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Environmental Engineering - I

Unit - I

Planning for water supply system

Introduction:-

The five essential requirements for humans existance are
(i) air
(ii) water
(iii) Food
(iv) Heat and
(v) Shelter

Contamination of these elements may causes health hazards not only to man but also animal and plant life.

Importance and necessity of water supply schemes:-

(i) For drinking and cooking
(ii) For bathing & washing.
(iii) For watering of lawns & gardens.
(iv) For growing of crops
(v) For heating & air conditioning systems
(vi) For street washing.
(vii) For fire fighting
(viii) For recreating swimming pools, fountains and cascades.
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Objectives :-

(i) To supply safe water to the consumes

(ii) To supply water in adequate quantity.

(iii) To make water easily available to consumers, so as to encourage person and household.

(iv) The water is one which is free from toxic substances and form minerals and organic matter.

Importance and necessity for planned water supply

(i) water is a chemical compound and may occur in a liquid form or in a solid form and or in a gaseous form.

(ii) It is necessary that the water required for their needs must be good, and it should not contain unwanted impurities or harmful chemical compounds or bacteria in it.

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In planning a water supply scheme, It is essential, to first of all, search a source of water in the vicinity of the town or city for which the scheme is to be desired. Sometimes, the water may be available nearby and sometimes it may be far away. Further it may be an underground well, or it may be a river, stream or a lake.

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The treated water is finally distributed to the residents and industrial depending upon their requirements, through a network of distribution system.

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While planning a water supply scheme, It is necessary to find out not only the total yearly water demand but also to assess the required average rates of flow and the variations in these rates.

(a) The following quantities are, therefore, generally assessed as recorded

(i) Total annual volume (V) in litres or million litres

(ii) Annual average rate of draft in "l" perday.

(iii) Annual average rate of draft in litres perday per person (litres per capita perday or LPCD) called as per capita demand.

(iv) Average rate of draft in litres perday per service

$$\Rightarrow \frac{V}{365} \times \frac{1}{\text{No. of services}}$$

(v) Fluctuations in flows expressed in terms of percentages ratios of max or minimum yearly, monthly, daily or hourly rates to their corresponding average values.

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The various types of water demands

(i) Domestic water demand

(ii) Industrial water demand.

(iii) Institution and commercial water demand

(iv) Demand for public uses.

(v) Fire demand

(vi) water required to compensate losses in wastes and thefts.

(i) Domestic water demand:-

The water requirement in private buildings for drinking, cooking, bathing, lawn, sprinkling, sanitary purposes etc.

The amount of domestic water consumption per person shall vary according to the living conditions of the consumers. As per IS: 1172-1993, the minimum domestic consumption for a town or a city with fully flushing system should be taken at 200 l/h/day.

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Minimum Domestic water consumption (Annual Avg) for Indian Towns & cities with full flushing systems as per IS 1172 - 1993.

Use	Consumption in litres per head per day (l/h/d).
Drinking	5
Cooking	5.
Bathing	75.
washing of clothes	25.
washing of utensils	15.
washing and cleaning of houses & residences	15.
Lawn watering & gardening	15.
Flushing of water closets	45.
Total	200.

Minimum Domestic Consumption (Annual Avg) for weaker sections & LIG colonies in small Indian Towns and cities.

Use	Consumption in l/h/d.
Drinking	5.
Cooking	5
Bathing	55.
washing of clothes	20
" " utensils	10
washing & cleaning of houses and residence	10
Flushing of water closets	30

Total => 135

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In a developed or an effluent country like U.S.A this figure usually goes as high as 340 l/h/d. This is because more water is consumed in rich living in air-cooling, air-conditioning, bathing in bath tubes, dish washing of utensils, car washing, home laundries, garbage grinders etc.

The total domestic water consumption usually amounts to 50-60% of the total water consumption.

The total domestic water demand = Total design Population × per capita domestic consumption.

Industrial water demand:-

The Industrial water demand represents the water demand of industries, which are either existing or are likely to be started in future, in the city for which water supply is being planned.

The ordinary per capita consumption on account of industrial needs of a city is generally taken as 50 l/p/ day.

The potential consumption on account of industrial needs of a city is generally taken as 50 l/p/day. The potential for industrial expansion should also be investigated so that the availability of water supply may attract such industries and add to economic prosperity of the community.

Some of the industries may develop their own water supplies. and may place a very little or virtually no demand on the public supplies.

In Industrial cities, the per capita water requirements may finally be computed to be as high as 450 l/p/ day or so, as compared to the normal Industrial requirement of 50 l/p/ d.

Water demand of certain Important Industries.

	Name of Industry & product	Unit of product or Raw material used	Appro. quantity of water required per unit of product / raw material in kilo litre.
1.	Automobiles	vehicles	40.
2.	Distillery	kilo litre	122–170.
3.	Fertilizer	Tonne	80–200.
4.	Leather (Tanned).	Tonne	40.
5.	Paper	Tonne	200–400.
6.	Special Quality Paper	"	400–1000
7.	Sugar	Tonne (crushed cane)	1–2.

Institution & commercial water demand:-

The water requirements of Institutions, such as hospitals, hotels, restaurants, schools & colleges, railway stations, offices, factories etc.

The quantity will certainly vary with the nature of the city & with the number & types of commercial establishments. & Institutions present in it.

On an avg, a per capita demand of 20 l/h/d is usually considered to be enough to meet such commercial & Institutional water requirements, although of course, this demand may be as high as 50 l/hr for highly commercialised cities.

Water requirements of Individual Institutions & commercial Establishments.

	Type of Institution or Commerical Establishment	Avg. water consumption in l/h/d.
1)	offices	45-90.
2)	Factories a) where bathrooms are provided.	45-90.
	b) where no bath rooms provided.	30 - 60.
3)	schools a) day scholars	45 - 90.
	b) residential	135 - 225.
4)	Hostels	135 - 180.
5)	Hotels	180 (per bed).
6)	Hospitals (including laundry) a) No. of bed not exceeding 100	340 (per bed).
	b) No. of bed exceeding 100	450 (per bed)
7)	Cinema halls & Theatres (per seat)	15.

6 (11)

Demand for Public use:-

The Quantity of water required for public utilities purposes, such as watering, of public parks, gardening, washing & sprinkling on roads, use in public fountains etc. Nominal amount not exceeding 5% of the total consumption.

Fire Demand:-

The Quantity of water required for extinguishing fires. Should be easily available & kept always stored in storage reservoirs.

Fire hydrants are usually fitted in the water mains at about 100 to 150m apart. The discharge of each stream should be about 1100 l/minute. Hence, in a big city having a population 50 lakhs if 6 fires break out in a day & each fire stands for 3 hours, the total amount of water required shall be given by

$= 6 \times (3 \times 1100) \times (3 \times 60)$

= [No. of. fires x Discharge x Time of each fire]

= 35,64,000 l/d

amount of water required per person

$\frac{35,64,000}{}$ ∠ 1 litre/p/d.

The high rate of water consumption during a fire considerably affects the design of distribution system, and hence while designing public water supply schemes, the rate of fire demand is sometimes treated as a function of population, and is worked out on the basis of certain emprical formulas, which are given below.

(i) Kuichlings Formula:-

$$Q = 3182\sqrt{P}$$

where Q = Amount of water required in l/min

P = Population in thousands.

(2) Freeman Formula:-

$$Q = 1136\left[\frac{P}{10} + 10\right]$$

(3) National Board of fire under writers Formula:

$$Q = 4637\sqrt{P}\left[1 - 0.01\sqrt{P}\right]$$

(4) Buston's Formula:.

$$Q = 5663\sqrt{P}$$

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Water required to compensate losses in thefts and wastes:-

The water lost in leakage due to bad plumbing or damaged meters, stolen water due to unauthorised water connections and other losses or wastes.

Per capita demand:-

The annual average daily consumption of each person (for all uses) called per capita demand (or).

Design period:-

The future period for which a provision is made in the water supply scheme is known as the design period.

Depends upon the possibilities of future development of the town, the possible future population of the region just by the end of the design period is generally estimated, using different methods such as.

(i) Arithmetical Increase method
(ii) Geometrical Increase method.
(iii) Incremental Increase method.
(iv) Decreasing rate method.
(v) Sample graphical method.
(vi) Comparative graphical method.
(vii) master plan method.
(viii) The apportionment method.
(ix) The logistic curve method.

The per capita Demand (q).

It is the annual average amount of daily water required by one person, and includes the domestic use, Industrial & commercial use, public use, wastes, thefts etc.

It can be expressed as.

per capita Demand in litres perday perhead

$$= \frac{\text{Total yearly water requirements of the city in litres (V).}}{365 \times \text{Design Population.}}$$

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(i) size of the city:-

The percapita demand for big city is generally large as compared to that for smaller towns.

Variations in per capita Demand with Population in India.

Population	Per Capita Demand in l/d/p
less than 20,000	110
20,000 - 50,000	110 - 150
50,000 - 2 lakhs	150 - 240
2 lakhs - 5 lakhs	240 - 275.
5 lakhs - 10 lakhs	275 - 335.
over 10 lakhs	335 - 360.

(ii) climate conditions:-

At hotter and dry places, the consumption of water is generally more, because. more of bathing, cleaning, air coolers, air conditioning sprinkling in lawns, gardens, roofs etc are involved, similarly, in extremely cold countries, more water may be

Break up of per capita Demand for an average Indian city.

use	Demand in l/h/d
(i) Domestic use	200
(ii) Industrial use	50
(iii) commercial use	20
(iv) civil or public use	10
(v) wastes & thefts etc	55
Total =	335.

Factors Affecting per capita demand:.

The annual average demand for water (like per capita demand) considerably varies for different towns or cities.

Ranges between 100 to 360 l/c/d for Indian conditions. These variation in total water consumption of different cities or towns depends upon various factors, which must be thoroughly studied and analysed before fixing the per capita demand for design purposes.

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more leakage from pipe joints, since metals contract with cold.

3. Types of Centry and Habits of People:-

Rich and upper class communities generally consume more water due to their affluent living standards.

middle class communities consumes average amounts, while the poor slum dwellers consume very low amounts.

The amount of water consumption is thus directly dependent upon the economic status of the consumers.

4. Industrial and commercial Activities:-

The pressure of Industrial or commercial activities at a particular place increase the water consumption by large amounts.

The industrial water demand is having no direct connection with the population or the size of the city, but more industries are generally situated in big cities, thereby increasing the per capita demand for big cities.

5. Quality of water supplies:-

If the quality and taste of the supplied water is good. It will be consumed more, because in that case, people will not use other sources such as private wells, hand pumps etc.

6. Pressure in the Distribution system:-

If the pressure in the distribution pipes is high & sufficient to make the water reach at 3rd or even 4th stores, water consumption shall definitely be more.

7. Development of sewerage facilities:-

The water consumption will be more, if the city is provided with "flush system" and shall be less if the old "conservation system" of latrins is adopted.

8. System of supply:-

The water may be supplied either continously for all the 24 hours of the day or may be supplied only for peak periods during the morning & evening.

Factors Affecting Losses and wastes:-

The large amount of water is lost in Leakages, wastes, thefts etc. In every water supply scheme, The various factors on which these Losses depend and the measures to control them are summarized below:

(i) water tight joints.

(ii) pressure in the Distribution system

(iii) system of supply

(iv) unauthorised connections.

Design period:-

A water supply scheme includes huge ca costly structures (such as dams, reservoirs, treatment work etc). which cannot be replaced or increased in their capacities, easily and conveniently.

In this future period or the number of years for which a provision is made in designing the capacities of the various components of the water supply scheme is known as design period.

The design period should neither to be Long nor should not be too short.

The design period cannot exceed the useful life of the component structure and is guided by the following considerations.

Factors Governing the Design Period:-

(i) useful life of component structures and the chances of their becoming old and obsolete. Design periods should not exceed those respective values.

(ii) Ease and difficulty that is likely to be faced in expansions, if undertaken at future dates.

(iii) Amount and availability of additional investment likely to be incurred for additional provisions.

(iv) Anticipated rate of population growth, including possible shifts in communities, industries and commercial establishments.

Design period values:-

Water supply projects, under normal circumstances, may be designed for a design period of 30 years.

The 30 years period is to be counted after the completion of the project.

Source of water:-

1) Surface sources
   (i) Rivers / streams
   (ii) Lakes.
   (iii) Ponds.
   (iv) Impound Reservoirs.
2) Under ground sources
   (i) springs.
   (ii) wells
   (iii) Infiltration galleries.

Streams:-

In mountaineous regions streams are found and are formed by the runoff. The discharge in streams is much in rainy season than other seasons.

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Lakes:-

In mountains at some places natural basins are formed with impervious beds. water from springs and streams generally flow towards these basins and lakes.

The quality of large lakes is good than that of the small lakes water is available only to those towns and cities situated near them.

ponds:-

These are depression in plains in which water is collected during rainy seasons. sometimes it was formed when much excavation is done for constructing embankment for road and railway. Generally the quantity of water in ponds is very small and contains large amount of impurities so it cannot be used for water supply.

Rivers:-

Rivers are the only surface sources of water which have maximum quantity of water which can be easily taken. Mostly all the cities which are situated near rivers discharge the used water of sewage into rivers, there fore care should be taken while drawing water from the river. River water has self-purification action due to which it automatically become clean in some distance travel from the point of disposal of sewage.

Imponded Reservoirs:-

Mostly its found that there is great variation in the quantity of river water during monsoon and summer season.

The discharge in some rivers remains sufficient to meet the hot weather demand. but in some rivers the flow becomes essential to store the water for summer season.

The water can be stored in the river by constructing a bund. a weir or a dam across the river at such places where minimum area of land is submerged in the water and the reservoir basin remains cup-shaped having maximum possible depth of water.

The construction of imponded reservoirs is not feasible under the following conditions.

(i) where the average annual flow is lower than the average demand.

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(ii) when the rate of flow in the stream in dry season is more than the demand.

Factors Governing the selection of a particular source of water:-

(i) The Quantity of available water

↳ Quantity at source should be sufficient enough to meet the various demands during the entire design period.

(ii) The Quality of available water.

↳ available at source must not be toxic, poisnous or in any other way injurious to health.

(iii) Distance of the source of supply.

↳ source must be situated as near the city as possible.

(iv) Elevation of the source of supply

↳ source should ~~not~~ be on high contain so as to make the gravity flow possible.

(V) General Topography of the intervening area

↳ The area b/w source and city should not be highly uneven.

Ground water:-

The rainfall that percolated below the ground surface, passes through the voids of rocks and joints the water table.

→ Near the upper portion of earth's crust potential storage of ground water.

The water storage capacity of g/w dependent upon

(i) porosity and permeability of rocks.

(ii) rate at which water is added to it by infiltration.

(iii) Evaporation lose, transpiration, seepage to surface courses and withdrawn by man.

$$\text{Porosity} = \frac{\text{vol. of voids}}{\text{vol. of soil.}}$$

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Zone of under ground water:-

(i) Zone of rock flowage → The zone in which rocks under permanent deformation.

(ii) Zone of rock fracture → Above zone of rock flowage.

* The zone further subdivided into two

(i) Zone of saturation.

(ii) Zone of aeration.

Aquifiers and their types:-

A permeable stratum or a geological formation of permeable material, which is capable of yielding appreciable quantities of ground water under gravity is known as aquifiers.

(i) Confined or Non-artesian aquifier.

(ii) unconfined or artesian aquifier.

Aquifuge:-

It is the geological formation, which is neither porous nor permeable. & hence it contains nor yields ground water. eg:- granite.

Aquiteral:-

It is that geological formation, which does not yield water freely to wells, due to its lesser permeability although seepage is possible through it yield is insignificant.

eg:- sandy clay.

Aquiclude:-

It is highly porous, containing large quantities of water but essentially impervious as not to yield water.

eg:- clay Layer.

The underground water is generally available in the following forms.

(i) Infiltration galleries.

(ii) Infiltration wells

(iii) springs.

(iv) wells including tube wells.

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The head loss caused by pipe friction can be found by using either of the following formula

(i) Darcy - weisbach formula:-

$$H_L = \frac{f' L V^2}{2 g d}$$

$H_L \rightarrow$ Head Loss in m

$L \rightarrow$ Length of pipe in m

$d \rightarrow$ diameter of pipe m

$V \rightarrow$ Mean velocity of flow m/sec

$g \rightarrow$ acceleration due to gravity m/sec

$f' \rightarrow$ friction factor.

$$f' = 0.04 \left[1 + \frac{1}{35 d} \right] \text{ for old pipes.}$$

$$f' = 0.02 \left[1 + \frac{1}{35 d} \right] \text{ for new pipes.}$$

2. Manning's Formula:-

$$H_L = \frac{n^2 v^2 . L}{R^{4/3}}$$

where,

n = Manning's rugosity co-efficient

L = Length of pipe (m)

V = Flow velocity (m/sec)

R = Hydraulic mean depth (m).

3. Hazen - William's Formula:-

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

where,

C_H = Co-efficient of hydraulic capacity

R = Hydraulic mean depth (m).

S = slope of the energy line.

V = Flow velocity.

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4. Modified Hazen-William's Formula:-

$$V = \frac{3.83\, C_R (d^{0.6575} (S_s)^{0.5525})}{\gamma^{0.105}}$$

γ = viscosity of liquid ($10^{-6}\, m^2/s$).

$$V = 143.534\, C_R\, R^{0.6575}\, S^{0.05525}$$

$C_R \rightarrow$ Roughness Co-efficient.

Water quality parameter:-

Pure water is a chemical compound with each of its molecule containing two hydrogen atoms and one oxygen atom and nothing else.

Pure water not available in nature.

1. Physical characteristics:-

Turbidity:-

It caused due to the presence of suspended and colloidal matter in the water.

The character and amount of turbidity depends on the type of soil over which the water has moved.

Ground water are generally less turbid than the surface water.

Turbidity is an optical property of water that causes light to be scattered and absorbed rather than transmitted in a straight line through the water.

It measured by a turbiditimeter. with optical observations and is expressed as the amount of suspended matter in mg/L or ppm.

Measurement of turbidity:-

Nephlometers are now standard device for measuring Low turbidity.

unit of Turbidity is Nephlometric Turbidity unit. (NTU).

Colour and its measurement:-

The colour in water is usually due to organic matter in colloidal condition, Some times it is also due to mineral and dissolved organic impurities.

The permissible colour for domestic water is 20 PPM. on platinum cobalt scale. The colour in water is not harmful but it is objectionable.

Temperature:-

The temperature of water is measured by means of ordinary thermometers. From the temperature the density, viscosity, vapour pressure and surface tension of water can be determined.

The saturation values of solids and gases that can be dissolved in water and the rates of chemical, bio chemical and biological activity are also determined on the basis of temperature.

The most desirable temperature for public supply is b/w 4.4°c - 10°c. Temp above 26°c are undesirable and above 35°c are un fit for public supply because it is not portable.

Taste and odour:-

Tastes and odours in water may be due to the presence of dead or live micro-organism, dissolved gases such as H_2S, CO_2 and oxygen combined with organic matter.

Mineral substance such as sodium chloride iron compounds and carbonates and sulphates of other substances.

The test of these are done by sense of smell and taste because these are present in such small proportions and difficult to detect them by chemical analysis.

Chemical characteristics:-

1) Total solids and suspended solids:-

Total solids = TSS + TDS.

=> Total solids can be obtained by evaporating a sample of water and weighing the dry residue.

=> TSS → Filtering the sample of water through fine filter, drying and weighing.

=> TDS → evaporating the filtered water and weighing the residue.

* Limit of TS => 500ppm.

pH value of water:-

$$pH' = -\log[H^+] = \log\left[\frac{1}{H^+}\right]$$

=) Negative logirithm of hydrogen ion.

=) If pH > 7 - alkaline.

pH < 7 - acidic.

* pH value measured using potentiometer or pH strip.
* It can also measured by indicators.

permissible limit → 6.6 – 8.4.

Hardness:-

Hardness are undesirable because they may lead to greater soap consumption, scale of boilers, cause corrosion and incrustated of pipes, making food tasteless etc.

* Temporary hardness or carbonate hardness

↳ presence of carbonates and bicarbonates of calcium and magnesium and these hardness can be easily removed to some or full extent by simple boiling or by adding lime to water.

* Permanent hardness or Non carbonate hardness
  ↳ presence of sulphates, chloride, and nitrates of calcium and magnesium and

They cannot be removed by simple boiling and therefore, such water required special treatment for softening.

Measurement of hardness (EDTA) method:-

Total hardness in mg/l as $CaCO_3$ is

$$= \left[Ca^{++} \text{ in mg/l} \times \frac{\text{Combining wt of } CaCO_3}{\text{Combining wt of } Ca^{++}} \right] + \left[Mg^{++} \text{ in mg/l} \times \frac{\text{Combining wt of } CaCO_3}{\text{Combining wt of } Mg^{++}} \right]$$

Chloride content:-

Chlorides are generally present in water in the form of Sodium chloride and may be due to leaching of marine sedimentary deposits, pollution from sea water, brine or Industrial and domestic use etc.

The concentration above 250 ppm produce a noticable salty taste in drinking water.

Nitrogen content:-

The presence of nitrogen indicate the presence of organic matter and may occur in one or more of the following forms.

Free ammonia:-

It indicates the very first stage of decomposition of organic matter. The presence of free ammonia indicates the presence of undecomposed organic matter and for portable water its value should not exceed 0.15 mg/L.

Albuminoid or organic nitrogen:-

It indicates the quantity of nitrogen present in water before the decomposition of organic matter are started. It should not exceed a value of about 0.3 mg/L

Nitrates:-

It indicates the presence of fully oxidised organic matter in water. not harmfull exceeding the limit of 45 mg/L, cause and affect of health of infants causes health hazardous.

Nitrites:-

It indicates the presence of partly decomposed organic matter.

This was highly dangerous and therefore the permissible amount of nitrite in potable water should be nil.

Permissible limits of metals and other chemical substances:-

(i) Iron => 0.3 PPM

(ii) Manganese => 0.05 PPM

(iii) Copper => 1.3 PPM

(iv) Sulphate => 250 PPM.

(v) Fluoride => 1.5 PPM.

Dissolved Gases:-

The various gases which may get dissolved in water due to its contact with the atmosphere or the ground surface may be nitrogen, methane, hydrogen sulphide, carbon di oxide and oxygen.

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Bacterial and microscopical Characteristics:-

Bacteria are the minute single cell organisms possessing no defined nucleous and having no green material (chlorophyll) to help them manufacture their own food.

They are generally present in raw and contaminated water. and are so small in length that cannot be seen with a naked eye and have to be examined under microscope. ~~eye~~

Certain other organisms such as viruses are also present.

Method of measuring coliform Bacteria:-

(i) membrane filter Technique.

(ii) MPN → Most probable number

(iii) coliform index