SAMPLE STUDY MATERIAL

Postal Correspondence Course

GATE, IES & PSUs

Civil Engineering

Environmental Engineering-B

Sewage disposal and air pollution

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CONTENT

ENVIRONMENTAL ENGINEERING-B

SEWAGE DISPOSAL AND AIR POLLUTION

CHAPTER-1

SEWAGE COLLECTION

Sewage:

- The mixture of water and waste products of a society including human excreta is known as sewage.

Sewerage:

- The art of collecting, treating and finally disposing of the sewage is called as sewerage.

Four operations are necessary in waste water management.

(1) Sewage collection (2) Sewage conveyance

(3) Sewage treatment (4) Sewage disposal

There is two system employed disposal of sewage.

1. Conservancy system: Conservancy system is an old system in which various types of waste such as night soil, garbage etc. are collected separately in vessel or deposited in pool or pit and then removed periodically at least once in 24 hours.

2. Water carriage system: In this system the collection, conveyance and disposal of various types of wastes are carried out with the help of water. Thus water is used as medium to convey the waste from its point of production to the point of its treatment or final disposal.

Sewage is broadly classified into:

(a) Domestic Sewage:

- It consists of liquid wastes originating from bath rooms, Kitchens etc. of the residential, commercial or institutional buildings.
- Extremely foul in nature.

(b) Industrial Sewage:

- It consists of liquid wastes originating from industrial processes of various industries etc.
- Nature of sewage depends on industry.

Note:

- The sum of domestic and industrial sewage is termed as sanitary sewage or sewage.
- Run-off resulting from the rain storms is called as storm sewage or storm drainage or drainage.

Drainage System can be classified as:

(a) Combined system:

õ It consists of drainage and sewage both.

õ It consists of a single set of bigger sized conduits for both.

õ Treatment of sewage of this system is costlier because it necessitates treatment of drainage and sewage both.

õ During non-monsoon seasons, sewer pipes are liable to frequent silting.

(b) Separate System:

õ It consists of two different set of conduits for drainage and sewage separately.

õ Separate conduits cannot be laid in congested areas.

õ Treatment of sewage is less costly in this system.

(c) Partially Separate System:

õ In this system, sometime a part of drainage water is admitted into the sewers and vice versa.

Note: Most of our existing system is a partially separated system.

For large cities and metropolitans preferably combined or partially combined system may be adopted.

For smaller towns separate system may be adopted.

Estimation of Sewage Discharge:

Sewage quantity in a sewer includes:

(i) Addition due to domestic sewage and industrial sewage.

(ii) Addition due to unaccounted private water supplies.

(iii) Addition due to infiltration.

(iv) Subtraction due to water losses.

(v) Subtraction due to water not entering the sewerage system.

- In India, net quantity of sewage produced is taken as equal to 75-80% of the accounted water supplied from the water-works.
- Hence, **per capita sewage** produced is taken as 75-80% of the per capita water demand/supplied to the public.

Table: Variations in per Capita Water Demand and Sewage Production with Population in India

S.No.	Populations	Per capita water demand in litres/day/person(q)	Per capita sewage production litre/day/person q' = 80% q.
1.	Less than 20,000	110	90
2.	20,000 — 50,000	110—150	90—120
3.	50,000 — 2 lakhs	150—180	150—170
4.	2 lakhs — 5 lakhs	180—210	170—190
5.	5 lakhs — 10 lakhs	210 — 240	170—190
6.	Over 10 lakhs	240—270	190—200

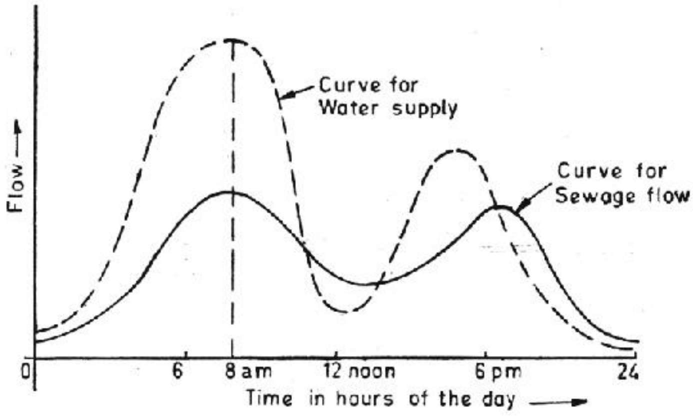


Figure: ***Hourly variation of sewage flow compared to that of water supply.***

Maximum Flow:

For areas of moderate sizes:

- **Maximum daily sewage flow** = 2 × Average daily sewage flow
- **Maximum hourly sewage flow** = 3 × Average daily sewage flow
- Estimation of maximum hourly flows for different types of sewers. Within the city's sewerage system:

Table: Hourly Variation in Sewage Flow

S.No.	Type of Sewer	Ratio of maximum flow to average flow
1.	Trunk mains above 1.25m in dia.	1.5
2.	Mains up to 1m in dia.	2.0
3.	Branches up to 0.5m in dia.	3.0
4.	Laterals and small sewers upto 0.25m in dia.	4.0

- The sizes of the sewer are designed for carrying the computed maximum hourly flows, with sewers running $\frac{3}{4}th$ full.

Minimum Sewage Flow:

- The requirement of minimum permissible velocity at the minimum flow is to avoid silting in sewer.
- Minimum daily flow $= \frac{2}{3} \times$ Average daily sewage flow.
- Minimum hourly flow $= \frac{1}{3} \times$ Average daily sewage flow.
- **The sewers must be checked for minimum velocities at their minimum hourly flows.**

<u>ESTIMATION OF DRAINAGE DISCHARGE:</u>

- Low sewage discharge during non-monsoon periods is termed as **Dry Weather Flow (D.W.F.).** The drainage discharge or rain run-off during monsoon season is approximately 20–25 times of D.W.F.

Peak Run-off:

- Peak run-off from a particular catchment depends on many factors namely: Intensity and duration of rainfall, climatic condition, type of precipitation, Soil moisture deficiency etc.

Time of concentration (T_c):

- It is the period after which the entire area will start contributing to the runoff.
- It has two parts.

(a) Inlet time or overland flow time or time of equilibrium (T_i)

- It is the time taken by water to flow over land from the critical point up to the point where it enters the drain mouth.

Hence, $T_i = \left(0.885\frac{L^3}{H}\right)^{0.385}$

Where, T_i = Inlet time (hr.)

L = Length of overland flow (Km)

H = Total fall of level between the critical point to the drain mouth (m.)

(b) Channel flow time or Gutter Flow time (T_f):

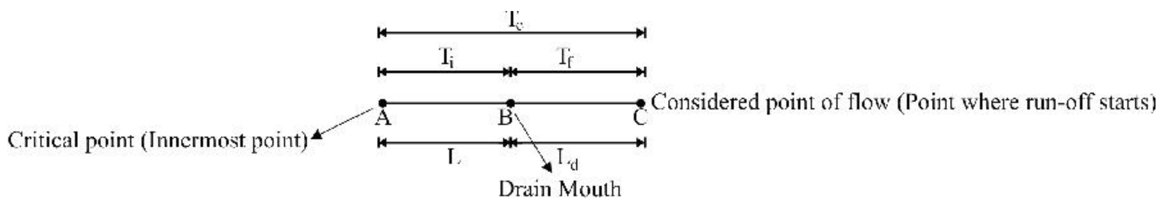
- It is the time taken by water to flow in the drain channel from the mouth to the considered point.

Hence, $T_f = \frac{L_d}{V_d}$

Where, L_d= Length of drain

V_d= Velocity in drain

i.e.



$T_c = T_i + T_f$

- Maximum Run-off $\rightarrow$ Will not occur if rainfall duration (T) >T_c or T<T_c

  $\rightarrow$ Will occur if rainfall duration (T) =T_c.

  Hence, the maximum run-off will be obtained when the rainfall duration equals to time ofconcentrationand this duration are called as **Critical Rainfall duration.**

RATIONAL FORMULA FOR ESTIMATING PEAK RUN-OFF:

Peak rate of run-off. $Q_p = \left(\frac{1}{36}\right) K.p_c.A$ (m^3/s)

Where, K = Co-efficient of run-off

A = Catchment area contributing to run-off at the considered point (hectares)

p_c= Critical rainfall intensity of the design frequency.

i.e. Rainfall intensity during the critical rainfall duration (cm/hr.)

- This formula is generally used for small catchments (less than 400 hectares)

Table: Values of Run-off Coefficient (K) for Various Surfaces

S.No.	Type of surface	Value of *K*
1.	Water-tight roof surface	0.70—0.95
2.	Asphalt pavement in good order	0.85—0.90
3.	Stone, brick, wood-block pavement with cemented joints	0.75—0.85
4.	Same as above with uncemented joints	0.50—0.70
5.	Water bond macadam roads	0.25—0.60
6.	Gravel roads and walks	0.15—0.30
7.	Unpaved streets and vacant lands	0.10—0.30
8.	Parks, lawns, gardens, meadows, etc.	0.05—0.25
9.	Wooden lands	0.01—0.20

- Intensity of rainfall is measured by (a) automatic rain gauges and (b) non-recording gauges. It is expressed in terms of **cm/hr.** However this value gives the rainfall intensity at rain gauge station and hence called point rainfall intensity.
- Hence, for entire catchment area:

  Critical rainfall intensity (p_c) = Point rainfall intensity × Dispersion factor (or areal distribution factor)

Method of Estimating Critical rainfall intensity (p_c):

(i) $p_c = p_0\left(\frac{2}{1+T_c}\right)$

Where, T_c= Time of concentration (hr.)

p_0 = Value of "one hour rainfall" of a given frequency obtained from the charts ×

Distribution factor

(ii) By representing Intensity duration curve by a generalized equation:

$$p = \frac{a}{T + b}$$

Where, p = Rainfall Intensity (cm/hr.)

T = Rainfall duration (minutes)

'a' and 'b' are constants

- By replacing 'T' by 'T_c' (Time of concentration). Corresponding critical rain fall intensity(p_c) is obtained.
- As per Health Ministry of Britain:

$$p = \frac{75}{T_C + 10}$$

Where 'T' varies between 5 to 20 minutes.

$$p = \frac{100}{T_C + 20}$$

Where 'T' varies between 20 to 100 minutes.

(iii) For localities where rainfall is frequent:

$$p = \frac{343}{T + 18}$$ for places where rains having frequency of 5 years.

(iv) For rains having frequency of 10 years:

$$p = \frac{38}{\sqrt{T}}$$

(v) For rains having frequency of 1 year:

$$p = \frac{15}{T^{0.62}}$$

(vi) Kuichling's formula:

$$p = \frac{267}{T + 20}$$ → **For storms having 10 years frequency**

$$p = \frac{305}{T + 20}$$ → **For storms having 15 years frequency**

Note:

- Formulas given from (ii) to (vi) are very empirical in nature and generally avoided in designing storm water drains in modern days. However, these can be used when absolutely no rainfall records are available.

Empirical Formula for estimating peak run-off:

- For larger areas (above 400 hectares), empirical formulas are used.

(i)Burkli-ziegler formula:

- Oldest empirical formula for determining the peak run-off rate.
- Followed in the entire U.S.A.
- $$Q_p = \left(\frac{1}{455}\right).k.p.A.\sqrt{\frac{S_0}{A}}$$

Where Q_p = peak run-off (m^3/s) K = Run-off co-efficient (average value = 0.7)

p = Maximum rainfall intensity (cm/hr.) A = Drainage area (hectares)

S_0 = Slope of ground Surface (m/km.)

(ii) Dicken's Formula:

- Useful for Indian Catchment (particularly North India)

$$Q_p = CM^{3/4}(m^2/s)$$

Where, M = Catchment area (Sq. km.)

C = A constant depending upon factors which affect run-off.

(iii) Ryve's Formula:

- It is generally applicable to south Indian catchment.

$$Q_p = C_1M^{2/3}(m^3/s)$$ Where, C_1 and M have same meaning as in Dicken's formula.

(iv) Inglis Formula:

- Applicable to the fan shaped catchments in old Bombay state of India.

$$Q_p = \frac{123.M}{\sqrt{M+10.4}} \approx 123\sqrt{M}$$ Where, M = Catchment area (Sq. Km)

(v) Nawab JungBahadur Formula:

- Applicable for Hyderabad Deccan catchments.

$$Q_p = C_2M\left(0.93-\left(\frac{1}{14}\right)\log M\right)$$

Where C_2 Varies between 48 to 60.

M = Catchment area (acres)

(vi) Dredge or Burge's Formula:

- Based upon Indian records:

$$Q_p = 19.6\frac{M}{L^{2/3}} (m^3/s)$$

Where, M = Catchment area (Sq. km.)

L = Length of drainage basin (km.)

HYDRAULIC DESIGN OF SEWERS:

Difference in design of water supply pipes and sewer pipes:

(i) Water supply pipes carry pure water without containing any kind of solid particles but sewer pipes contains sewage containing suspended solid particles.

- Hence sewer pipes are laid at such a gradient so as to generate self-cleansing velocities at different possible discharges to avoid silting or clogging of sewers.

(ii) Water supply pipes carry water under pressure but sewer pipes carry sewage under gravity.

Provision of free-board in sewer:

- Sewer pipes of sizes less than 0.4m diameter are designed as running 1/2 full at maximum discharge and pipes of size greater than 0.4m diameter are designed as running 2/3 rd or 3/4th full at maximum discharge.
- Free boards or extra space are provided to cater variations in estimation of discharges due to various reasons.

Table: Values of Freeboard to be adopted for the design of S.W. Drains

Peak discharge in the drain for which designed, in cumecs	Freeboard to be left in meters
Below 0.3	0.3
0.3—1.0	0.4
1—5	0.5
5—10	0.6
10—30	0.75
30—150	0.90
More than 150	1.0

Determination of Flow velocities in sewers and drains:

- The sewers and drains are generally designed as open channels except in cases where it is required to design as flowing under pressure e.g. Inverted siphons.

1. Chezy's Formula:

- Velocity of flow in channel

$$\boxed{V = C\sqrt{r.i}}\ (m/s)$$

Where r = Hydraulic mean radius

i = Hydraulic gradient equal to ground slope for uniform flow

C= Chezy's constant

Hence, Discharge, $\boxed{Q = AV.}$ where A = Flow area.

V = Velocity as calculated above

- Chezy's constant depends upon various factors such as the shape and size of the channel, roughness of channel surface, hydraulic characteristics of channel etc.
- Chezy's constant 'C' is found by:

(a) Kutter's Formula:

$$C = \frac{\left(23 + \frac{0.00155}{i}\right) + \frac{1}{n}}{1 + \left(23 + \frac{0.00155}{i}\right) \cdot \frac{n}{\sqrt{r}}}$$

Where, n = Rugosity coefficient depending upon the type of channel surface.

i = Bed slope of sewer for uniform flows.

r = Hydraulic mean radius.

Table: Mannings or Kutter'sRugosity Coefficients (n)

S.No.	Pipe Material	Values of *n* at full depth for	
		Good interior surface condition	Fair interior surface condition*
(1)	(2)	(3)	(4)
1.	Salt glazed stoneware pipes	0.012	0.014
2.	Cement concrete pipes	0.013	0.015
3.	Cast-iron pipes	0.012	0.013
4.	Brick, unglazed sewers/drains	0.013	0.015
5.	Asbestos cement	0.011	0.012
6.	Plastic (smooth) pipes	0.011	0.011

(b) Bazin's formula:

$$C = \frac{157.6}{1.81 + \frac{K}{\sqrt{r}}}$$

Where, r = Hydraulic mean radius or Hydraulic mean depth of channel

K = Bazin's constant

S.No.	Type of the inside surface of the sewer or drain	Value of *K*
1.	Very smooth surfaces.	0.11
2.	Smooth brick and concrete surfaces.	0.29
3.	Rough brick and concrete surfaces.	0.50
4.	Smooth rubble and masonry surfaces.	0.83
5.	Good earthen channels.	1.54
6.	Rough earthen channels	3.17

2. Manning's Formula:

- Velocity, $V = \frac{1}{n} r^{2/3} . i^{1/2}$ where, n = manning's constant or Kutter'srugosity coefficient

  (r, i has same meaning as mentioned above)

3. Crimp and Burge's formula:

- Commonly used in England

$$V = 83.5 r^{2/3} . i^{1/2}$$

4. William-Hazen's Formula:

- Generally used for flows under pressure i.e. water supply pipes and is seldom used for sewer pipe designing.

$$V = 0.85 C_H . r^{0.63} i^{0.54}$$ WhereC_H= Co-efficient

Table: Value of C_H for William Hazen's formula

S.No.	Type of pipe material	Value of C_H for	
		New pipe	Design Purposes
1.	Concrete and R.C.C. pipes	140	110
2.	Cast iron pipes	130	100
3.	Galvanised iron pipes	120	100
4.	Steel pipes with welded joints	140	100
5.	Steel pipes with riveted joints	110	95
6.	Steel pipes with welded joints lined with cement for bituminous enamel	140	110
7.	Asbestos cement pipes	150	120
8.	Plastic pipes	150	120

Maximum and Minimum Velocities:

- The flow velocities in the sewers should be such that neither the suspended materials get silted up nor the sewer pipes material get scoured out.

(A) Minimum velocities:

- The velocity which will even scour the deposited particles of a given size is known as self-cleansing velocity.

Shield's expression for self-cleansing velocity:

Self-cleansingvelocity, V_s:

$$V_s = C\sqrt{Kd'(G-1)}$$ Where, value of

K = 0.04 for inorganic matters present in sewage

K = 0.6 for organic matters present in sewage

d' = Diameter of grain

G = Specific gravity (Inorganic = 2.65 organic = 1.2)

C = chezy's constant.

Where

- Chezy's constant

(i) $C = \sqrt{\dfrac{8g}{f'}}$ where f' = friction factor

g = 9.81 m/s^2

………. From Darcy-weisbachformula.

(ii) $C = \dfrac{1}{n}.r^{1/6}$ …… from manning's formula

- Hence, a minimum velocity **0.45 m/s.** and an average velocity **0.90 m/s** are developed in sewers to remove sand impurities up to 1 mm diameter and organic particles up to 5mm. diameter.
- Hence, minimum velocity generated in the sewer:-
  (i) Prevent the sewage from getting stale and preventing the evolution of foul gases.
  (ii) Keep the sewer size under control.

- **National Building Organization (N.B.O) of India's recommendation for gradients are:**

Table : N.B.O. Recommendations for Small Sewers

Dia. Of the sewer in mm	Gradient required to generate self cleansing velocity	Velocity generated in the sewer when running half full, for which depth, small sewers are usually designed
100	1 in 60	0.58 m/sec
150	1 in 100	0.61 m/sec
225	1 in 120	0.79 m/sec

(B) Maximum Velocities :

- The maximum velocity should be such that it may not cause scouring and wear and tear of the pipe material. Which ultimately reduces their life span and carrying capacities.

Table : Non-scouring Limiting Velocities in Sewers and Drains

S.No.	Sewer Material	Limiting velocity in m/sec
1.	Vitrified tiles and glazed bricks	4.5—5.5
2.	Cast iron sewers	3.5—4.5
3.	Stone ware sewers	3.0—4.0
4.	Cement concrete sewers	2.5—3.0
5.	Ordinary brick-lined sewers	1.5—2.5
6.	Earthen channels	0.6—1.2

Hydraulic Characteristics of Circular sewer sections running full or partially full.

Consider a circular section as shown in figure:

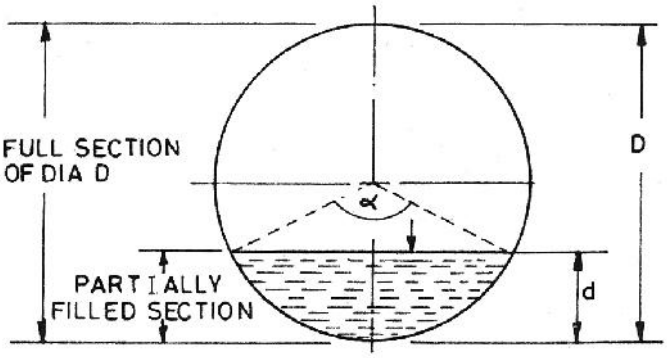


Figure : ***Partially filled circular sewer section***

- **When running full,**

(i) Hydraulic Mean depth or , $(R) = \dfrac{Area(A)}{\text{wetted Perimeter (P)}} = \dfrac{\frac{®}{4}D^2}{®\,D}$

OR

Hydraulic mean radius (H.M.D.) $\boxed{R = \dfrac{D}{4}}$

(ii) Velocity, $V = \dfrac{1}{n}.r^{2/3}\sqrt{i}$ where i = Bed slope

(iii) Discharge Q = A.V.

- **When running partially:**

(iv) Depth, $d = \dfrac{D}{2}\left(1 - \cos.\dfrac{\sim}{2}\right)$

∴ Proportionate Depth $= \dfrac{d}{D} = \dfrac{1}{2}\left(1 - \cos\dfrac{\sim}{2}\right)$

(v) Cross-section area, $a = \dfrac{®D^2}{4}\left[\dfrac{\sim}{360°} - \dfrac{\sin\sim}{2®}\right]$

∴ Proportionate area $= \dfrac{a}{A} = \dfrac{\sim}{360°} - \dfrac{\sin\sim}{2®}$

(vi) Wetted perimeter, $p = ®.D.\dfrac{\sim}{360°}$

∴ Proportionate perimeter, $\dfrac{p}{P} = \dfrac{\sim}{360°}$

(vii) Hydraulic mean depth (H.M.D.)

$$r = \frac{a}{p} = \frac{D}{4}\left[1 - \frac{360°.\sin\sim}{2®\sim}\right]$$

$\therefore$ Proportionate H.M.D. $= \frac{r}{R} = \left[1 - \frac{360°.\sin\sim}{2®\sim}\right]$

(viii) Velocity, $v = \frac{1}{n} r^{2/3}\sqrt{i}$

$\therefore$ Proportionate velocity $= \frac{v}{V} = \frac{r^{2/3}}{R^{2/3}}$. [Assuming n as constant with depth]

$$= \left[1 - \frac{360°.\sin\sim}{2®\sim}\right]^{2/3}$$

(ix) Discharge, $q = a.v$

$\therefore$ Proportionate discharge $= \frac{q}{Q} = \frac{a}{A}.\frac{v}{V} = \left[\frac{\sim}{360°} - \frac{\sin\sim}{2®}\right].\left[1 - \frac{360°.\sin\sim}{2®\sim}\right]^{2/3}$