

LECTURE NOTES
WATER SUPPLY AND WASTE WATER ENGINEERING
5TH SEMESTER
DIPLOMA(CIVIL ENGINEERING)



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Chapter1: Introduction to Water Supply ,Quantity and Quality of water

Topics to be covered:

- i)Necessity of treated water supply**
- ii)Per capita demand, variation in demand and factors affecting demand**
- iii)Methods of forecasting population, Numerical problems using different methods**
- iv)Impurities in water–organic and inorganic ,Harmful effects of impurities**
- v)Analysis of water–physical, chemical and bacteriological**
- Water quality standards for different uses**

Necessity of treated water supply

- To provide the community with good quality potable water with sufficient quantity to meet their requirements
- To prevent the population from deadly water borned diseases such as cholera, dysentery etc by providing them with treated good quality water

Per capita demand , variation in demand and factors affecting demand

$$\text{Per capita water demand (liters/capita/day)} = \frac{\text{Totalannualaveragewaterconsulptionofcommunity}}{\text{population} \times 365}$$

Water demand of a community (IS1172:1993)

- Domestic water demand
- Industrial water demand
- Institutional or commercial water demand
- Demand for public use
- Fire demand
- Demand to compensate losses and theft

Domestic/residential water demand

- It includes water requirements for drinking, cooking, bathing, washing of clothes, utensils etc.
- Provision is sometimes made to domestic animal.
- IS1172-1171recommendspercapitawater consumptionof135 L/day?

Average domestic water consumption in an Indian city:

Use	Consumption in L/day/person
Drinking	5
Cooking	5
Bathing	55
Washing clothes	20

Washing utensils	10
Washing and cleaning of houses	10
Flushing toilet	30
Total	135

Industrial water demand

- The presence of industries near the cities has a great impact on the water demand.
- The quantity of water demand depends upon type of industries.
- For a city with moderate factors a provision of 40liters / day /capita for each purpose.

Institutional water demand

- It includes the water used in hospitals, schools, hostels, colleges, hotels, railway & bus stations, cinema halls etc.
- According to IS 1172-1171 recommendation a per capita water consumption is 45lit/day is required under this head.

Demand for public or civil use

- Water requirement for public or civil uses are :-
- Road washing
- Sanitation
- Public parks
- Firefighting
- For road washing in the municipality area a provision of 5 liters/day/head is made.
- Similarly for sanitary purposes such as flushing, sewer system etc. A provision of 3-10 liters /day/head is made.
- Water required for maintaining public parks may be 2-3liters/day/sq. m

Fire demand

- Water required for fire fighting is known as fire demand.
 - Fire may takes place due to faulty electric wires by short-circuiting, fire catching materials, explosions, bad intension of criminal people.
 - Fire demand can be calculated from the following formula:
 - Kuichling's formula : $Q=3182\sqrt{P}$
 - Boston's formula : $Q=5663\sqrt{P}$
 - Freeman formula : $Q=1136(p/10+10)$
 - National board of fire underwriters formula : $Q=4640\sqrt{p(1-0.01\sqrt{p})}$
- Where Q=Quantity of water in liters/day
p= population of thousand

The unit of fire demand will be in **liters/m in** for all the above formulas.

Q. Compute the fire demand for a city having population of 140,000 using various formulas.

Demand to compensate losses and theft

- Leakage & overflow from service reservoirs
- Leakage of main service pipe connections
- Leakage & losses of consumers' premises.
- Large leakage & wastage from public taps
- Losses in the supply line are many due to defective ,pipe joints, crack pipes, loose, valves & fittings.
- In India a per capita water consumption of 55litres /day is required under this head.

Per capita water demand

- For the purpose of estimation of total requirement of water the demand is calculated on an average basis & is expressed in liters/day /capita
- It is obtained by dividing the quantity of water supply during the year by no. of days in the year & the no. of persons served

Per capita water demand(liters/capita/day)

$$= \frac{\text{Total annual average water consumption of community}}{\text{population} \times 365}$$

For an average ,Indian town ,the requirements of water in various uses are:

- Domestic use-135lpcd
 - Industrial use-40lpcd
 - Public use-25lpcd
 - Institutional and commercial use-15lpcd
 - Losses & thefts-55lpcd
- Total(per capita water demand)=270lpcd

Q. What will be the average quantity of water required by a city of population 50,000?

Variation in water demand:

- Seasonal variation
- Daily or hourly variation

Seasonal variation:

- The water demand varies from season to season. In summer the demand will be maximum whereas will be minimum in winter season

- People will tend to use more water in bathing, cooling, watering lawn etc. in summer season than the winter season.

Daily or hourly variation:

- In most of the Indian city the peak demand occurs in the morning & evening. During the night hour the consumption is below the average.
- This variation depends on the general habits of the people, climatic condition, and character of the city such as residential, industrial or commercial.

The variations are as follows:

Average daily water demand (Q) = Population $\times$ per capita water demand

Maximum daily water demand = $Q_{\max(\text{daily})} = 1.8Q$

Maximum hourly water demand = $Q_{\max(\text{hourly})} = 1.5Q_{\max(\text{daily})} = 2.7Q$

Factors affecting water demand:

The variation in per capita water demand in Indian cities depends on following factors:

- Size & type of community
- Standard of living
- Climatic condition
- Quality of water
- Cost of water
- Water pressure
- Method of supply

Size & type of community

- The fluctuation in demand depends upon the size of the city.
- In a large city the fluctuation maybe less with higher demand.
- In a small city per capita consumption is expected to be less ,because there are only limited uses of water.
- The presence of industries in a small city increases its demand.

Standard of living

- The higher the standard of living ,the higher the demand.
- Such as the per capita water demand of the town increase with the standard of living of the people .The people will start use of air conditioners, room coolers, maintenance of lawns, use of flush latrines, use of automatic dish washer etc. with the rise in their standard of living.

Climatic condition

- In the community located in a hot climate the water used will be increased by bathing, lawn sprinkling etc.
 - Similarly in extreme cold climates the water may be wastage due to freezing in pipes resulting increase consumption.
 - Hence extremes at hot & cold cause variation in demand.
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- Quality of water-Poor quality of water results in a reduction in use
 - Pressure in the supply-High pressure results in increase use while low pressure results in decrease use
 - Method of supply-The water supply may be intermediate. Generally intermediate supply will reduce the rate of demand.
 - Cost of water - If cost of water is more people will reduce the usage of water hence demand will be less and vice versa.

Methods of forecasting population, Numerical problems using different methods

Population: Population indicates total no. of human beings living in a certain area at any particular time.

Population density: It indicates the no. of persons per unit area.

Population forecasting: It is the method of forecast the population in the coming decades.

Methods of population forecasting:

- Arithmetic increase method
- Geometric increase method
- Incremental increase method
- Decrease rate of growth method

Arithmetical increase method

- It is the simplest method of population forecasting.
- In this method per decade increase in population is assumed to be constant.

Mathematically $\frac{dp}{dt}=k$

Where $\frac{dp}{dt}$ is the rate of change of population

k is the constant

Let P_0 be the latest known last decade population data

$\bar{x}$ be the arithmetic average of per decade increase in population

Population after 1 decade, $P_1 = P_0 + \bar{x}$

Population after 2 decade, $P_2 = P_1 + \bar{x} = P_0 + 2\bar{x}$

Population after n decades, $P_n = P_0 + n\bar{x}$

Problem: The following is the population data of a city available from past census records. Determine the population of the city in 2011 by arithmetic increase method.

Year	1931	1941	1951	1961	1971	1981	1991
population	12000	16,500	26,800	41,500	52,500	68,000	74,100

Solution:

Year	Population	Increment per decade
1931	12,000	----
1941	16,500	4,500
1951	26,800	10,300
1961	41,500	14,700
1971	52,500	11,000
1981	68,000	15,500
1991	74,100	6,100
Total increment		62100
Average increment per decade($\bar{x}$)		$62100/6$ $= 10350$

Latest known population (P_0) = 74,100

Number of decades (n)=(2011-1991)/10=2

Population after n decades, $P_n = P_0 + n\bar{x}$

$$= 74,100 + 2 \times 10,350 = 94,800$$

Geometric increase method

In this method it is assumed that the % increase in population from decade to decade is constant.

Let $\bar{r}$ (ork) be the geometric average of per decade percentage increase in population (assumed to be constant)

To find future population, $\bar{r}$ is compounded with the existing population.

Population after 1 decade, $P_1 = P_0 + \frac{\bar{r}}{100} P_0 = P_0 (1 + \frac{\bar{r}}{100})$

$$\text{Population after } n \text{ decades, } P = P_0 \left(1 + \frac{\bar{r}}{100}\right)^n$$

$$\text{Population after } n \text{ decades, } P_n = P_0 \left(1 + \frac{\bar{r}}{100}\right)^n$$

$$\bar{r} \text{ can be found out as } \bar{r} = \frac{r_1 + r_2 + \dots + r_n}{n}$$

Problem: The following is the population of a city available from past census records. Determine the population of the city in 2011 by Geometric increase method.

Year	1931	1941	1951	1961	1971	1981	1991
population	12000	16,500	26,800	41,500	52,500	68,000	74,100

Solution:

Year	Population	Increment/ decade	%increase/ decade
1931	12,000	_____	_____
1941	16,500	4,500	37.5
1951	26,800	10,300	62.42
1961	41,500	14,700	54.85
1971	52,500	11,000	26.50
1981	68,000	15,500	29.52
1991	74,100	6,100	8.97
Average % age increment per decade ($\bar{r}$)			31.07

Latest known population (P_0) = 74,100

Number of decades (n) = (2011-1991)/10 = 2

$$\begin{aligned} \text{Population after } n \text{ decades, } P_n &= P_0 \left(1 + \frac{\bar{r}}{100}\right)^n \\ &= 74100 \left(1 + \frac{31.07}{100}\right)^2 \end{aligned}$$

Exercise:

The following is the population of a city available from past census records. Determine the population of the city in 2010, 2030 and 2050 by arithmetic and Geometric increase method.

Year	Population
1970	40000
1980	46000
1990	53000
2000	58000

Impurities in water—organic and inorganic,Harmful effects of impurities

Raw water→Treatment→Wholesome water

Quality of water(testing of water)

- To know the extent of impurities present in the water ,based on which degree of treatment is decided.
- To ensure the quality of water before supply

Impurities in water**Based on size of impurities:**

- Suspended impurities(macro)[10^{-1} mmto 10^{-3} mm]
- Colloidal impurities(micro)[10^{-3} mmto 10^{-6} mm]
- Dissolved impurities (micro)[10^{-6} mmto 10^{-8} mm]

Suspended impurities

- The suspended particles which have the same specific gravity as that of water are mixed in the water.
- E.g. clay ,organic and inorganic matters etc.
- These impurities are macroscopic and the size of these impurities ranges from 10^{-1} mm to 10^{-3} mm.

Colloidal impurities

- It is very finely divided dispersion of particles in water. All the colloidal impurities are electrically charged (due to presence of ions) and remain in continuous motion.
- E.g. acid materials like silica, glass, acquire negative charge where as basic materials such as metallic oxide, aluminum oxide, ferrous oxide are positively charged.

- Due to the electric charge action all the colloidal particles remain in motion and don't settle which makes its removal very difficult.
- Most of the time colloidal impurities impart color to the water. The size of colloidal particles ranges between 10^{-3} mm to 10^{-6} mm.

Dissolved impurities

- Some impurities are dissolved in water when it moves over the rocks soil etc. These dissolved impurities may contain organic compounds, inorganic salts and gases etc.
- The size of the dissolved particles varies from 10^{-6} mm to 10^{-8} mm.

Based on nature of impurities:

- Organic impurities: Presence of organic impurities promotes growth of micro-organisms in the water which is objectionable.
- Inorganic impurities: Inorganic impurities of natural origin are harmless but human generated are hazardous in nature. E.g. cadmium, chromium, nickel, lead, zinc, mercury, etc. are toxic in nature.

Based on state of matter:

- Physical impurities
- Chemical impurities
- Biological impurities

Harmful effects of impurities

- Bacteria-cause disease
- Protozoa-cause odour
- Clay, silt-cause turbidity
- Carbonate-cause hardness
- Sulphate -cause hardness
- Bicarbonate-cause alkalinity and hardness
- Fluorides-cause mottled enamel of teeth
- Chloride-taste and salinity
- Manganese-cause black or brown color
- Iron oxide-cause taste corrosiveness, hardness and color
- Metal lead-cause lead poisoning

Analysis of water—physical ,chemical and bacteriological

The analysis of water is done to identify the impurities present in the water based on which treatment procedures should be adopted in the treatment plants before supplying the water to the public.

The quality of treated water is also checked before supply to confirm it fulfills the requirement of the standards laid down by the public health department.

The following tests which are done during water analysis

- Physical tests
- Chemical tests
- Bacteriological tests

Physical water quality

It assesses the extent of physical impurities present in the water. Physical water quality parameters are those which respond to human senses.

- 1) Temperature
- 2) Color
- 3) Turbidity
- 4) Taste and odour

Temperature

- The temperature of water is measured by means of ordinary thermometers.
- Warm temperature is ideal for microbial growth
- Solubility of gases depends on temperature. Higher the temperature lower will be solubility.
- Chemical reactions are temperature controlled.
- Density, viscosity, vapor pressure and surface tension of water depends on temperature.
- The desirable range of temperature is 10 to 20°C

Color

- Apparent color → Suspended solids
 - True color → Dissolved solids
- Before testing the color of the water, the suspended matter should be removed.
- Color in water is measured on Burgess Scale (platinum scale) and expressed in terms of True Colour Unit (TCU).
 - The device used to measure the colour is known as tintometer.
 - 1 TCU = 1 mg of platinum as a chloro platinate ion mixed in 1 litre of distilled water, then the colour produced is taken as 1 standard TCU
 - The permissible limit for domestic water is 5 to 20 TCU

Turbidity

- The opaqueness in water is known as turbidity. It is the resistance to passage of light through the water by the suspended and colloidal particles.

- Turbidity is measured in silica scale and expressed in terms of turbidity units (TU).
- 1TU=1mg of finely divided silica mixed in 1 litre of distilled water, then the turbidity produced is taken as 1 standard turbidity unit.
- Turbidity is measured by turbidimeters (Jackson turbidity unit: JTU) and nephelometers (nephelometric turbidity unit: NTU).

Taste and Odour

- Taste and odours in water may be due to the presence of dead or alive micro organism, dissolved gases, mineral substances etc.
- The water having bad smell or odour is objectionable and should not supply to the public.
- Odour in water is measured by a device called Osmoscope(200ml capacity) and is expressed in terms of Threshold Odour Number (TON)
- TON is a dilution ratio at which odour is just detectable.
- Drinking water standard for odour = <3TON
- There is no test for taste. Generally a sample having bad colour is expected to taste bad. Taste is expressed as Flavored Threshold Number (FTN).

Chemical water quality

- The following are the different chemical water quality parameters

1. Solids

The residue left on evaporation is called solids.

- Total solids (TS)
- Suspended solids
- Total dissolved solids(TDS)

The presence of solid in water is measured by gravimetry method(weight measurement) and expressed in terms of mg/L or ppm (parts per million).

Total solids: Measured as the ratio of weight of residue after oven drying of raw water to the total volume of water taken

Suspended solids: Suspended solids are measured by filtration method. Filter paper of pore size smaller than the smallest suspended particles is used for filtration. The weight of solid retained on filter paper is measured and expressed in mg/L.

Total dissolved solids (TDS): It includes both colloidal and dissolved particles. TDS of a water sample is measured as the weight retained after oven drying of a filtered sample per the volume of filtered sample.

Drinking water standards for TDS=<500mg/L

2. pH

pH is the measure of potential of hydrogen ion concentration in water.

Water treatment is pH sensitive as extreme pH causes damage in property such as pipes etc. and hence increases the cost of treatment.

Measurement of pH:

- pH paper : approximate method
- Titrimetry : not being used now a days
- pH meter: (potentio meter) It is a digital electronic device measures pH very accurately

Drinking water standard for pH: 6.5 to 8

3. Acidity

- The measure of ability of water to neutralize base
- Acidity in water is generally caused by excess minerals or presence of CO_2
- Acidity in water causes corrosion problem and tuberculation (micro-projection)
- It is measured by titrimetry and expressed in terms of mg/L as CaCO_3
Titrant : NaOH
Indicator : Methyl orange/phenolphthalein

4. Alkalinity

- The measure of ability of water to neutralize acids
- It is caused by hydroxyl ions (OH^-) carbonates and bicarbonates
- Alkalinity causes scaling (growth of thin layer inside pipes), incrustation, and bitter taste to the water.
- It is measured by titrimetry method. Titrant: H_2SO_4
Indicator : Methyl orange/phenolphthalein

5. Hardness

- It is the property of water which prevents the lathering of the soap. It is caused due to the presence of carbonate & sulphate of calcium and magnesium in the water.
- Hardness in water causes: corrosion, scaling, bitter taste, increased soap consumption
- Hardness is measured by versenate method (EDTA method) which is a titrimetry method.
Titrant: EDTA
Indicator: Erichrome black T
Change in color : wine red to blue

Hardness in mg/L as CaCO ₃	Type of water
<75	soft
75-150	Moderately hard
150-300	Hard
>300	Very hard

6. Chlorides

- Sodium chloride is the main substance in chloride water. The natural water near the mines and sea has dissolved sodium chloride.
- Excess of chlorides is dangerous and unfit for use. The chloride can be reduced by diluting water. Chloride above 250ppm is not permissible for drinking water.
- The chloride can be determined by titrating the water with silver nitrate and potassium chromate. In this titration process yellow color will change into brick red color in the presence of chlorides.

7. Chlorine test

- Dissolved free chlorine is never found in natural waters.
- Residual chlorine is determined by the starch-iodide test. In this test, potassium iodide and starch solution are added to the sample of water due to which blue color is formed. This blue color is then removed by titrating with N/100 sodium thiosulphate solution and the quantity of chlorine is calculated.
- The residual chlorine should remain between 0.5 p.p.m. in the water so that it remains safe against bacteria.

8. Iron and manganese

- These are generally found in ground water. If it is present in water then the water is not suitable for domestic, bleaching, dyeing and laundering purposes.
- The presence of iron & manganese in water makes brownish red color in it, leads to the growth of micro-organism & corrodes the water pipes.
- The quantity of iron & manganese is determined by colorimetric methods. In this method some coloring agents are added in the water and colors so formed are compared with standard color solution.
- It is generally in 0.3 p.p.m

9. Dissolved gases test

Oxygen: Surface waters contain large amount of dissolved oxygen, because they absorb it from the atmosphere. The presence of oxygen in water is

necessary to keep it fresh & sparkling, but more quantity of oxygen causes corrosion to the pipe materials.

Carbon dioxide:

- The water absorbs carbon dioxide from the atmosphere. It causes hardness in water.
- The presence of carbon dioxide can be easily determined by mixing of the lime solution in the water. If it gives milky white color then carbon-dioxide is present in the water.

Nitrogen:

- The presence of nitrogen in the water indicates the presence of organic matters in the water.
- The presence of nitrates is not so harmful, but in no case its quantity should increase 45 ppm, because excess presence of nitrate will cause disease to the children.
- It is determined by color matching methods. In this method the color is obtained if phenol-di-sulphonic acid & potassium hydroxide are added. The colors so developed are compared with standard colors.

Biological water quality

In biological/bacteriological analysis of water the following two tests are done.

- Total count of bacteria
- E-coli test

Total count of bacteria

- In this method total number of bacteria present in a milliliter of water is counted. The sample of water is diluted; 1 ml of sample water is diluted in 99 ml of sterilized water. Then 1 ml of diluted water is mixed with 10 milliliter of agar or gelatin.
- This mixture is then kept in incubator at 37 degree centigrade for 24 hours or at 20 °C for 48 hours. After the sample will be taken out from the incubator & colonies of bacteria are counted by means of microscope.

Escherichia coli (E-coli) test

- Now a day a new technique of finding out the E-coli is developed which is called “membrane filter technique”.
- In this method the sample of water is filtered through a sterilized membrane of special design due to which all the bacteria are retained on the membrane.
- The member is then put in contact of culture medium – M – Endos medium in the incubator for 24 hours at 37 °C. The membrane after incubating is taken out and the colonies of bacteria are counted by means of microscope.
- For drinking water it is necessary that it must be free from pathogenic bacteria.

Water quality standards for different uses

Water quality parameters	Acceptable limits
Temperature	10-15.6°C
Odour	0-4
Colour	10-20ppm
Turbidity	5-10ppm
Taste	No objectionable taste
Total solids	<500ppm
Hardness	75-115ppm
Chlorides	<250ppm
Iron and manganese	<0.3 ppm
PH value	6.5to8
Lead	<0.1ppm
Arsenic	< 0.05 ppm
Sulphate	< 250ppm
Carbonate alkalinity	<120ppm
Dissolve oxygen	5-6 ppm
MPN	<=1nos per 100ml
E-coli index	nil

