range of 3 to 50 g.l, depending on the origin of the sludge and on the type of solid-liquid separation process used, resulting in a large volume of excess sludge to be handled

The two main objectives of sludge treatment processes are therefore to:

- Increase the concentration of solids, in order to reduce the excess sludge volume to be treated and disposed-of
- Reduce the fraction of biodegradable matter and the pathogen concentration, in order to obtain a stable and safe end product that does not constitute a public health risk

It will be shown that the gravitary sludge thickener is a small but indispensable unit, as it provides a low-cost method to increase the excess sludge concentration and hence reduces overall investment costs. For sludge stabilisation two biological processes can be used : aerobic- and anaerobic digestion. Both processes will have a positive influence on the hygienic quality of the sludge. After digestion, the reduction of the water content of the sludge is effected by applying physical processes (filtration, centrifugation, flotation or evaporation), possibly preceded by preparatory processes to accelerate or enhance liquid-solid separation, such as coagulation and flocculation with metal salts or poly-electrolytes.

In this section the following subjects will be discussed:

- Excess sludge quantity and composition
- Aerobic sludge stabilisation
- Anaerobic sludge stabilisation

MODULE 5

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Sewage disposal

Composition of Sewage.—When a house is supplied with running water, the ordinary method of disposing of most household wastes is to transport them by flowing water to a disposal plant. The mixture of household wastes and water is called sewage. The amount of sewage that is produced in a house is nearly equal to the quantity of water that is used in the house.

Sewage consists of the waste water from kitchens, laundries, and bathrooms, and of human excretions mixed with a large quantity of water. Each 1000 parts of sewage contains only about 1 or 2 parts of solid matter, of which about one-half is suspended in the water and one-half is dissolved. Somewhat more than one-half of the solids of sewage are decomposable organic matter, and the remainder consists of substances (such as minerals) which will not decompose. There is not much difference in the average composition of samples of sewage from various sources, whether they are taken from a large public sewer or from the discharge pipe of a small house.

Sewage contains 1,000,000 or 2,000,000 bacteria in each cubic centimeter. About 10 per cent. of the bacteria are colon bacilli from the human intestine. Some may be disease germs that were discharged from the bodies of human beings. Most of the bacteria are the ordinary ones of decay and putrefaction.

Dangers from Sewage.—Sewage is dangerous to health principally on account of the disease germs which it contains. The principal danger is that the sewage may convey the disease germs into a well or stream or ether source of water-supply. The danger is not proportional to the number of germs that enter the water. A few in a glass of drinking-water are almost as dangerous as large numbers. The great volume of water with which human excretions are mixed in sewage makes it probable that disease germs will be carried into a water-supply from an elaborate sewer system more readily than they will from the undiluted excretions of a primitive disposal place. The conveniences of plumbing and of a sewage system are accompanied by an increased responsibility for care in the final disposal of the sewage.

Sewage flowing into a body of water is a menace to the health of those who bathe in the water. There is a possibility that oysters taken from sewage-laden water may contain disease germs. The pollution of salt waters at seaside resorts may affect the health of visitors from inland towns, and of people of communities in which oysters are received from polluted waters. The sewage disposal system of a community may have an influence on the health of people living far away from the community.

Another danger from sewage is that house-flies may transmit disease germs from it to food or to the mouths and eyes of persons.

An argument for the proper disposal of sewage is that it is offensive to sight and smell, and is a nuisance that is not to be tolerated in respectable communities. Cesspools overflowing on the ground are among the principal nuisances with which a rural health officer has to deal.

Disposal Systems.—The problem in sewage disposal is to remove the decomposable organic substances and the bacteria from the water, and to destroy them so that they will not be offensive to the senses or dangerous to health. An unsuccessful disposal method that has been thoroughly tested is that of holding the sewage in a tank and treating it with chemicals, such as copperas or alum, which will coagulate the solids so that they will either float on the surface or settle to the bottom. The clarified liquid may then be drawn off. This system is expensive, uncertain, and impractical, and a health officer will seldom need to give it consideration.

Another system is the distribution of the sewage over the surface of farm lands. This, too, has been thoroughly tried, and has nearly always proved unsuccessful. The sewage has very little fertilizing value; a large area is required for its disposal; the cost of labor makes the system expensive; and the presence of disease germs renders the crops dangerous for human food. A health officer will do right if he condemns a system of surface disposal because of danger to health and of expense.

A third system of sewage disposal is to discharge the sewage into a lake, or river, or bay, or other body of water. This is a dangerous method of disposal, especially if the body of water is used as a source of water-supply. The natural purification of the water depends largely on the oxidizing action of the oxygen that is naturally dissolved in the water. If the proportion of sewage to the water into which it is discharged is as 1 to 200, the quantity of oxygen in the water will be decreased to such a degree that some kinds of fish cannot live in the water. If the proportion of sewage to water is as 1 to 50, the quantity of oxygen will be decreased to such a degree that putrefaction may take place. But disease germs may remain alive in the water even though the water does not become offensive to the senses. One of the great problems with which departments of health have to deal is the prevention of pollution of bodies of water with sewage.
Nearly every system of sewage disposal with which a health officer has to deal depends for its action on bacterial decomposition, with a further purification by oxidation or by filtration through the soil. If the purification is complete, the organic substances in the sewage will either be removed or completely oxidized to carbon dioxide, water, and nitrates, sulphates, phosphates, and other minerals which are naturally found in ground water; and the water which flows away will be free from bacteria. It is possible to purify sewage to such a degree that it is fit for use as drinking-water.

The devices which are commonly used for purifying sewage are: 1, a collecting tank; 2, subsurface irrigation pipes; 3, a contact bed; 4, a sprinkling filter; 5, a sand filter; and 6, a chlorinating apparatus. These devices are often used in various combinations, as, for example, a collecting tank, a sprinkling filter, and a chlorinating apparatus.

Settling Tank.—Every efficient system of sewage disposal makes use of a collecting tank in which the raw sewage is received. A collecting tank is not filled and then emptied before it receives more sewage, but the sewage flows through it continuously. It is made of sufficient size to hold at least the quantity of sewage that is produced during twelve or twenty-four hours. The sewage therefore remains in the tank for from twelve to twenty-four hours, and during that time it undergoes two processes: 1, sedimentation, and 2, putrefaction. While sewage is flowing slowly through a collecting tank, the heavy particles of solid matter sink to the bottom, and the lighter ones float on the surface. For this reason a collecting tank is often called a settling tank or sedimentation basin. An efficient tank will usually remove somewhat less than one-half of the solid matters that are suspended in the sewage.

An active bacterial action also takes place in a collecting tank. The action is one of putrefaction, and for this reason the receptacle is often called a septic tank. The result of the putrefaction is to liquefy some of the solid bits of matter that float in the sewage, and to decompose some of the substances that are dissolved in it. The action is rapid during the first few hours that a particular mass of sewage remains in the tank, but after that period of time the action is slow. There is no advantage in retaining the liquid part of sewage in a septic tank for a longer time than a day. A septic tank will remove about half of the decomposable substances which are contained in sewage, and the effluent will undergo further offensive decomposition unless it is subjected to a greater degree of purification.

Cesspool.—The cesspool is the type of sewage disposal plant in which a health officer is especially interested, for it usually constitutes the entire disposal system of houses which are not connected with a public sewer system. A cesspool is an underground septic tank from which the liquid slowly escapes through the soil. The actions which take place in it are sedimentation and putrefaction. The liquid which escapes is slowly filtered through the soil, and its organic matter is slowly oxidized by the oxygen which penetrates the soil. The effluent finally reaches the underground water. The degree to which it is purified will depend largely on its quantity, the character of the soil, and the depth at which the ground water is reached. Fine sand makes an efficient filter. Coarse gravel, or a fissure in rock, allows the liquid to pass through almost unchanged. If the quantity is considerable, the purifying capacity of the soil may be exceeded. If the ground water lies near the surface of the soil, the purifying action will be slow, and the effluent will not soak away from the cesspool.

Safely of a Cesspool.—The safety and efficiency of a cesspool will depend principally on: 1, the capacity of the soil to absorb the effluent; 2, its nearness to a well or spring or other source of water-supply; and, 3, the care with which it, is maintained. If houses are near together, the soil may he saturated with sewage to such a degree that all the ground water is polluted. Under these conditions cesspools may still be safe if all the wells are closed and only a public water-supply is used. If the soil has not sufficient capacity to absorb the effluent, the installation of subsurface irrigation pipes will often solve the problem of the final disposal of the liquids.

Construction of a Cesspool.—A cesspool is usually constructed with circular sides and arched top, and is built of brick or stone laid without mortar. No bottom is laid in it, and perforations are sometimes left in its sides to allow the liquid to soak away readily. A standard size for a cesspool of an ordinary house is 7 feet in diameter and the same in depth.

It is necessary to provide a cesspool with a cover which fits tightly enough to exclude flies and mosquitoes. Uncovered cesspools breed a large proportion of the mosquitoes which annoy the people of villages. It is not necessary that the cover should be perforated for the escape of gases.
It is economic to construct two connected cesspools. The outlet pipe of the first cesspool is provided with an elbow which extends downward about 2 feet in order to draw oil only the portion of the liquid which is comparatively clear. The bottom of the first cesspool soon becomes clogged with sediment, but the bottom of the second cesspool should remain porous for years. The expense of frequently cleaning a single cesspool will soon exceed the cost of a second one.
Maintenance of a Cesspool.—A cesspool that is acting properly will act continuously for months and years. About a foot of sediment will collect on the bottom, and a foot of scum will float on the surface. This quantity of sediment and scum will not increase, for the processes of putrefaction will go on continuously, and will slowly reduce the solid matters to gases and liquids. The perfect action of a cesspool requires that the bacterial action shall be as active as possible. Some persons put chloride of lime or other antiseptics into their cesspools, expecting to lessen the offensiveness of the sewage. About the only effect of the antiseptic is the undesirable one of restraining the liquefying action of the bacteria, thus increasing the quantity of sediment and clogging the cesspool until it overflows. Antiseptics in a cesspool do more harm than good.
When the bottom of a cesspool becomes clogged, the proper remedy is to pump out the liquid contents and remove a few inches of the earth until clean soil is reached, and replace it with clean sand. If the bottom soil is simply turned over, the mud which clogs the soil remains, and the condition of the cesspool is soon as bad as ever.

Large quantities of gases, such as marsh gas, are produced during the process of putrefaction. The mixture of these gases with air is explosive, and serious accidents have resulted from lowering a lantern into the cesspools too soon after they were opened.

Subsurface Irrigation.—When the capacity of the soil to dispose of liquids is limited from any cause, such as the nearness of the ground water to the surface or the close texture of the subsoil, a system of subsurface irrigation is often used as an accessory to a cesspool. It is also well adapted as the main feature of the disposal plant of a large country house or a small institution. The system consists of small pipes of agricultural tiling laid with open joints in rows 3 to 6 feet apart a foot or two beneath the surface of the soil. The pipes receive the effluent from a cesspool or septic tank, and distribute it into the upper layers of the soil where the oxidizing and nitrifying bacteria are especially abundant and active. The pipes may be laid in a front yard with benefit to the lawn. An acre of subsurface irrigation tiling will take care of from 15,000 to 25,000 gallons of sewage effluent daily. The heat of the sewage will prevent the soil around the pipes from freezing even when the ground elsewhere is frozen.

Construction of a Subsurface Irrigation Bed.—The tiling of a subsurface irrigation bed is laid with a slope of about 4 inches in 100 feet in order that the in-flowing sewage will not rush to the outer end of the system, but will distribute itself uniformly through all the tiling. The joints are wrapped with a thin layer of excelsior, and their upper surfaces are covered with tarred paper in order to exclude sand and yet allow space for the escape of the liquid.

The raw sewage from a house is received into a dosing tank whose capacity is equal to that of the subsurface pipes. An automatic device discharges the contents of the filled tank suddenly in order that the whole pipe system may be flooded. While the tank is refilling, the liquid in the pipes soaks away, oxygen penetrates the ground, and the soil becomes prepared for a new dose of sewage. The service of a sanitary engineer is usually required in constructing a subsurface irrigation system.

When irrigation tiling is laid in order to increase the capacity of a cesspool located in a low area, it is usually impossible to construct a dosing tank. The effluent then drains into the tiling constantly, and there are a probability that a sediment will collect in the joints and finally clog them. One remedy for this condition is to build the cesspool above ground, sufficiently elevated to allow the construction of a dosing tank.

Elements in a Disposal Plant.—It is not economic to dispose of large quantities of sewage effluent by direct absorption into the soil. The plan that is usually adopted by a large institution, or a village, or a city is to subject the effluent to purification to a degree that it may be safely discharged into a stream or other body of water. Four processes of purification that are commonly employed are: 1, sedimentation in a septic, or settling, tank; 2, oxidation by aerobic bacteria; 3, filtration; and 4, chlorination. A septic or settling tank is nearly always used in every system for the preliminary treatment of the sewage.

Imhoff Tank.—When a large quantity of sewage is treated in a septic tank, there is a considerable accumulation of sediment called sludge. An Imhoff tank is a special form of receiving basin that is designed to liquefy the maximum amount of sludge, and to require the removal of the sludge with the least frequency. It consists of a deep concrete tank which is divided into an upper and a lower compartment. The bottom of the upper compartment opens into the lower by a narrow slit. The raw sewage is received into the upper compartment, and as it slowly flows along, its sediment falls into the lower compartment and there undergoes putrefactive decomposition. The action which takes place in the upper compartment is principally a sedimentation of the coarser solids with but little action by the anaerobic bacteria on the finer solids or the dissolved substances. The greater part of the purification of the liquid is accomplished later by aerobic bacteria to whose action the effluent is subjected either in a contact bed, or a sprinkling filter, or a sand filter.

Contact Bed.—A contact bed consists of a large tank about 3 feet deep filled with pieces of stone about the size of hen's eggs. The effluent from the sedimentation tanks is oxidized by aerobic bacteria which cling to the stones. After three or four hours the liquid is drawn off and the bed is allowed to lie empty for a few hours in order that a new supply of oxygen may penetrate the beds. A contact bed will remove about two-thirds of the organic matter and bacteria that is in the liquid. One acre of beds will treat about 500,000 gallons of sewage daily or about the quantity that is produced by 5000 people.

Sprinkling Filter.—A broken-stone bed in which the sewage is sprinkled upon the surface is called a sprinkling filler. Oxidation in it takes place rapidly owing to the intimate contact of the liquid with the air, and to the thin sheets in which it trickles clown between the stones. An efficient sprinkling filter will act about three times as rapidly as a contact bed, and will remove over 80 per cent. of the solids and bacteria from the sewage.

Sand Filter.—A sand filter consists of a bed of sand, usually about one-quarter of an acre in area and 4 feet deep, surrounded by an embankment, and under drained. The effluent from the collecting tank undergoes oxidation and filtration in it, and if the bed is working properly over 90 per cent. of the solids and bacteria are removed. The effluent is discharged upon a sand filter in a sudden gush only once or twice a day. The liquid soaks away quickly, and the nitrifying bacteria then act on the filtrate for some hours. If the bed is continuously soaked with sewage it will have little or no purifying action, owing to the impossibility of oxygen penetrating it. A sand filter is usually constructed in several beds, and the effluent is discharged upon each in rotation. An acre of sand filter will dispose of about 100,000 gallons of sewage daily, or about the quantity that is produced by 1000 persons. A sand filter is economic in sandy soils where land is cheap.

After a sand filter has been in use for some weeks, a scum of grease and fine solids forms on the surface and clogs the sand. It is necessary that each bed should be thrown out of use frequently and dried in order that the scum and an inch or two of the surface sand may be removed.
Late in the fall the surface sand of a filter must be deeply furrowed and ridged in order to prevent freezing. A layer of ice forms on the surface and is supported by the ridges. The ice protects the sewage and soil beneath it from freezing. A sand filter that is properly ridged will remain in good condition throughout a severe winter.

Chlorination.—The final process in the complete purification of sewage is the sterilization of the effluent with chlorine in the form of chloride of lime or of liquid chlorine. The chlorine acts by combining with the hydrogen of the impurities, thus forming hydrochloric acid and liberating oxygen in an active form. The oxygen immediately combines with the organic matter and bacteria and oxidizes them. The quantity of chlorine that is needed will depend on the amount of impurities that are in the liquid. From 1 to 10 parts of chlorine in each 1,000,000 parts of sewage are usually required.

Tests of Efficiency.—A health officer can perform two tests to determine the efficiency of a sewage disposal plant. The first test is the determination of the stability of the effluent, or its liability to undergo further decomposition and putrefaction. If the coarse particles are removed from sewage and the total amount of organic matter is reduced to a quarter of its original amount, the effluent will usually be stable. The test may be performed by taking a jar of the purified sewage and setting it aside for several days in a room of ordinary temperature. If no turbidity or offensive odor develops, the sewage is stable, and will not undergo decomposition when it is discharged into a body of water or upon a filter-bed. The effluent from a collecting tank or from a contact bed is seldom stable. That from a sprinkling filter or a sand filter is usually stable if the system is properly operated.

A second test of the efficiency of a sewage disposal system is the determination of the number of colon bacilli in the treated sewage. Intestinal bacteria are rather long lived in sewage, but they do not multiply in number. A disposal plant will reduce the number of colon bacilli in about the same degree that it reduces the quantity of organic matter. The reduction in the number of colon bacilli per cubic centimeter as the sewage passes through the disposal plant is therefore a reliable indication of the efficiency of the purification process, and of the destruction of disease germs which may be in the sewage. A health officer can have the test done by sending samples of the sewage to a laboratory in sterile 2-ounce bottles. A health officer must take a series of samples, one from the stream of sewage before it enters the collecting tank, one from the stream of effluent that flows from the tank, one from the effluent from the contact bed, or sprinkling filter, or sand filter, and one from the effluent after final sterilization. These samples will show a progressive diminution in the number of bacilli, and none will be found in the last sample if the system is 100 per cent. efficient.

Choice of a System of Disposal.—The system of disposal that is needed for a particular locality will depend largely on what disposition is finally made of the effluent. If the effluent is discharged into a large body of water, an Imhoff tank with chlorine treatment of the effluent will constitute an efficient system. If the effluent from a disposal plant is discharged into a small stream which is used as a source of water-supply, it may be necessary that the disposal plant shall consist of a collecting tank, a sprinkling filter, a sand filter, and a chlorinating apparatus. The disposal plant must be adapted to the particular locality which it serves.

Sewer System.—A sewer system consists of collecting pipes or sewers, and a disposal plant. A health officer has little to do with the sewers directly, except when they are broken or obstructed. The construction and maintenance of sewers are engineering problems with which an engineering department has to deal.

A health officer has very little power over a private sewer system, except to require that the disposal shall be done in a sanitary manner. He cannot require a householder or the managers of an institution to install any particular type of sewer system. But a health officer who understands sewer systems will often be asked to give advice regarding their installation and management. If a health officer condemns a sewer system at a private residence, or an institution, he should be able to advise the owners or managers what system to install in its place, where to locate the disposal plant, and how to manage the system.

Manufacturers and contractors often exploit patented systems which are merely complicated adaptations of well-known principles. A householder can usually get a practical plumber to design a simple, inexpensive system which is adapted to the soil of the locality. It is a good plan for a health officer to consult the plumbers regarding the costs of standard sewer pipes, cesspools, and disposal plants in his locality. A health officer can also promote public health by advising the plumbers regarding the standard methods of sewage disposal which are efficient and economical in his locality.

Public Sewer System.—When a city, village, or congested district needs a public sewer system, the health officer is the person from whom the people and officials naturally seek advice. The manner of establishing a sewer district is prescribed by statute law in some of the states. For example, the New York State law relating to sewers in towns is found in the town law, Art. 11, Secs. 230-248; and the law relating to village sewers are found in the village law, Art. 11, Secs. 260-278, and in the public health law, Art. 3, Sec. 21a; and the relation of sewage to stream pollution and potable waters are found in the public health law, Art. 5, Secs. 73-87. It is the duty of a health officer to know the laws relating to sewers and sewage in his district, and to advise the people and officials concerning them.

The question sometimes arises of the advisability of the construction and operation of a public sewer system by a private person or corporation who would charge for its use. It is not wise to make the use of a sewer dependent on money payments. If the water-supply of a house is cut off, the occupants can obtain a temporary supply from a neighbor without undue hardship or danger; but if a house is cut off from sewer connections, the resulting pollution of the house and soil may be dangerous to health.

Designing and constructing a public sewer system are problems of engineering and business which are under the jurisdiction of the business department of a municipal government. It is the duty of a health officer to give advice regarding the sanitary problems to be solved. But the decision regarding the solution of the problems does not lie with him or with the board of health, hut with the engineering and business departments.

Operation of a Disposal Plant.—The operation of a disposal plant is under the control of the business departments of a municipal government, but it is the duty of a health officer to make inspections and take bacteriologic samples of the sewage in order to have records of the efficiency of the plant. The health officer of a rural community is the official who is best qualified to take samples and to secure their examination.

PROBLEMS

1. Design the dimensions of a septic tank for a small colony of 150 persons provided with an assured water supply from the municipal head-works at a rate of 120 litres per person per day. Assume any data required.

Solution: The quantity of water supplied = per capita rate * population

=120*150 litres/day = 18,000 l/day.

Assuming that 80% of water supplied becomes sewage, we have

The quantity of sewage produced = 18,000 *0.8 = 14,400 l/day.

Assuming the detention time to be 24hrs, we have

The quantity of sewage produced during the detention period (i.e. the capacity of the tank)

=14,400*24/24=14,400 litres.

Now assuming the rate of deposited sludge as 30 litres/capita/year and also assuming the period of cleaning as 1 year, we have

The volume of sludge deposited=30*150*1=4500 litres.

Total required capacity of the tank = capacity for sewage + capacity for sludge

14400+4500 = 18900 litres = 18.9 cu..

Assuming 1.5m as the depth of the tank, we have

The surface area of the tank = 18.9/1.5 m^2 = 12.6 m^2

If the ratio of the length to width is kept as 3:1, we have

3*B2=12.6

B=√12.6/3 = √4.2 = 2.05m =2.1m

Provide width = 2.1m

Provide length of the tank = 6m

Area of cross-section provided = 6*2.1 =12.6m^2

Thus, the dimensions of the septic tank will be 6m*2.1m*(1.5+0.3)m overall depth (0.3m used as free-board)

Hence use a tank of size 6m*2.1m*1.8m

2. An average operating data for conventional activated sludge treatment plant is as follows:
   1. Wastewater flow = 35000 m3/day
   2. Volume of aeration tank = 10900m3
   3. Influent BOD = 250mg/l
   4. Effluent BOD = 20mg/l
   5. Mixed liquor suspended solids (MLSS) = 2500mg/l
   6. Effluent Suspended solids = 30mg/l
   7. Waste sludge suspended solids =9700mg/l
   8. Quantity of waste sludge = 220m3/d

   Based on the above information determine,

a. Aeration period (hrs)
b. Food to micro-organisms ration (F/M) (kg BOD per day/kg MLSS)
c. Percentage efficiency of BOD removal
d. Sludge age (days)

Solution: Given values are symbolized as

$Q=35000m^3/d$; $V=10900m^3$

$Y_0=250$ mg/l; Y_E = 20mg/l

X_t = 2500 mg/l; X_E=30mg/l

X_R=9700 mg/l; $Q_W=220m^3/d$

a. Aeration period (t) in hr,

T=V/Q*24

=10,900*24/35000=7.5hr

b. F/M ratio

F=Mass of BOD removed

$=Q*Y_0$

=35000*250gm/day

=35000*250/1000 kg/day=8750 kg/day.

M= Mass of MLSS

=V*XT=10900m3*2500gm/m3(i.e. mg/l)

10900*2500/1000 kg =27250 kg

F/M Ratio = 8750/27250= 0.32kg BOD per day/kg of MLSS

c. Percentage efficiency of BOD removal = incoming BOD –Outgoing BOD/(Incoming BOD)

=(250-20/250)*100%=230/250*100%=92%

d. Sludge age in days (θ_c) is given by,

$(\theta_c)= X_t*V/[(Q_W*X_R)+(Q-Q_W)*X_E]$

$= 27250$ kg/($220m^3$/d*9700mg/l)+($35000m^3/d-220m^3/d$)30mg/l

= 27250kg/[220*9700/1000kg/d + (35000-220)30/1000kg/d]

= 27250/(2134+1043.4)

= 27250/3177.4

=8.58 days.

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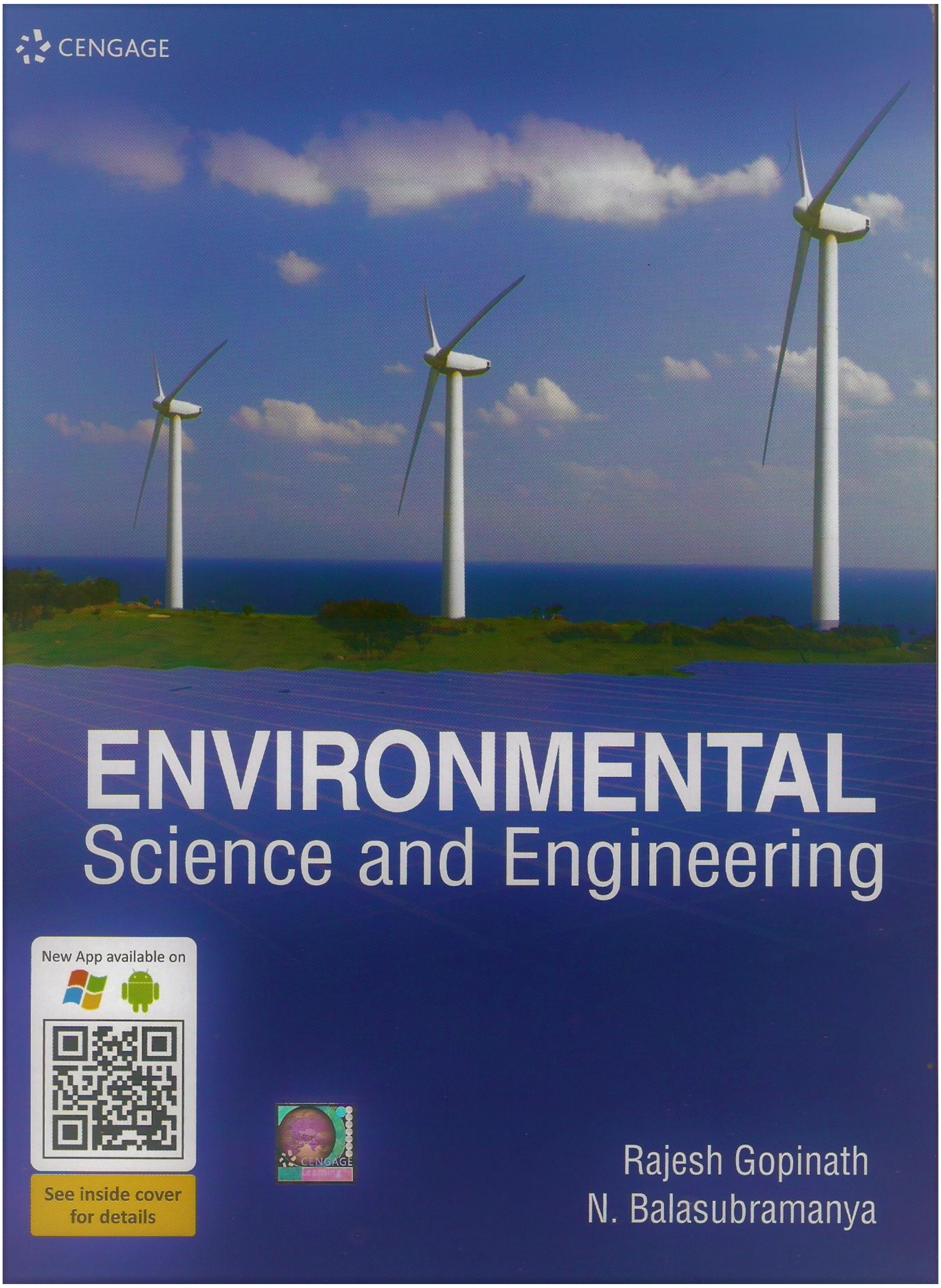
For Additional Reading



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