Chapter 1

Water Supply Engineering-I

CHAPTER HIGHLIGHTS

- ☞ *Introduction*
- ☞ *Population forecasting and water demand*
- ☞ *Sources and conveyance of water*
- ☞ *Quality of water*

Introduction

In order to design a proper water work project, it is essential to determine the quantity of water required daily. This involves population determined and rate of demand. This chapter deals with the population estimation and methods of meeting the demand.

Population Forecasting and Water Demand

The demand can be of various types (As per IS: 1172–1993)

1. Demand of average Indian town **without** full flushing system (for LIG)

(a)	Domestic (50–60%)	–	135 lpcd
(b)	Industrial and commercial (20–25%)	–	70 lpcd
(c)	Public use (5–10%)	–	10 lpcd
(d)	Losses and thefts (15–20%)	–	55 lpcd
	Total demand	–	270 lpcd

2. **With** full flushing system (HIG)

(a)	Domestic	–	200 lpcd
(b)	Industrial and commercial	–	70 lpcd
(c)	Public use	–	10 lpcd
(d)	Losses and thefts	–	55 lpcd
	Total demand	–	335 lpcd

Industrial and Commercial Demand

Type of Building	lpcd
For nursing homes, boarding schools and hostels	135
For offices	40 to 90
For day schools	40 to 90
For residential schools	135 to 225
For hotels	180 lit/bed
For restaurants	70 lit/seat
Hospitals (<100 beds)	340 lit/bed
Hospitals (> 100 beds)	450 lit/bed
Bus and railway stations, airport	70

Fire demand is generally **5–10%** of total demand of the city. Fire demand is generally calculated using different empirical formulae.

1. **Kuichling's formula:**

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

Where,

Q = Demand in lit/min

P = Population in thousands

2. **Buston's formula:**

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

3. **Freeman's formula:**

$$Q = 1136\left(\frac{P}{10}+10\right) \text{ and } F = 2.8\sqrt{P}$$

Where, F = Number of simultaneous fire streams.

4. **National board of fire under writers formula:**

$$Q = 4637\sqrt{P}\ (1-0.01\sqrt{P})$$

As per Indian conditions, a provision of 1 liter per head per day will be sufficient for fire fighting. Each fire hydrant provided for this purpose has 3 streams and each stream discharges 1100 liters per head per day.

SOLVED EXAMPLES

Example 1

Compute fire demand for a city having population of 200000 using various formulae.

Solution

Population in thousands, $P = 200$

Kuiching's formula:

$$Q = 3182\sqrt{P} = 3182\sqrt{200}$$
$$= 45000.2 \text{ lit/min}$$

Buston's formula:

$$Q = 5663\sqrt{P} = 5663\sqrt{200}$$
$$= 80086.9 \text{ liters/min}$$

Freeman's formula:

$$Q = 1136\left(\frac{P}{10}+10\right)$$
$$= 1136\left(\frac{200}{10}+10\right)$$
$$= 34080 \text{ lit/min}$$

Number of fire streams:

$$F = 2.8\sqrt{P} = 2.8\sqrt{200} = 39.5 \approx 40$$

National board of fire under writer's formula:

$$Q = 4637\sqrt{200}\ (1-0.01\sqrt{200})$$
$$= 56303.0 \text{ lit/min.}$$

Factors Affecting Rate of Demand

1. **Size and type of community:** Large city has large per capita income and small city has small per capita income.
2. **Standard of living:** Higher the standard of living higher is the demand and greater the variation in demand.
3. **Climatic conditions:** In hot climates the water demand is more while in cold climates the water demand is less.
4. **Quality of water:** Higher the quality of water higher the demand.
5. **Pressure in supply:** Higher the pressure more is the demand.
6. **System of supply:** Continuous supply will increase the demand and intermittent supply reduce the demand.
7. **Sewerage system:** Use of water increase when sewers are installed in an area previously without them.
8. **Water rates:** Increase in water rates reduces consumption.
9. Age of community and lawn sprinkling both are directly proportional to the water demand.

Variation in Rate of Demand

1. Maximum seasonal consumption = 130% of annual average daily rate of demand
2. Maximum monthly consumption = 140% of annual average daily rate of demand
3. Maximum daily consumption = 180% of annual average daily consumption
4. Maximum hourly consumption = 150% of average for the day.

Total draft = Maximum daily demand + Fire demand or maximum hourly demand whichever is greater.

Design Period

A reasonable future period for which provision is made in water supply scheme in known as design period.

Component	Design Period
Dams	50 years
Conveying main pipes	30 years
Distribution system	30 years
Water treatment units	15 years
Pumps, service reservoirs	15 years

Population Forecasting Methods

Population forecasting can be done in various methods.

1. **Arithmetical increase method:** This is the most simple method of population forecast. The increase in population for each decade is found and from that an average increment is found. Thus the future population after n decades is:

$$P_n = P + nI$$

Where

P_n = Future population at the end of n decades

P = Present population

I = Average increment for a decade

This method is used for forecasting population in large and old cities.

2. **Geometric increase method:** It is assumed that percentage increase in population from decade to decade is constant. Consider I_g is the average percentage increase per decade, the population P_n after n decades is given by:

$$P_n = P\left(1+\frac{I_g}{100}\right)^n$$

Where, $I_g = (r_1 \times r_2 \times r_3 \ldots r_n)^{\frac{1}{n}}$.

Example 2

The population figures in growing town are as follows:

Year	Population
1970	46000
1980	53000
1990	58000
2000	61000

The predicted population in 2010 by arithmetic regression method is _____.

Solution

Year	Population	Per Decade Increase in Population
1970	46000	
1980	53000	7000
1990	58000	5000
2000	61000	3000

$$I = \frac{7000+5000+3000}{3} = 5000$$

$$P_n = P_0 + n(I)$$

$$n = \frac{2010-2000}{10} = 1;\ P = 61000$$

$$P_{2010} : P = P + 1(I)$$

$$= 61000 + 1(5000) = 66000.$$

Example 3

Population data pertaining to a community is given in the following table. Find population in the year 2030 by geometrical increase method.

Year	Population
1980	60000
1990	70000
2000	100000
2010	180000

Solution

Year	Population	Per Decade % Increase in Population
1980	60000	((70 – 60)/60) × 100 = 16.66
1990	70000	((100 – 70)/70) × 100 = 42.85
2000	100000	((180 – 100)/100) × 100 = 80
2010	180000	

$$n = \frac{2030-2010}{10} = 2 \text{ decades}$$

$$P = 180000$$

Geometric average of per decade percentage increase in population (I_g),

$$= (r_1 \times r_2 \times r_2)^{\frac{1}{3}} = 38.5\%$$

$$P_n = P_{2030} = P_0\left[1+\frac{I_g}{100}\right]^n$$

$$= 180000 \times \left(1+\frac{38.5}{100}\right)^2$$

$$= 345280.5.$$

3. **Incremental increase method:** It is the combination of arithmetic average method and geometrical average method. The actual increase in each decade is first found and then the increment in increase for each decade is found. From these an average increment of increase is found.

$$P_n = P + nI + \frac{n(n+1)}{2} r$$

Where

P = Present population

I = Average increase

r = Average incremental increase

n = Number of decades.

Example 4

Past population data of a town is given in the table. Find the population in the year 2030 by incremental increase method.

Year	1980	1990	2000	2010
Population	27000	42000	52000	72000

Solution

Year	Population	Per Decade Increases in Population	Increment Over Increase in Population
1980	27000	15000	–5000
1990	42000	10000	+10000
2000	52000	20000	
2010	72000		

$$\bar{I} = \frac{15000 + 10000 + 20000}{3} = 15000$$

$$r = \frac{-5000 + 10000}{2} = 2500$$

$$P = 72000;\ n = \frac{2030 - 2010}{10} = 2 \text{ decades}$$

$$P_n = P = n\bar{I} + \frac{n(n+1)}{2} r$$

$$P_{2030} = 72000 + 2(15000) + \frac{2(2+1)}{2}(2500) = 109500.$$

4. **Decreasing rate method:** It is used for cities whose rate of increase goes on reducing as they reach saturation.

$$P_n = P_0 \times \left[1 + \frac{r_0 - D}{100}\right] \times \left[1 + \frac{r_0 - 2D}{100}\right] \times \cdots \times \left[1 - \frac{r_0 - nD}{100}\right]$$

Example 5

Year	1980	1990	2000	2010
Population	60000	73700	81400	89500

Estimate the population of year 2020 by decreasing rate of growth method.

Solution

Year	Population	Per Decade % Increase in Population	Decrease in % Increase in Population
1980	60000		
1990	73700	22.8	12.36
2000	81400	10.44	0.49
2010	89500	9.95	

$$P_0 = 89500$$

$$r_0 = 9.95$$

$$n = \frac{2020 - 2010}{10} = 1 \text{ decade}$$

$$\bar{D} = \frac{12.36 + 0.49}{2} = 6.425\%$$

$$P_{2020} = 89500\left[1 + \frac{9.95 - (1)(6.425)}{100}\right] = 92654.8.$$

5. **Graphical method:** A graph plotted between time and population is smoothly extended to desired time. The graph is called 'logistic curve'. It is unsafe to use this method alone.

Factors Affecting Population Growth

1. Economic factors: Development of industries, discovery of oil, etc.
2. Development programmes: Development of national projects.
3. Social facilities: Educational, medical, reactional and other social facilities.
4. Tourism
5. Communication links: Connection of town with other big cities.

Sources and Conveyance of Water

Sources of Water

Types of source of water:

1. Surface source of water
2. Sub-surface sources of water

Surface Sources of Water

1. **Lakes and ponds:** Lake water has plenty of algae, weeds and other vegetables.
2. **Streams or rivers:** River water is pure at the mountain but when it approaches the plain it becomes deteriorated.
3. **Storage reservoirs:** They are the main source of water supply for big cities.
4. **Oceans:** They are highly saline.

Sub-surface Sources of Water

1. **Infiltration galleries:** A horizontal tunnel usually rectangular in cross-section and having permeable boundaries so that ground water can infiltrate in to it.
2. **Infiltration wells:** It is a shallow well-constructed in series along the bank of river to collect water seeping through banks of river.
3. **Springs:** It is a natural outflow of ground water which appears at ground surface as current or stream of flowing water.
4. **Wells:** Wells are of two types:
   (a) Open wells—large diameter and low yield.
   (b) Tube wells—small diameter, long pipe sunk into the ground intercepting one or more water bearing strata.

Conveyance of Water

Pressure conduits is generally measured by:

Darcy–Weisbach equation:

$$h_f = \frac{fLV^2}{2gd} = \frac{fLQ^2}{12.1d^5}$$

Hazen–Williams equation:

$$V = 0.85\, c_H (R)^{0.63} (S)^{0.54}$$

Quality of Water

Types of Water

- **Mineral water:** It contains minerals like Mg, Ca and Fe.
- **Contaminated water:** It contains pathogenic bacteria unfit for drinking.
- **Polluted water:** It contains un-desirable substances rendering it unfit for drinking.
- **Wholesome water:** Chemically may not be pure but does not contain any harmful element for human.
- **Palatable water:** Water is aesthetically looking good.
- **Potable water:** Water is fit for drinking.
- **Pure water:** It is chemical compound (H_2O).

Characteristic of Water

Physical Characteristics

1. **Turbidity:** It is caused due to suspended materials such as clay, silt or other finely divided organic and inorganic matter. It is measured on silica scale. The instrument used to measure turbidity is turbiditymeter. There are different types of turbiditymeter.
   - **(a) Jackson's turbidimeter:** used to measure high turbidity (>25 ppm) unit is JTU.
   - **(b) Baylis turbidimeter:** It is used to record even low turbidity values of 0 ppm to 2 ppm
   - **(c) Nephelometers:** It is used for turbidity range of 0–1 ppm. Its unit is NTU and FTU.

   Turbidity is the measure of resistance to the passage of light through water.
2. **Colour:** It is the indication of dissolved organic matters from decaying vegetation or some inorganic coloured soils, growth of algae, metallic ions (Fe and Mn). It is measured by platinum cobalt method the permissible limit is 5–20 ppm.
3. **Test and odour:** It is due to dissolved organic matter or organic salts, dissolved gases, etc. Taste is expressed in flavour threshold number and odour is expressed as threshold odour number.

$$\text{Threshold number} = \frac{(A+B)}{A}$$

Where

A = Volume of raw water sample

B = Volume of distilled water used for dilution

Permissible limit is 1–3. Osmoscope is the instrument used to measure odour. Values in osmoscope range from 0–5 which are denoted by *PO*.

4. **Temperature:** Temperature of water to be supplied should be between 10°–20°C. It is measured by normal thermometer. But in case of large bodies temperature is measured by capillary thermometer.
5. **Specific conductivity:** It is done to know the dissolved salt content and it is determined by dionic water tester.
6. **Impurities in water:** The impurities in water can be classified into following three types:
   - Suspended impurities—cause turbidity, e.g., silt, clay, bacteria, etc.
   - Colloidal impurities—finely divided particles, not visible to naked eye.
   - Dissolved impurities—These include organic compound, inorganic salts and gases. For example, salt $CaCl_2$, $MgCl_2$, CO_2, etc., and metals like Iron causes red colour, manganese causes brown colour, lead and arsenic causes poisoning and gases like oxygen causes corrosion of metals, chlorine and ammonia causes bad taste, CO_2 and H_2S cause acidity in water.

Chemical Characteristics

1. **Total solids, suspended solids and dissolved solids:** Total solids = Suspended solids + Dissolved solids.

   Suspended solids are found by filtering water sample by Whatman filter paper and total solids can be found by evaporating a sample of water and weighing the dry residue left. Permissible limit of total dissolved solids is 500 to 1000 ppm.

$$\text{Total solids} = \frac{W_2 - W_1}{V} \times 10^6$$

Where

W_2 = Final weight in gram

W_1 = Initial weight in gram

V = Volume of water sample in millilitre

Example 6

A 200 ml water sample is drawn to an empty dry container whose initial weight is 89.323 g. After oven drying the sample at 106°C for 6 hours, its final weight measured to be 89.346 g. The total solids, concentration in mg/lit is _____.

Solution

$$\text{Total solids} = \frac{W_2 - W_1}{V} \times 10^6$$

$$= \frac{89.346 - 89.323}{200} \times 10^6 = 115 \text{ mg/lit.}$$

2. **pH value of water:** It is the hydrogen ion concentration in water.

$$\text{Concentration of } H^+ = \frac{10^{-14}}{\text{Concentration of } OH^-}$$

For pure water $[H^+] = [OH^-]$

$$= 10^{-7} \text{ moles/lit}$$

$$\text{pH} = \log_{10} \frac{1}{H^+} = \log_{10} \frac{1}{10^{-7}} = \log_{10} 10^7 = 7$$

- If pH > 7 then the water is said to be basic.
- If pH = 7 then the water is said to be neutral.
- If pH < 7 then the water is said to be acidic.
- The value of pH is determined by colorimetric method.
- Alkalinity in water is due to the bicarbonates of Ca and Mg and carbonates, hydroxides (OH) of Ca, Mg, K, Na.
- Acidity is caused by the mineral acids, free CO_2, sulphates of Fe and aluminium.
- The permissible limit of pH of water is 6.6 to 8.5.

Example 7

A water has pH value equal to 8. The hydrogen ion concentration equal to

Solution

$$\text{pH} = \log_{10} \frac{1}{H^+}$$

$$8 = \log_{10} \frac{1}{H^+}$$

$$H^+ = 10^{-8} \text{ mol/lit}$$

3. **Hardness:** It is the characteristic which prevents the formulation of lather with soap.

There are two types of hardness:

(a) Carbonate hardness is the temporary hardness caused by HCO_3^- and CO_3^{2-} of Ca^{+2} & Mg^{+2} and can be removed by addition of lime.

(b) Non-carbonate hardness is the permanent hardness caused by SO_4^{2-}, Cl^-, NO_3 of Ca^{+2} and Mg^{+2} and can be removed by demineralization process and zeolite process.

- Hardness < 75 ppm is called soft water.
- Hardness > 200 ppm is called hard water.
- Hardness is generally measured by EDTA test.

Total hardness in mg/lit as CaCO3

$$= \left[Ca^{+2} \text{ in mg/l} \times \frac{\text{Equivalent weight of } CaCO_3}{\text{Equivalent weight of } Ca^{2+}} \right] +$$

$$\left[Mg^{+2} \text{ in mg/l} \times \frac{\text{Equivalent weight of } CaCO_3}{\text{Equivalent weight of } Mg^{2+}} \right]$$

- $\text{Equivalent weight} = \frac{(\text{molecular weight})}{\text{valency}}$

The molecular weights of elements are as follows:

$Ca^{++} = 40$

$Mg^{++} = 24$

$Sr^{++} = 87.6$

$CaCO_3 = 100$

$CO_3^{2-} = 60$

$HCO_3^- = 61$

OH– = 17

$$\text{Total hardness} = \left[Ca^{++} \text{mg/lit} \times \frac{50}{20} \right] + \left[Mg^{++} \text{ mg/lit} \times \frac{50}{12} \right]$$

If TH > Alkalinity, then CH = Alkalinity

TH ≤ Alkalinity, then CH = TH, NCH = 0

- One British degree of hardness = 14.5 ppm of $CaCO_3$
- One French degree of hardness = 10 ppm of $CaCO_3$
- One American degree of hardness = 17.15 ppm of $CaCO_3$
- Alkalinity in mg/lit as $CaCO_3$

$$= \left[HCO_3^- \text{ in mg/lit} \times \frac{\text{Equivalent wt of } CaCO_3}{\text{Equivalent wt of } HCO_3} \right]$$

$$+ \left[CO_3^{2-} \text{ in mg/lit} \times \frac{\text{Equivalent wt of } CaCO_3}{\text{Equivalent wt of } CO_3^{2-}} \right]$$

- Total alkalinity =

$$\left[HCO_3^- \text{ mg/lit} \times \left(\frac{50}{61} \right) \right] + \left(CO_3^{2-} \text{ in mg/lit} \times \frac{50}{30} \right).$$

Example 8

Total alkalinity of sample is 300 mg/lit as $CaCO_3$. The Ca^{++} is 220 mg/lit, Mg^{++} is 70 mg/lit. What is total hardness, carbonate hardness, non-carbonate hardness?

Solution

TA = 300 mg/lit of $CaCO_3$

$$\text{TH} = Ca^{+2} \times \frac{50}{20} + Mg^{2+} \times \frac{50}{12}$$

$$= 220 \times \frac{50}{20} + 70 \times \frac{50}{12}$$

$$= 841 \text{ mg/lit of } CaCO_3$$

$\therefore$ TH > TA

$$CH = TA = 300 \text{ mg/lit } CaCO_3$$

$$NCH = TH - CH = 841 - 300$$

$$= 541 \text{ mg/lit of } CaCO_3.$$

4. **Chloride content:** The permissible limit of chloride content is 250 mg/lit. It is present in the form of sodium chloride.
5. **Nitrogen content:** It indicates presence of organic matter and the extent to which it has undergone decomposition. Excess of a nitrogen causes methemoglobenimia (blue baby disease).

   Forms of nitrogen content:

   (a) **Free ammonia:** Indicates presence of undecomposed organic matter and it is the first stage decomposition.

   (b) **Albuminoid nitrogen:** It indicates decomposition of organic matter has started. Permissible limit is less than 0.15 ppm.

   (c) **Nitrites:** It indicates the presence of partly decomposed organic matter. The permissible limit is nil.

   (d) **Nitrates:** It indicates fully oxidized organic matter. The permissible limit is less than 45 ppm.

   (e) Total Kjeldahl nitrogen = Free ammonia + Organic nitrogen.
6. **Metals and chemical substances:**
   - Iron and manganese—Iron < 0.3 ppm, Mn < 0.05 ppm, causes discolouration of clothes.
   - Copper—permissible limit 1 to 3 mg/lit, affects human lungs and other respiratory organs.
   - Sulphate—permissible limit < 250 mg/lit, causes laxative effect on body and diarrhea.
   - Flourides—permissible limit < 1 ppm causes cavities, permissible limit > 1.5 ppm causes fluorosis and deformation of bones.
7. **Dissolved gasses:**
   - H_2S—It gives bad taste and odour.
   - CO_2—It indicates biological activity and causes corrosion in pipe lines.
   - Dissolved oxygen—determined by Winkler's method, permissible limit for potable water is 5–10 ppm.
   - Nitrogen—Indicates the presence of organic matter.
8. **Biochemical oxygen demand (BOD):** Permissible limits of BOD of safe drinking water is nil.

Microscopic Characteristics

It is the study about the presence of bacteria, virus, algae, protozoa.

Bacteria (1 to 4 Microns in Size) Bacteria is single celled organism.

Classification:

1. Non-pathogenic bacteria: They are harmless, e.g., escherichia coliform or E. coli.
2. Pathogenic bacteria: They are harmful and causes water borne diseases.
   - Detection of 'E. coli' indicates the probable presence of 'pathogens'.
   - E. coli bacteria is used as indicator organism.

Classification based on shape:

1. Cocci—Sphere shaped bacteria
2. Bacilli—Rod shaped bacteria
3. Spirilla—Twisted rod shaped bacteria

To detect and measure coliform bacteria, the following tests are available:

1. **Total count test:** In this test bacteria are cultivated on specially prepared medium of agar for different dilutions of sample of water with distillated water. The diluted sample is placed in incubator for specified time at specified temperature. The bacteria colonies so formed are counted and results are computed per 100 ml.
2. **E. coli test:** Divided into:

   (a) Presumptive test

   (b) Confirmed test

   (c) Completed test.

   In these tests, if gas is produced after incubation, it is reported as positive and further tests are to be followed to confirm e-coil. If no gas is produced it is presumed that there is no bacteria and the test is treated as negative.
3. **Membrane filter technique:** This is recent method. Sample is filtered through sterile membrane with pore size 5–10 mμ.

   The bacteria is retained on the membrane. The membrane is put in contact with suitable nutrient. [M-Endo's medium] which inhibits growth of bacteria other than coli form group. Then placed in incubator at prescribed conditions and the visible colonies are counted with microscope.

Most probable number (MPN): It is the bacterial density which is most likely to be present in water. It is used to report the amount of bacteria present.

- To determine MPN, confirmed or completed tests results are required.
- Permissible limits: MPN should be Nil.

Micro Organic Plants These are tiny plants, e.g., algae, plankton, etc.

- They cause bad taste and odour and interface with smooth working of filter.
- To control algae, copper sulphate chemical is mixed in water.

Protozoa: These are unicellular animals.

Water Borne Diseases

Diseases which spread primarily through contaminated water and important of these water borne diseases are:

1. **Bacterial infections:**
   (a) Typhoid fever
   (b) Diarrhea
   (c) Cholera
   (d) Bacillary dysentery
2. **Viral infections:**
   (a) Infection hepatitis
   (b) Poliomyelitis
   (c) Gastroenteritis
3. **Protozoal infections:** Amoebic dysentery.

Exercises

1. The population of a city at previous consecutive census years was 4,00,000, 5,58,500, 7,76,000 and 10,98,500 respectively. The anticipated population at the next census to the nearest 5,000 would be _____.

2. Water distribution systems are sized to meet the
(A) maximum hourly demand.
(B) average hourly demand.
(C) maximum daily demand and fire demand.
(D) average daily demand and fire demand.

3. The present population of a community is 28000 with an average water consumption of 4200 m^3/d. The existing water treatment plant has a design capacity of 6000 m^3/d. It is expected that the population will increase to 44000 during the next 20 years. The number of years from now when the plant will reach its design capacity, assuming an arithmetic rate of population growth, will be
(A) 5.5 years (B) 8.6 years
(C) 15.0 years (D) 16.5 years

4. The pH of water admitted in to a treatment plant was 6.0 in the morning. Consequent to inflow of raw water from a different source. It changed to 8.0 in the next 24 hours. Assuming linear variation in time of the hydrogen ion concentration, the time mean pH value of the water over this 24 hours period will be _____.

5. Methmoglobinemia, the blue baby syndrome is caused by consuming water containing excess of
(A) fluoride (B) phosphate
(C) nitrate (D) nitrite

6. Hardness of water is caused by the presence of which of the following in water?
(A) Chlorides and suplhates
(B) Calcium and magnesium
(C) Nitrites and nitrates
(D) Sodium and potassium

7. A rapid test to indicate the intensity of pollution in river water is **[GATE, 1992]**
(A) biochemical oxygen demand.
(B) dissolved oxygen.
(C) MPN.
(D) total dissolved solids.

8. Bacteriological examination of drinking water for Escherischia Coliforms (E. Coli) is performed because
(A) they are pathogenic causing intestinal diseases.
(B) their presence indicates viral contamination of water.
(C) they are used as indicator organisms for probable presence of pathogens.
(D) they represent unique indicator organism for sewage pollution.

9. The temporary hardness of water is caused by
(A) dissolved carbon dioxide.
(B) bicarbonates and carbonates of calcium and magnesium.
(C) bicarbonates of sodium and potassium.
(D) carbonates of calcium and magnesium.

10. Break point chlorination of water involves addition of chlorine in an amount sufficient to
(A) react with any ammonia and readily oxidizable organic matter.
(B) kill giardia cysts.
(C) react with inorganic matter.
(D) reduce bacterial growth in filters.

11. The most important water quality parameter for domestic use of water is
(A) carbonate hardness.
(B) non carbonate hardness.
(C) coli form group of organisms.
(D) chlorides.

12. Presence of fluoride in water greater than permissible level of 1.5 mg/lit causes
(A) cardiovascular disease
(B) methmoglobinemia
(C) hepatitis
(D) dental fluorosis

13. Alkalinity of water can be defined correctly in one of the following ways:
(A) It is the measure of ability of water to neutralize oxygen.
(B) It is the measure of ability of water to neutralize carbonates.
(C) It is the presence of ion in water that will neutralize hydrogen ions.
(D) It is the measure of ability of water to neutralize hydroxides.

14. MPN index is a measure of one of the following:
(A) Coliform bacteria
(B) BOD_5
(C) Dissolved Oxygen content
(D) Hardness

15. The microbial quality of treated piped water supplies is monitored by
(A) microscopic examination.
(B) plate count of heterotrophic bacteria.
(C) coliform MPN test.
(D) identification of all pathogens.

16. Excessive fluoride in drinking water causes
(A) alzheimer's disease.
(B) motting of teeth and embrittlement of bones.
(C) methamoglobinemia.
(D) skin cancer.

17. Temporary hardness in water is caused by the presence of
(A) bicarbonates of Ca and Mg.
(B) sulphates of Ca and Mg.
(C) chlorides of Ca and Mg.
(D) nitrates of Ca and Mg.

18. Blue baby disease (methaemoglobinemia) in children is caused by the presence of excess
(A) chlorides (B) nitrate
(C) fluoride (D) lead

19. Two samples of water A and B have pH values of 4.4 and 6.4 respectively. How many times is sample A more acidic than sample B?
(A) 0 (B) 50
(C) 100 (D) 200

20. Use of coagulants such as alum
(A) results in reduction of pH of the treated water.
(B) results in increase in pH of the treated water.
(C) results in no change in pH of the treated water.
(D) may cause an increase or decrease of pH of the treated water.

21. Aeration of water is done to remove
(A) suspended impurities
(B) colour
(C) dissolved salts
(D) dissolved gases

22. The following chemical is used for coagulation:
(A) Ammonium chloride
(B) Aluminium chloride
(C) Aluminium sulphate
(D) Copper sulphate

23. The Ca^{2+} concentration and Mg^{2+} concentration of water sample are 160 mg/lit and 40 mg/lit as their ions respectively. The total hardness of the water sample in terms of $CaCO_3$ in mg/lit is approximately equal to
(A) 20 (B) 200
(C) 267 (D) 567

24. In natural water hardness is mainly caused by
(A) Ca^{++} and Mn^{++}
(B) Ca^{++} and Fe^{++}
(C) Na^{+} and K^{+}
(D) Ca^{++} and Mg^{++}

25. The results of analysis of a raw water sample are given below:
Turbidity : 5 mg/lit
pH : 7.4
Fluorides : 2.5 mg/lit
Total Hardness : 300 mg/lit
Iron: 3.0 mg/lit
MPN : 50 per 100 ml
From the data given above, it can be inferred that water needs removal of
(A) turbidity followed by disinfection.
(B) fluorides and hardness.
(C) iron, followed by disinfection.
(D) fluorides, hardness and iron followed by disinfection.

26. Results of a water sample analysis are as follows

Cation	Concentration (mg/lit)	Equivalent Weight
Na^{+}	40	23
Mg^{+2}	10	12.2
Ca^{+2}	55	20
K^{+}	2	39

(Milliequivalent weight of $CaCO_3$ = 50 mg/meq)
Hardness of the water sample in mg/lit as $CaCO_3$ is
(A) 44.8 (B) 89.5
(C) 179 (D) 358

27. Most of the turbidity meters work on the scattering principle. The turbidity value so obtained is expressed in
(A) CFU (B) FTU
(C) JTU (D) NTU

28. Hardness of water is directly measured by titration with ethylene diamine tetracetic acid (EDTA) using
(A) eriochrome black T indicator.
(B) ferrion indicator.
(C) methyl orange indicator.
(D) phenolphathalein indicator.

29. The organism which exhibits very nearly the characteristics of an ideal pathogenic indicator is
(A) Entamoeba histolytica
(B) Escherichia coli
(C) Salmonella typhi
(D) Vibrio comma

30. A standard multiple tube fermentation test was conducted on a sample of water from a surface stream. The results of the analysis for the confirmed test are given below:

Sample Size (ml)	Number of Positive Results Out of 5 Tubes	Number of Negative Results Out of 5 Tubes
1.0	4	1
0.1	3	2
0.01	1	4

MPN index and 95% confidence limits for combination of positive results when five tubes used per dilutions (10 ml, 1.0 ml, 0.1 ml) are as follows:

Combination of Positive	MPN Index per 100 ml	95% Confidence Limit	
		Lower	Upper
4–2–1	26	12	65
4–3–1	33	15	77

Using the above MPN index table, the most probable number (MPN) of the sample is
(A) 26 (B) 33
(C) 260 (D) 330

31. Population levels over 5 decades of a small town are given below:

Years	Population
1960	2,50,000
1970	2,80,000
1980	3,40,000
1990	4,20,000
2000	4,90,000

The population of the town in the year 2020 estimated by arithmetic increase method will be
(A) 5,10,000
(B) 5,90,000
(C) 6,10,000
(D) 6,90,000

32. Which one of the following organisms is responsible for enteric fever?
(A) ECHO
(B) Salmonella typhi
(C) Entamoeba histolytica
(D) Echinococcus

33. Match List I (Parameters) with List II (Units) and select the correct answer using the code given in the lists:

	List I		List II
a.	Turbidity	**1.**	TON
b.	Pathogen	**2.**	TCU
c.	Odour	**3.**	JTU
d.	Colour	**4.**	MPN

Codes:

	a	b	c	d
(A)	2	1	4	3
(C)	2	4	1	3

	a	b	c	d
(B)	3	1	4	2
(D)	3	4	1	2

34. **Assertion (A):** Fluorides should always be present in drinking water up to a value 1.5 mg/lit.
Reason(R): Such a water helps clean the teeth well.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not a correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

35. Total Kjedahl nitrogen is a measure of
(A) total organic nitrogen.
(B) total organic and ammonia nitrogen.
(C) total ammonia nitrogen.
(D) total inorganic and ammonia nitrogen.

36. 1 TCU is equivalent to the colour produced by
(A) 1 mg/lit of chloroplatinate ion.
(B) 1 mg/lilt of platinum ion.
(C) 1 mg/lit platinum in form of chloropatinate ion.
(D) 1 mg/lit of organic chloroplatinate ion.

37. If tomato juice is having a pH of 4.1, the hydrogen ion concentration will be
(A) 10.94×10^{-5} mol/lit
(B) 9.94×10^{-5} mol/lit
(C) 8.94×10^{-5} mol/lit
(D) 7.94×10^{-5} mol/lit

38. Match List I with List I and select the correct answer using the codes given in the lists:

	List I		List II
a.	Release valve	**1.**	Reduce high inlet pressure to lower outlet pressure
b.	Check valve	**2.**	Limit the flow of water to single direction
c.	Gate valve	**3.**	Remove air from the pipeline
d.	Pilot valve	**4.**	Stopping the flow of water in the pipeline

Codes:

	a	b	c	d
(A)	3	2	4	1
(C)	3	4	2	1

	a	b	c	d
(B)	4	2	1	3
(D)	1	2	4	3

39. A synthetic samples of water is prepared by adding 100 mg kaolinite (a clay minear) 200 mg glucose, 168 mg NaCl, 120 mg $MgSO_4$ and 111 mg $CaCl_2$ to 1 litre of

pure water. The concentrations of total solids (TS) and fixed dissolved solids (FDS) respectively in the solution in mg/lit are equal to

(A) 699 and 599 (B) 599 and 399
(C) 699 and 199 (D) 699 and 399

Direction for question 40 and 41:

A water contains the following dissolved ions:
$[Na^+] = 56$ mg/lit; $[Ca^{2+}] = 40$ mg/lit
$[Mg^{2+}] = 30$ mg/lit'; $[Al^{3+}] = 3$ mg/lit
$[HCO_3] = 190$ mg/lit; $[Cl^-] = 165$ mg/lit
Water pH is 7
Atomic weights: Ca = 40; Mg = 24; Al = 27; H = 1;
C = 12; O = 16; Na = 23; Cl = 35.5.

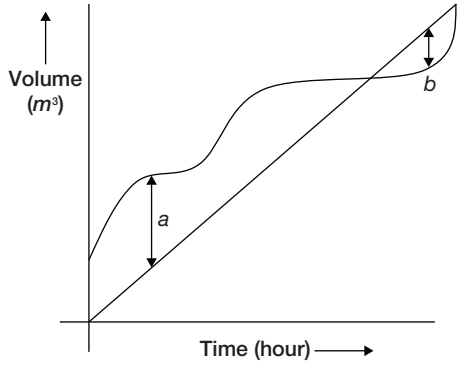
40. The total hardness of the sample in mg/lit as $CaCO_3$ is

(A) 484 (B) 450
(C) 242 (D) 225

41. The non-carbonate hardness of the sample in mg/lit as $CaCO_3$ is

(A) 225 (B) 156
(C) 86 (D) 0

42. The given figure shows roughly the daily mass curves of supply and demand from an elevated reservoir. The minimum required capacity of the reservoir is given by:



(A) $a - b$ (B) $a + b$
(C) $a \times b$ (D) larger of a or b

43. In Delhi it has been decided to provide 200 litre per head per day in 2020. Estimate the domestic water requirements of this city in 2020 by projecting the population of the town by incremental increase method.

Year	Population
1970	2, 37, 98, 624
1980	4, 50, 78, 325
1990	5, 53, 86, 432
2000	6, 91, 87, 241

(A) 18641 MLD (B) 19094 MLD
(C) 20986 MLD (D) 22782 MLD

44. A standard multiple tube fermentation test was conducted on a sample of water from a stream. The results of the analysis of the confirmed test are given below:

Sample Size (ml)	Number of Positive Results Out of 5 Tubes	Number of Negative Results Out of 5 Tubes
10	2	3
1	0	5
0.1	2	3

MPN Index and 95% confidence limits for combination of positive results when 5 tubes used per dilution (1 ml, 0.1 ml, 0.01 ml) are as follows:

Combination of Positives	MPN Index Per 100 ml	95% Confidence Limit	
		Lower	Upper
1 – 3 – 5	280	120	360
2 – 0 – 2	330	160	380
3 – 5 – 3	140	100	210

Using the above MPN index table, the most probable number (MPN) of the sample is

(A) 25 (B) 14
(C) 28 (D) 33

45. 12 mg of copperas is consumed with lime at a coagulation basin per litre water. Determine the quantity of copperas and the quick lime required to treat 20 MLD. [$F_e = 56$, S = 32, O = 16, Ca = 40, H = 1]

(A) 240 and 16 kg/day
(B) 240 and 48.4 kg/day
(C) 180 and 16 kg/day
(D) 180 and 48.4 kg/day

46. A town with a population of one lakh is to be supplied with water, daily at 120 lit/head. The variation in demand is as follows:
6–10 am—50% of total demand
10–12 pm—10% of total demand
12–6 pm—5% of total demand
6–12 am—30% of total demand
12–6 am—5% of total demand

Determine the capacity of service reservoir assuming pumping to be at uniform rate and the period of pumping from 6–10 am and 6–10 pm. (Neglect fire demand)

(A) 1.2 ML (B) 2.4 ML
(C) 3.6 ML (D) 4.8 ML

47. A 30 cm diameter sewer with an invert slope of 1 in 400 is running full. Calculate the rate of flow in the sewer. (use mannings equation and $N = 0.015$)

(A) 0.02 m^3/s (B) 0.03 m^3/s
(C) 0.04 m^3/s (D) 0.05 m^3/s

48. If the per capita contribution of suspended solids and BOD is 100 g and 60 g, find the population equivalent of 50,000 litres daily of industrial waste water containing 1800 mg/lit of suspended solids.

(A) 800 (B) 900
(C) 1000 (D) 1100

49. Blue baby disease in children is caused by the presence of excess
(A) chlorides (B) nitrates
(C) flourides (D) lead

50. Identify the incorrect match from the following:
(A) BOD–Strength of Sewage
(B) Nitrate–Methemoglobinemia
(C) Methane–Product of anaerobic decomposition
(D) COD–Biodegradability of waste water

51. If the average daily water consumption of a city is 1,00,000 m^3; then maximum daily consumption on peak hourly demand will be _____.
(A) 1,00,000 m^3
(B) 1,50,000 m^3
(C) 1,80,000 m^3
(D) 2,70,000 m^3

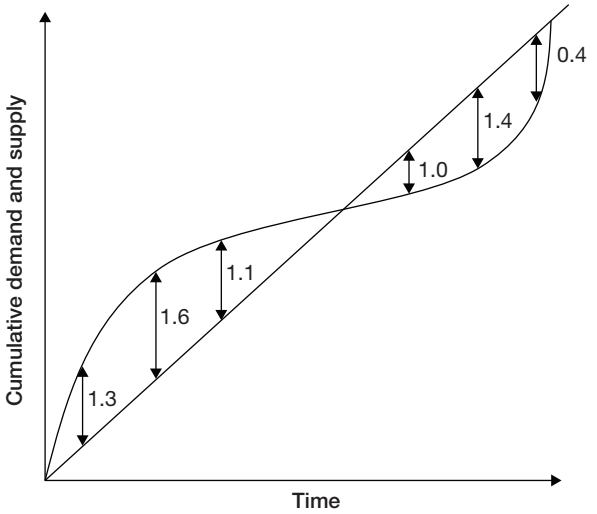
52. Results of a water sample analysis are as follows:

Cation (mg/lit)	Concentration Weight	Equivalent Weight
Na^{+2}	40	23
Mg^{+2}	10	12.2
Ca^{+2}	55	20
K^{+}	2	39

Hardness of water sample in mg/lit as $CaCO_3$ is _____.
(A) 44.8 (B) 89.5
(C) 179 (D) 358

53. Figure below shows the mass curve which is drawn for cumulative water demand and supply versus time.

Then find the balancing storage capacity of the reservior, in ML?



(A) 1.5 (B) 1.6
(C) 0.2 (D) 3

54. A standard multiple-tube fermentation test was conducted on a sample of water. The results of the analysis for the confirmed test are given below:

Sample Size (ml)	Number of Positive Results Out of 5 Tubes	Number of Negative Results Out of 5 Tubes
10	4	1
1	2	3
0.1	1	4
0.01	0	5

MPN index for combination of positive results when 5 tubes used per dilutions (10 ml, 1.0 ml, 0.1 ml) are given as follows.

Combination of Positives	MPN Index per 100 ml
5 – 4 – 3	280
4 – 3 – 1	33
4 – 2 – 1	26
2 – 1 – 0	7

Using the above MPN index table, what is the most probable number (MPN) of the sample?
(A) 260 (B) 280
(C) 28 (D) 70

55. The following data is available regarding various types of area and the corresponding impermeability factors of a town.

Type	Percentage of Area	Impermeability Coefficient
Roofs	15%	0.9
Pavements	20%	0.8
Lawns, Vegetation	40%	0.15
Unpaved	15%	0.20
Wooded	10%	0.05

If the total area is 20 hectares and time of concentration for the area is 30 minutes, find the maximum storm water flow.
Use following formula for intensity of rainfall:

$$R_i = \frac{900}{t + 60}$$

(A) 0.127 m^3/s
(B) 0.216 m^3/s
(C) 0.294 m^3/s
(D) 0.347 m^3/s

56. Identify the correct relation from the following
(A) BOD > COD > TOD
(B) COD > BOD > TOD
(C) TOD > BOD > COD
(D) TOD > COD > BOD

57. West–Geak method is used to measure _____.
(A) HC (B) NO_x
(C) SO_x (D) CO

58. If total hardness and alkalinity of a water sample are 250 mg/lit and 200 mg/lit as $CaCO_3$ respectively, what are values of carbonate and non-carbonate hardness?
(A) 50 mg/lit and 250 mg/lit
(B) 50 mg/lit and 200 mg/lit
(C) 200 mg/lit and 50 mg/lit
(D) 250 mg/lit and 50 mg/lit

59. A septic tank is to be designed for a small colony of people with the following data:

Number of people = 1200

Water supply rate = 130 lpcd and 80% of water converts in to sewage

Detention time = 36 hours

Sludge accumulation = 35 lit/person/year

Desludging interval = 10 months

The required volume for the septic tank in m^3 is _____.
(A) 30 m^3 (B) 187 m^3
(C) 217 m^3 (D) 157 m^3

60. If 3 days BOD of waste water is determined as 150 mg/lit at 20°C, its ultimate BOD will be _____. (Take rate constant as 0.28/day to the base '*e*')
(A) 222 mg/lit (B) 264 mg/lit
(C) 294 mg/lit (D) 324 mg/lit

61. Two samples of water A and B have pH values of 4.8 and 6.2 respectively. How many times sample A is more acidic than sample B?
(A) 100 (B) 50
(C) 25 (D) 10

Previous Years' Questions

1. The presence of hardness in excess of permissible limit causes **[GATE, 2007]**
(A) cardio vascular problems.
(B) skin discolouration.
(C) calcium deficiency.
(D) increased laundry expenses.

2. The alkalinity and the hardness of a water sample are 250 mg/lit and 350 mg/lit as $CaCO_3$ respectively. The water has **[GATE, 2007]**
(A) 350 mg/lit carbonate hardness and zero non-carbonate hardness.
(B) 250 mg/lit carbonate hardness and zero non-carbonate hardness.
(C) 250 mg/lit carbonate hardness and 350 mg/lit non-carbonate hardness.
(D) 250 mg/lit carbonate hardness and 100 mg/lit non-carbonate hardness.

3. A waste water sample contains $10^{-5.6}$ mol/lit of OH^- ions at 25°C. The pH of this sample is **[GATE, 2008]**
(A) 8.6 (B) 8.4
(C) 5.6 (D) 5.4

4. Match List I (Estimation method) with List II (Corresponding indicator) and select the correct answer using the codes given in the lists: **[GATE, 2008]**

	List I		List II
a.	Azide modified winkler method for dissolved oxygen	1.	Eriochrome Black T
b.	Dichromate method for chemical oxygen demand	2.	Ferroin
c.	EDTA titrometric method for hardness	3.	Potassium chromate
d.	Mohr or argentometric method for chlorides	4.	Starch

Codes:

	a	b	c	d		a	b	c	d
(A)	3	2	1	4	(B)	4	2	1	3
(C)	4	1	2	3	(D)	4	2	3	1

Direction for questions 5 and 6:

Following chemical species were reported for water sample from a well:

Species	Concentration (Milliequivalent/lit)
Chloride (Cl^-)	15
Sulphate (SO_4^{2-})	15
Carbonate (CO_3^{2-})	05
Bicarbonate (HCO_3^-)	30
Calcium (Ca^{2+})	12
Magnesium (Mg^{2+})	18
pH	8.5

5. Total hardness in mg/lit as $CaCO_3$ is **[GATE, 2009]**
(A) 1500 (B) 2000
(C) 3000 (D) 5000

6. Alkalinity present in the water in mg/lit as $CaCO_3$ is **[GATE, 2009]**
(A) 250 (B) 1500
(C) 1750 (D) 5000

Direction for questions 7 and 8:

ION concentrations obtained for a ground water sample (having pH = 8.1) are given in the following table:

ION	ION concentration (mg/lit)	Atomic Weight
Ca^{2+}	100	Ca = 40
Mg^{2+}	6	Mg = 24
Na^+	15	Na = 23
HCO_3^-	250	H = 1, C = 12, O = 16
SO_3^{2-}	45	S = 32, O = 16
Cl^-	39	Cl = 35.5

7. Total hardness (mg/lit as $CaCO_3$) present in the water sample is **[GATE, 2010]**
(A) 205 (B) 250
(C) 275 (D) 308

8. Carbonate hardness (mg/lit as $CaCO_3$) present in the water sample is **[GATE, 2010]**
(A) 205 (B) 250
(C) 275 (D) 289

9. Anaerobically treated effluent has MPN of total coliform as 10^6/100 ml. After chlorination, the MPN value declines to 10^2/100 ml. The percent removal (%R) and log removal (log R) of total coliform MPN is **[GATE, 2011]**
(A) %R = 99.90; log R = 4
(B) %R = 99.90; log R = 2
(C) %R = 99.99; log R = 4
(D) %R = 99.99; log R = 2

10. Chlorine gas (8 mg/lit as Cl_2) was added to a drinking water sample. If the free chlorine residual and pH was measured to be 2 mg/lit (as Cl_2) and 7.5 respectively, what is the concentration of residual OCl^- ions in the water? Assume that the chlorine gas added to the water is completely converted to HOCl and OCl^-. Atomic weight of Cl = 35.5

Given $OCl^- + H^+ \rightarrow HOCl$, $K = 10^{7.5}$ **[GATE, 2011]**
(A) 1.408×10^{-5} moles/lit
(B) 2.817×10^{-5} moles/lit
(C) 5.634×10^{-5} moles/lit
(D) 1.127×10^{-4} moles/lit

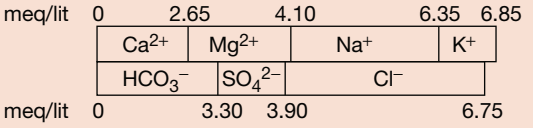
11. A water sample has a pH of 9.25. The concentration of hydroxyl ions in the water sample is **[GATE, 2012]**
(A) $10^{9.25}$ moles/lit (B) $10^{-4.75}$ moles/lit
(C) 0.302 mg/lit (D) 3.020 mg/lit

12. Some of the non-toxic metals normally found in natural water are **[GATE, 2014]**
(A) arsenic, lead and mercury.
(B) calcium, sodium and silver.
(C) cadmium, chromium and copper.
(D) iron, manganese and magnesium.

13. Total Kjeldahl Nitrogen (TKN) concentration (mg/lit as N) in domestic sewage is the sum of the concentrations of **[GATE, 2015]**
(A) organic and inorganic nitrogen in sewage.
(B) organic nitrogen and nitrate in sewage.
(C) organic nitrogen and ammonia in sewage.
(D) ammonia and nitrate in sewage.

14. A groundwater sample was found to contain 500 mg/lit total dissolved solids (TDS). TDS (in %) present in the sample is _____. **[GATE, 2015]**

15. A sample of water has been analyzed for common ions and results are presented in the form of a bar diagram as shown. **[GATE, 2016]**



The non-carbonate hardness (expressed in mg/lit as $CaCO_3$) of the sample is
(A) 40 (B) 165
(C) 195 (D) 205

Answer Keys

Exercises

1. 1413333.33	**2.** C	**3.** C	**4.** 6.2967	**5.** C	**6.** B	**7.** D	**8.** C	**9.** B
10. A	**11.** C	**12.** D	**13.** C	**14.** A	**15.** C	**16.** B	**17.** A	**18.** B	**19.** C
20. A	**21.** D	**22.** C	**23.** D	**24.** D	**25.** D	**26.** C	**27.** D	**28.** A	**29.** B
30. D	**31.** C	**32.** B	**33.** D	**34.** A	**35.** B	**36.** C	**37.** D	**38.** A	**39.** D
40. C	**41.** C	**42.** B	**43.** D	**44.** D	**45.** B	**46.** B	**47.** C	**48.** B	**49.** B
50. D	**51.** D	**52.** C	**53.** D	**54.** D	**55.** B	**56.** D	**57.** C	**58.** C	**59.** C
60. B	**61.** C							

Previous Years' Questions

1. D	**2.** D	**3.** D	**4.** B	**5.** A	**6.** C	**7.** C	**8.** A	**9.** C	**10.** A
11. B	**12.** D	**13.** C	**14.** 0.05	**15.** A					