WATER SUPPLY AND TREATMENT

INTRODUCTION

SECTION A UNIT I–WATER QUANTITY

IMPORTANCE AND NECESSITY FOR PLANNED WATER SUPPLIES

- Water is extremely useful since two third of human body is constituted of water.

- The main concern is not only with quantity but also with quality of water

- Water is not only used for drinking purpose but also for domestic and industrial purpose.

WATER DEMANDS

The various types of water demands, which a city may have, may be broken down into following classes:

- Domestic water demand
- Industrial water demand
- Institutional and commercial water demand
- Demand for public uses
- Fire demand
- Water reqd to compensate losses in wastes and thefts.

WATER DEMANDS

- **Domestic water demand**: which includes water for drinking, cooking, bathing, gardening etc. It shall vary according to the living condition of consumer.
  With full flushing system 200 l/h/day
  Economically weaker section 135 l/h/day

- **Industrial Water demand**: either existing or likely to be started in future in the city for which water supply is planned. The ordinary per capita consumption on account of industrial needs of city is taken as 50l/person/day

WATER DEMANDS

- **Institutional and commercial water demand**: water demands in hospitals, hotels, schools and colleges, railway station etc come in this. On an average, a per capita demand of 20 l/h/day in general although it may go up to 50 l/h/day for highly commercialized section.

- **Public use**: for public utility purposes like public parks, washing of roads etc. A nominal amount not exceeding 5% of total consumption.

WATER DEMANDS

- **Fire demand**: fire hydrants are usually fitted in the water mains at 100 to 150m apart and fire fighting pumps are immediately connected to them once the fire breaks out to throw water at pressure.
- The min water pressure available should be 100 to 150KN/m^2 .For cities having population above 50,000 the water required in kiloliters is 100 $\sqrt{(P)}$ where P is the population in thousands.

WATER DEMANDS

- The rate of fire demand is usually taken as a function of population, and is worked out on the basis of certain empirical formula as:

a) **Kuichling formula**: $Q=3{,}182\sqrt{(P)}$ where Q is amount of water reqd in l/min. and P is population in thousands.

b) **Freeman formula**: $Q=1136[P/10+10]$

c) **Bustons formula**: $Q=5663\sqrt{(P)}$

Water required to compensate losses in thefts and wastes like bad plumbing, stolen water etc which is usually kept as 15% of total consumption.

TOTAL REQUIREMENT OF WATER FOR A TOWN OR CITY

- The annual average daily draft in l/day required by a town can be obtained by multiplying the probable no. of persons who are going to use the facility and the per capita demand (q).
- The future period for which a provision is made in the water supply scheme is called the design period. Whenever we design we do it for the future also. Therefore its important to estimate population.

POPULATION ESTIMATION

- Arithmetical increase method
- Geometrical increase method
- Incremental increase method
- Decreasing rate method
- Simple graphical method
- Comparative graphical method
- Master plan method
- The apportionment method
- The logistic curve method

PER CAPITA DEMAND

Per capita demand (q) in liters per day per head =

$$q = \frac{\text{total yearly water requirement of the city in liters (V)}}{365 * \text{design population}}$$

Factors affecting per capita demand:

- Size of city
- Climatic conditions: in extreme weather conditions more water reqd.
- Types of gentry and habits of people.
- Industrial and commercial activities
- Quality of water supply

CONT:

- Pressure in the distribution system
- Development of sewerage facility
- System of supply: continuous or intermittent supply.
- Cost of water
- Policy of metering and methods of charging.

FACTORS AFFECTING LOSSES AND WASTES

- Water joints should be tight. Bad plumbing at joints lead to water leakage at these points.
- Pressure in the distribution system: high pressure leads to higher leakage losses. Desirable to keep these pressure as minimum as possible.
- System of supply: intermittent supply loss is less.
- Metering : when supplies are metered, wastage is considerably reduced.
- Unauthorised connection:

VARIATION IN DEMAND

- Seasonal variation: summer more, winter less and rainy season minimum.
- Daily variation: peak hours where consumption is more like early hours or late evenings like (8am – 10am and 6pm–8pm)

Assessment of normal variation:

- Max daily consumption: 1.8*average daily demand
- Max hourly consumption:1.5*average hourly consumption

Maximum hourly consumption of the max day ie, **peak demand**

$=1.5$*average hourly consumption of max day

$$=1.5*\left(\frac{\text{max.daily demand}}{24}\right) = 1.5*(1.8*q/24)$$

$= 2.7(q/24) = 2.7$(annual avg hourly demand)

Goodrich's formula $p=180\ t^{-0.10}$ where p is percent of annual avg draft (max by average) for the time t in days and t is time in days from 1/24 to 365.

Coincident draft: sum of max daily demand and fire draft.

VARIOUS UNITS OF WATER SUPPLY SCHEME

- The source supply(designed for max daily consumption): such as wells, rivers etc.
- The pipe mains for taking water from source to service reservoir (max daily demand)
- The filter and other units (max daily draft)
- Pumps for lifting the water (max daily)
- Distribution system (for max hr draft of max day or coincident draft with fire whichever is >)
- Service reservoir to take care of hourly fluctuation, fire demands etc (only 2 hrs storage)

DESIGN PERIODS AND POPULATION FORECAST

- A water supply scheme is of very high cost and therefore we always design it futuristically for a time period called design period. This design period should neither be long or short.

  Factors governing design period:

1. Useful life of component structures and chances of their becoming old and obsolete.
2. Ease and difficulty that is likely to be faced in expansion, if undertaken at future dates.
3. Amount and availability of additional investment likely to be incurred for additional provisions.
4. The rate of interest on borrowing and additional money invested.
5. Anticipated rate of population growth.

Generally design period is kept as 30 years.

POPULATION GROWTH

The three main factors responsible for changes in population are:

- Births
- Deaths
- Migration

Growth curve is a S shaped curve with log population along y axis and log time along x axis. This is also called **logistic curve.** The curve represents early growth at increasing rate and late growth at decreasing rate as saturation value is approached.. The transitional middle curve follows arithmetic increase.

POPULATION FORECASTING METHOD

- **Arithmetic increase method**: based on assumption that population increases at constant rate ie, dp/dt is constant.

$P_n=[P_0+nx']$ where P_n = prospective forecasted population after n decades from present.

P_0 = population at present

n= no.of decades b/w now and future.

x'= avg of population increase in known decades.

POPULATION FORECASTING METHOD

- **Geometric Increases method**: per decade percentage increase or percentage growth rate (r) is assumed to be constant and the increase is compounded over the existing population every decade. This method is called uniform increase method.

$P_n = P_0 [1 + r/100]^n$ where P_0 is the initial population, P_n is the future population after n decades and r is the assumed growth rate.

POPULATION FORECASTING METHOD

- **Incremental Increase Method**: here the per decade growth rate is not assumed to be constant but is progressively increasing or decreasing depending on whether the average of incremental increases in the past data is positive or negative.

  $P_n = P_0 + nx' + n(n+1)/2 * y'$ where P_0 is the initial population, P_n is the future population after n decades, x' is avg increase of population of known decades and y' is avg incremental increase of known decades.

POPULATION FORECASTING METHOD

- **Decreasing rate of growth method**: here the avg decrease in percentage increase is worked out and is then subtracted from the latest percentage increase for each successive decade. This is applicable only in cases where rate of growth shows a downward trend.
- **Simple graphical method**:a graph is plotted b/w time and population. The curve is then smoothly extended upto desired year. This gives very approximate results.

POPULATION FORECASTING METHOD

- **Comparative graphical method**: here cities having conditions and characteristics similar to the city whose future population is to be estimated are selected. It is then assumed that city under consideration will develop as the selected similar cities have developed in the past.
- **Zoning method**: bigger metros are allowed to expand only in planned manner. Here the city is divided into various zones and the master plan will give us as to when and where the given number of houses and industries would be developed.

POPULATION FORECASTING METHOD

- **The ratio method or apportionment method**: here the cities census population is expressed as percentage of population of the whole country. The ratios of local population to national population are worked out for these decades. A graph is then plotted b/w time and these ratios and extrapolated to the ratio corresponding to the future design year. This ratio is multiplied with expected national population at the end of the design period.

POPULATION FORECASTING METHOD

- **Logistic curve method**: under normal conditions population of a city grows as per the logistic curve . According to P.F.Verhulst the entire curve AD is represented by first order equation.

$$P = \frac{P_s}{1 + m \log^{-1}(nt)}$$

where Ps is saturation population, P is population at any time t from origin A, m(constant) $= \frac{P_s - P_0}{P_0}$ and n(constnt) = – KPs

SECTION A UNIT II– WATER QUALITY

<u>Raw Water Source</u>

The various sources of water can be classified into two categories:

- Surface sources, such as
  - Ponds and lakes;
  - Streams and rivers;
  - Storage reservoirs; and
  - Oceans, generally not used for water supplies, at present.
- Sub-surface sources or underground sources, such as
  - Springs;
  - Infiltration wells ; and
  - Wells and Tube-wells.

WATER QUALITY

The raw or treated water is analysed by testing their physical, chemical and bacteriological characteristics:

Physical Characteristics:

- Turbidity
- Colour
- Taste and Odour
- Temperature

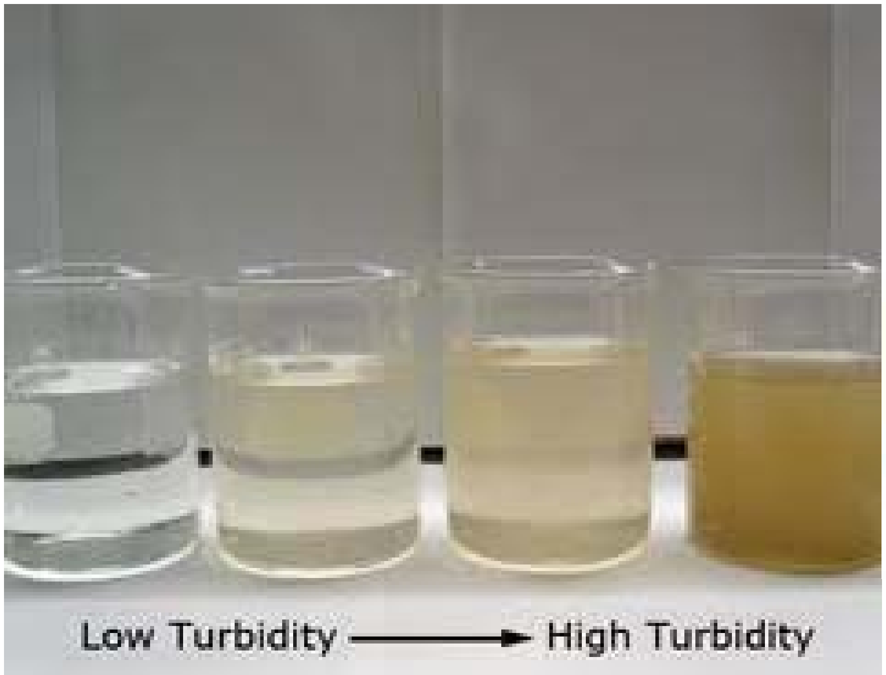
CHEMICAL CHARACTERISTICS:

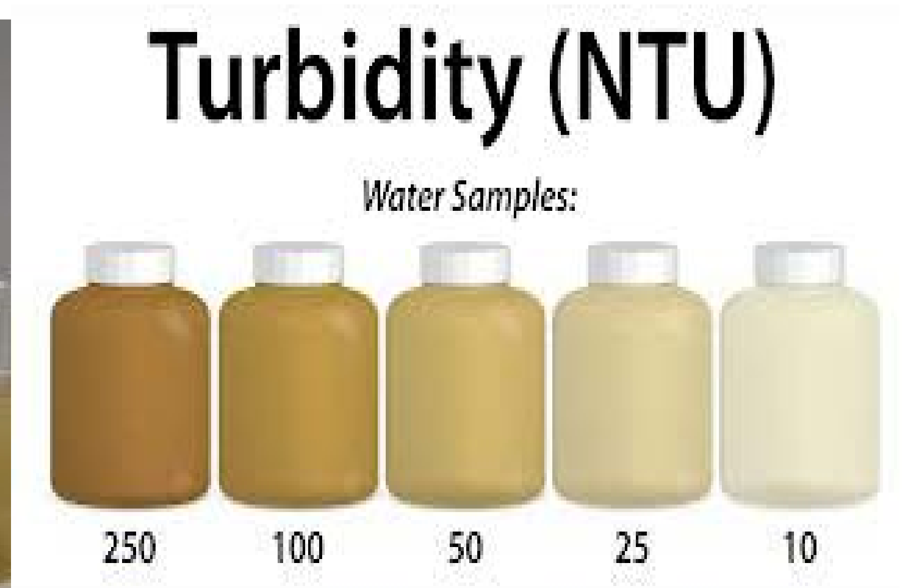
- pH
- Acidity
- Alkalinity
- Hardness
- Chlorides
- Sulphates
- Iron
- Solids
- Nitrates

Turbidity

- If a large amount of suspended solids are present in water, it will appear turbid in appearance. The turbidity depends upon fineness and concentration of particles present in water.
- Originally turbidity was determined by measuring the depth of column of liquid required to cause the image of a candle flame at the bottom to diffuse into a uniform glow. This was measured by Jackson candle turbidity meter.
- These days turbidity is measured by applying Nephelometry, a technique to measure level of light scattered by the particles at right angles to the incident light beam. The scattered light level is proportional to the particle concentration in the sample.
- The unit of expression is *Nephelometric Turbidity Unit* (NTU). The IS values for drinking water is *10 to 25 NTU*.

TURBIDITY


Low Turbidity → High Turbidity


Turbidity (NTU)
Water Samples:
250
100
50
25
10

Colour

- Dissolved organic matter from decaying vegetation or some inorganic materials may impart colour to the water.
- It can be measured by comparing the colour of water sample with other standard glass tubes containing solutions of different standard colour intensities.
- The standard unit of colour is that which is produced by one milligram of platinum cobalt dissolved in one litre of distilled water. The IS value for treated water is *5 to 25 cobalt units.*

COLOR

Taste and Odour

- Odour depends on the contact of a stimulating substance with the appropriate human receptor cell. Most organic and some inorganic chemicals, originating from municipal or industrial wastes, contribute taste and odour to the water.
- Taste and odour can be expessed in terms of odour intensity or threshold values.
- A new method to estimate taste of water sample has been developed based on flavour known as 'Flavour Profile Analysis' (FPA). The character and intensity of taste and odour discloses the nature of pollution or the presence of microorganisms.

Temperature

- The increase in temperature decreases palatability, because at elevated temperatures carbon dioxide and some other volatile gases are expelled.

- The ideal temperature of water for drinking purposes is *5 to 12 °C* – above 25 °C, water is not recommended for drinking.

pH and Acidity

- pH value denotes the acidic or alkaline condition of water. It is expressed on a scale ranging from 0 to 14, which is the common logarithm of the reciprocal of the hydrogen ion concentration. The recommended pH range for treated drinking waters is *6.5 to 8.5*.
- The acidity of water is a measure of its capacity to neutralise bases. Acidity of water may be caused by the presence of uncombined carbon dioxide, mineral acids and salts of strong acids and weak bases. It is expressed as mg/L in terms of calcium carbonate. Acidity is nothing but representation of carbon dioxide or carbonic acids. Carbon dioxide causes corrosion in public water supply systems.

CONT:

- Water becomes acidic when H+ ions concentration increases and and it becomes alkaline when H+ ions concentration decreases.
- Acidic water causes tuberculation and alkaline water causes incrustation.
- For potable water pH should be between 6-9 preferably b/w 7 to 8.5
- Measured by colourimetric method and electrometric method.

Alkalinity

- The alkalinity of water is a measure of its capacity to neutralise acids. It is expressed as mg/L in terms of calcium carbonate.
- The various forms of alkalinity are (a) hydroxide alkalinity, (b) carbonate alkalinity, (c) hydroxide plus carbonate alkalinity, (d) carbonate plus bicarbonate alkalinity, and (e) bicarbonate alkalinity, which is useful mainly in water softening and boiler feed water processes.
- Alkalinity is an important parameter in evaluating the optimum coagulant dosage.

Hardness

- If water consumes excessive soap to produce lather, it is said to be hard. Hardness is caused by divalent metallic cations. The principal hardness causing cations are calcium, magnesium, strontium, ferrous and manganese ions. The major anions associated with these cations are sulphates, carbonates, bicarbonates, chlorides and nitrates.
- The total hardness of water is defined as the sum of calcium and magnesium concentrations, both expressed as calcium carbonate, in mg/L.
- Hardness are of two types, temporary or carbonate hardness and permanent or non carbonate hardness. Temporary hardness is one in which bicarbonate and carbonate ion can be precipitated by prolonged boiling. Non-carbonate ions cannot be precipitated or removed by boiling, hence the term permanent hardness. IS value for drinking water is **300 mg/L as $CaCO_3$**.

Chlorides

- Chloride ion may be present in combination with one or more of the cations of calcium, magnesium, iron and sodium.
- Chlorides of these minerals are present in water because of their high solubility in water. Each human being consumes about six to eight grams of sodium chloride per day, a part of which is discharged through urine and night soil.
- Thus, excessive presence of chloride in water indicates sewage pollution. IS value for drinking water is 250 to 1000 mg/L

Sulphates

- Sulphates occur in water due to leaching from sulphate mineral and oxidation of sulphides. Sulphates are associated generally with calcium, magnesium and sodium ions.
- Sulphate in drinking water causes a laxative effect and leads to scale formation in boilers. It also causes odour and corrosion problems under aerobic conditions.
- Sulphate should be less than 50 mg/L, for some industries. Desirable limit for drinking water is 150 mg/L. May be extended upto 400 mg/L

Iron

- Iron is found on earth mainly as insoluble ferric oxide. When it comes in contact with water, it dissolves to form ferrous bicarbonate under favourable conditions.
- This ferrous bicarbonate is oxidised into ferric hydroxide, which is a precipitate. Under anaerobic conditions, ferric ion is reduced to soluble ferrous ion.
- Iron can impart bad taste to the water, causes discolouration in clothes and incrustations in water mains. IS value for drinking water is 0.3 to 1.0 mg/L.

LEAD AND ARSENIC

- Lead is a well known cumulative poison. Under normal conditions the concentration of lead should be less than 0.05 mg/l
- Arsenic poisoning or *arsenicosis* is a condition caused by the ingestion, absorption or inhalation of dangerous levels of arsenic.
- If the arsenic has been ingested orally, the first signs and symptoms of arsenic poisoning will appear within thirty minutes, and may include some of the following:
- drowsiness
- headaches
- terrible diarrhea

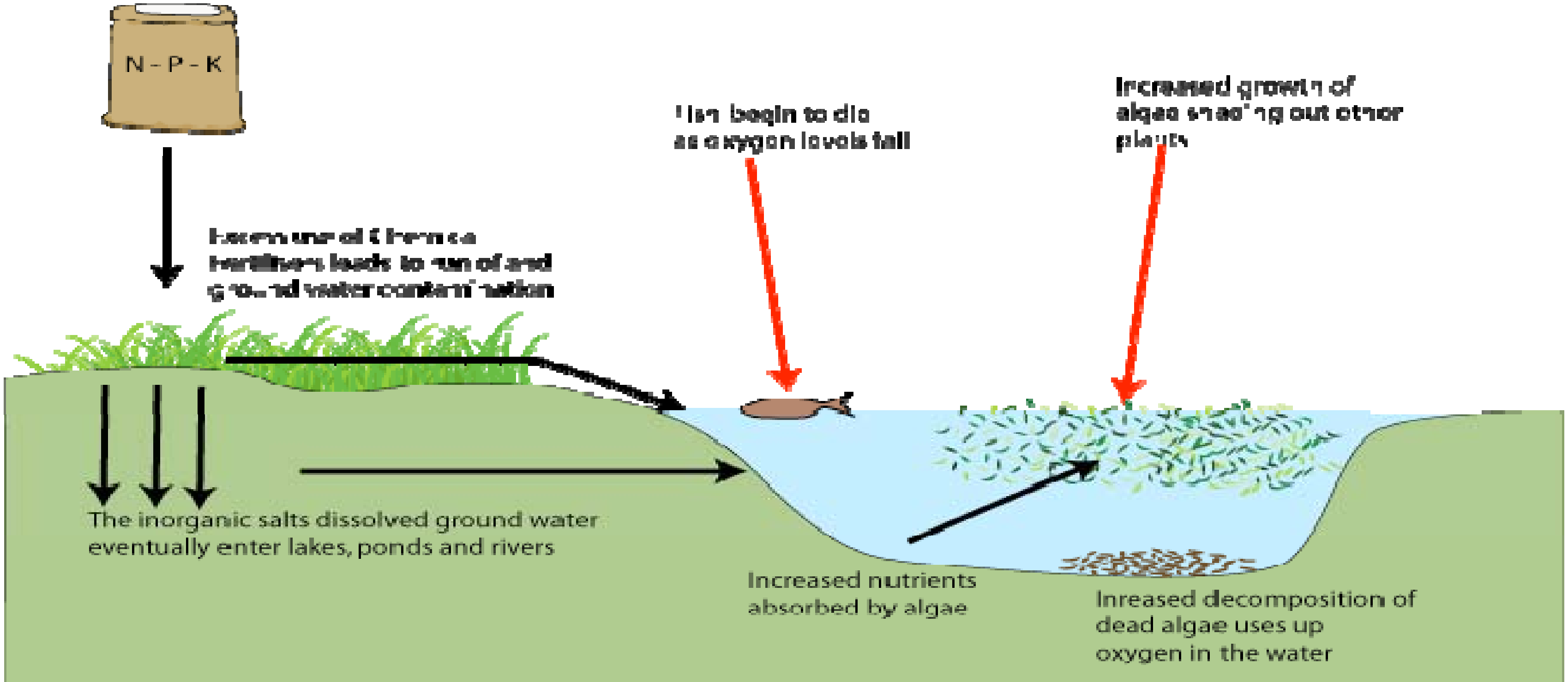

Dangers of lead and arsenic poisoning
Arsenic poisoning
Nerve damage
Skin damage:
■ Hyperkeratosis (scaling skin)
■ Pigment changes
Increased cancer risk:
■ Lung
■ Bladder
■ Kidney and liver cancers
Circulatory problems in skin
Lead poisoning
High levels of lead
■ Mental retardation, coma, convulsions and death
Low levels of lead
■ Reduced IQ and attention span, impaired growth, reading and learning disabilities, hearing loss and a range of other health and behavioral effects.
Sources: Alliance to End Childhood Lead Poisoning and news wires
The Denver Post

Solids

- The sum total of foreign matter present in water is termed as 'total solids'. Total solids is the matter that remains as residue after evaporation of the sample and its subsequent drying at a defined temperature (103 to 105 °C).
- Total solids consist of volatile (organic) and non-volatile (inorganic or fixed) solids. Further, solids are divided into suspended and dissolved solids. Solids that can settle by gravity are settleable solids.
- The others are non-settleable solids. IS acceptable limit for total solids is **500 mg/L** and tolerable limit is **3000 mg/L** of dissolved limits.

NITROGEN AND ITS COMPOUNDS

- Present in 4 forms: ammoniacal nitrogen, albuminoid nitrogen, nitrites and nitrates.
- Nitrates in surface waters occur by the leaching of fertilizers from soil during surface run-off and also nitrification of organic matter.
- Presence of high concentration of nitrates is an indication of pollution.
- Concentration of nitrates above 45 mg/L cause a disease methemoglobinemia (blue baby disease). IS value is **45 mg/L**.


N - P - K
The inorganic salts dissolved ground water
eventually enter lakes, ponds and rivers
Increased nutrients
absorbed by algae
Inreased decomposition of
dead algae uses up
oxygen in the water

Bacteriological Characteristics:

- Bacterial examination of water is very important, since it indicates the degree of pollution. Water polluted by sewage contain one or more species of disease producing pathogenic bacteria.
- Pathogenic organisms cause water borne diseases, and many non pathogenic bacteria such as *E.Coli*, a member of coliform group, also live in the intestinal tract of human beings.
- *Coliform* itself is not a harmful group but it has more resistance to adverse condition than any other group. So, if it is ensured to minimize the number of coliforms, the harmful species will be very less. So, coliform group serves as indicator of contamination of water with sewage and presence of pathogens.

Disease and Transmission	Microbial Agent	Sources of Agent in Water Supply	General Symptoms
Amoebiasis(hand-to-mouth)	Protozoan (*Entamoeba histolytica*) (Cyst-like appearance)	Sewage, non-treated drinking water, flies in water supply	Abdominal discomfort, fatigue, weight loss,diarrhoea, bloating, fever
Cryptosporidiosis(oral)	Protozoan (*Cryptosporidium parvum*)	Collects on water filters and membranes that cannot be disinfected, animal manure, seasonalrunoff of water.	Flu-like symptoms, watery diarrhea, loss of appetite, substantial loss of weight, bloating, increased gas, nausea
Cyclosporiasis	Protozoan parasite (*Cyclospora cayetanensis*)	Sewage, non-treated drinking water	cramps, nausea, vomiting, muscle aches, fever, and fatigue
Giardiasis (fecal-oral) (hand-to-mouth)	Protozoan (*Giardia lamblia*) Most common intestinal parasite	Untreated water, poor disinfection, pipe breaks, leaks, groundwater contaminati on, campgroundswhere humans and wildlife use same source of water. Beavers and muskrats cr eate ponds that act as reservoirs for Giardia.	Diarrhea, abdominal discomfort, bloating, andflatulence
Microsporidiosis	Protozoan phylum (*Microsporidia*), but closely related to fungi	*Encephalitozoon intestinalis* has been detected in groundwater, the origin of drinking water [5]	Diarrhea and wasting in immunocompro misedindividuals..

Disease and Transmission	Microbial Agent	Sources of Agent in Water Supply	General Symptoms
Botulism	*Clostridium botulinum*	Bacteria can enter an open wound from contaminated water sources. Can enter the gastrointestinal tract by consuming contaminated drinking water or (more commonly) food	Dry mouth, blurred and/or double vision, difficulty swallowing, muscle weakness, difficulty breathing, slurred speech, vomiting and sometimes diarrhea. Death is usually caused byrespiratory failure.
Campylobacteriosis	Most commonly caused by*Campylobacter jejuni*	Drinking water contaminated with feces	Produces dysentery like symptoms along with a high fever. Usually lasts 2–10 days.
Cholera	Spread by the bacterium *Vibrio cholerae*	Drinking water contaminated with the bacterium	In severe forms it is known to be one of the most rapidly fatal illnesses known. Symptoms include very watery diarrhea, nausea, cramps, nosebleed, rapid pulse, vomiting, andhypovolemic shock (in severe cases), at which point death can occur in 12–18 hours.
E. coli Infection	Certain strains of *Escherichia coli* (commonly *E. coli*)	Water contaminated with the bacteria	Mostly diarrhea. Can cause death in immunocompromised individuals, the very young, and the elderly due to dehydration from prolonged illness.

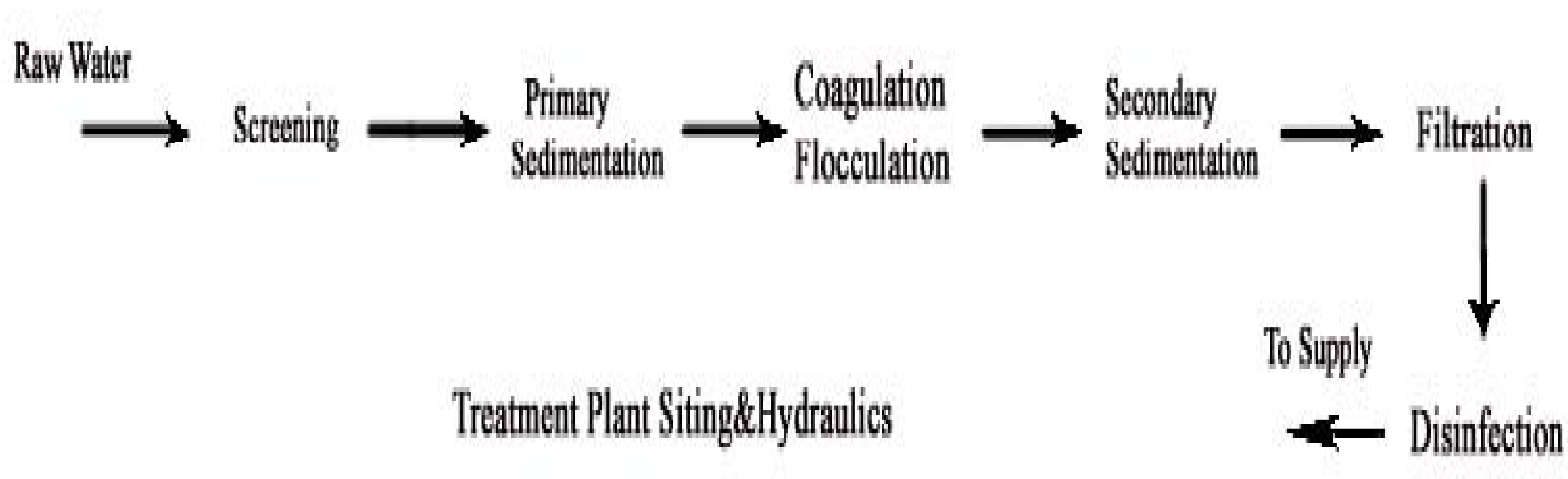
Disease and Transmission	Microbial Agent	Sources of Agent in Water Supply	General Symptoms
SARS (Severe Acute Respiratory Syndrome)	Coronavirus	Manifests itself in improperly treated water	Symptoms include fever, myalgia, lethargy, gastrointestinal symptoms, cough, and sore throat
Hepatitis A	Hepatitis A virus (HAV)	Can manifest itself in water (and food)	Symptoms are only acute (no chronic stage to the virus) and include Fatigue, fever, abdominal pain, nausea, diarrhea, weight loss, itching, jaundice and depression .
Poliomyelitis(Polio)	Poliovirus	Enters water through the feces of infected individuals	90-95% of patients show no symptoms, 4-8% have minor symptoms (comparatively) with delirium, headache, fever, and occasional seizures, and spastic paralysis, 1% have symptoms of non-paralytic aseptic meningitis. The rest have serious symptoms resulting in paralysis or death
Polyomavirus infection	Two ofPolyomavirus:JC virus and BK virus	Very widespread, can manifest itself in water, ~80% of the population hasantibodies to Polyomavirus	BK virus produces a mild respiratory infection and can infect the kidneys of immunosuppressed transplant patients. JC virus infects the respiratory system, kidneys or can cause progressive multifocal leukoencephalopathy in thebrain (which is fatal).

SECTION B UNIT III–WATER TREATMENT

The available raw waters must be treated and purified before they can be supplied to the public for their domestic, industrial or any other uses.

The extent of treatment required to be given to the particular water depends upon the characteristics and quality of the available water, and also upon the quality requirements for the intended use.

SCHEMATIC DIAGRAM OF WATER TREATMENT



WATER TREATMENT

Depending upon the magnitude of treatment required, proper unit operations are selected and arranged in the proper sequential order for the purpose of modifying the quality of raw water to meet the desired standards.

Indian Standards for drinking water are given in the table given in next page:

Indian Standards for drinking water

- PHYSICAL PROPERTIES

Parameter	Desirable-Tolerable	*If no alternative source available, limit extended upto*
Turbidity (NTU unit)	< 10	25
Colour (Hazen scale)	< 10	50
Taste and Odour	Un-objectionable	Un-objectionable

CHEMICAL PROPERTIES

pH	7.0-8.5	6.5-9.2
Total Dissolved Solids mg/l	500-1500	3000
Total Hardness mg/l (as $CaCO_3$)	200-300	600
Chlorides mg/l (as Cl)	200-250	1000
Sulphates mg/l (as SO_4)	150-200	400
Fluorides mg/l (as F)	0.6-1.2	1.5
Nitrates mg/l (as NO_3)	45	45
Calcium mg/l (as Ca)	75	200
Iron mg/l (as Fe)	0.1-0.3	1.0

The typical functions of each unit operations are given in the following table:

Unit treatment	Function (removal)
Aeration, chemicals use	Colour, Odour, Taste
Screening	Floating matter
Chemical methods	Iron, Manganese, etc.
Softening	Hardness
Sedimentation	Suspended matter
Coagulation	Suspended matter, a part of colloidal matter and bacteria
Filtration	Remaining colloidal dissolved matter, bacteria
Disinfection	Pathogenic bacteria, Organic matter and Reducing substances

The types of treatment required for different sources are given in the following table:

Source	Treatment required
1. Ground water and spring water fairly free from contamination	No treatment or Chlorination
2. Ground water with chemicals, minerals and gases	Aeration, coagulation (if necessary), filtration and disinfection
3. Lakes, surface water reservoirs with less amount of pollution	Disinfection
4. Other surface waters such as rivers, canals and impounded reservoirs with a considerable amount of pollution	Complete treatment

SCREENING

Screening

A screen is a device with openings for removing bigger suspended or floating matter in sewage which would otherwise damage equipment or interfere with satisfactory operation of treatment units.

Types of Screens

- **Coarse Screens**: Coarse screens also called racks, are usually bar screens, composed of vertical or inclined bars spaced at equal intervals across a channel through which sewage flows. Bar screens with relatively large openings of 75 to 150 mm are provided ahead of pumps, while those ahead of sedimentation tanks have smaller openings of 50 mm.

CONT:

- Bar screens are usually hand cleaned and sometimes provided with mechanical devices. These cleaning devices are rakes which periodically sweep the entire screen removing the solids for further processing or disposal. Hand cleaned racks are set usually at an angle of 45° to the horizontal to increase the effective cleaning surface and also facilitate the raking operations.
- **Medium Screens**: Medium screens have clear openings of 20 to 50 mm.Bar are usually 10 mm thick on the upstream side and taper slightly to the downstream side.
- **Fine Screens**: Fine screens are mechanically cleaned devices using perforated plates, woven wire cloth or very closely spaced bars with clear openings of less than 20 mm. Fine screens are not normally suitable for sewage because of clogging possibilities.

Primary Sedimentation

- Primary sedimentation in a municipal wastewater treatment plant is generally plain sedimentation without the use of chemicals. In treating certain industrial wastes chemically aided sedimentation may be involved. In either case, it constitutes *flocculent settling*, and the particles do not remain discrete as in the case of grit, but tend to agglomerate or coagulate during settling. Thus, their diameter keeps increasing and settlement proceeds at an over increasing velocity. Consequently, they trace a curved profile.
- The settling tank design in such cases depends on both *surface loading* and *detention time*.

CONT:

- Long tube settling tests can be performed in order to estimate specific value of surface loading and detention time for desired efficiency of clarification for a given industrial wastewater using recommended methods of testing.
- Scale-up factors used in this case range from 1.25 to 1.75 for the overflow rate, and from 1.5 to 2.0 for detention time when converting laboratory results to the prototype design.

SECTION C UNIT IV- WATER CONVEYANCE SYSTEM

<u>Intake Structure</u>

The basic function of the intake structure is to help in safely withdrawing water from the source over predetermined pool levels and then to discharge this water into the withdrawal conduit (normally called intake conduit), through which it flows up to water treatment plant.

<u>Factors Governing Location of Intake</u>

- As far as possible, the site should be near the treatment plant so that the cost of conveying water to the city is less.
- The intake must be located in the purer zone of the source to draw best quality water from the source, thereby reducing load on the treatment plant.

CONT:

- The intake must never be located at the downstream or in the vicinity of the point of disposal of wastewater.
- The site should be such as to permit greater withdrawal of water, if required at a future date.
- The intake must be located at a place from where it can draw water even during the driest period of the year.
- The intake site should remain easily accessible during floods and should noy get flooded. Moreover, the flood waters should not be concentrated in the vicinity of the intake.

CONT:

Many times in water distribution network because the pressures could be very low and we have to meet that minimum seven meters of head of residual pressure and we need to boost up these pressures so the pumping is also required to boost up pressures in water distribution networks in certain cases.

We also need pumping in water distribution networks to transport water through treatment plants because a lot of energy loss occurs in piping so we have to get over these frictional losses and we need to have pumping for transporting water through treatment plants.

TYPES OF INTAKE

Depending on the source of water, the intake works are classified as follows:

PUMPING

A pump is a device which converts mechanical energy into hydraulic energy. It lifts water from a lower to a higher level and delivers it at high pressure. Pumps are employed in water supply projects at various stages for following purposes:

- To lift raw water from wells.
- To deliver treated water to the consumer at desired pressure.

CONT:

- To supply pressured water for fire hydrants.
- To boost up pressure in water mains.
- To fill elevated overhead water tanks.
- To back-wash filters.
- To pump chemical solutions, needed for water treatment.

CLASSIFICATION OF PUMPS

Based on principle of operation, pumps may be classified as follows:

- Displacement pumps (reciprocating, rotary)
- Velocity pumps (centrifugal, turbine and jet pumps)
- Buoyancy pumps (air lift pumps)
- Impulse pumps (hydraulic rams)

CAPACITY OF PUMPS

Work done by the pump,

- H.P.=gQH/75

where, g= specific weight of water kg/m^3, Q= discharge of pump, m^3/s; and H= total head against which pump has to work.

- H= H_s + H_d + H_f + (losses due to exit, entrance, bends, valves, and so on)

where, H_s=suction head, H_d = delivery head, and H_f = friction loss.

Efficiency of pump (E) = gQH/Brake H.P.

Total brake horse power required = gQH/E

Provide even number of motors say 2,4,... with their total capacity being equal to the total BHP and provide half of the motors required as stand-by.

CONVEYANCE

There are two stages in the transportation of water:

- Conveyance of water from the source to the treatment plant.
- Conveyance of treated water from treatment plant to the distribution system.

In the first stage water is transported by gravity or by pumping or by the combined action of both, depending upon the relative elevations of the treatment plant and the source of supply.
In the second stage water transmission may be either by pumping into an overhead tank and then supplying by gravity or by pumping directly into the water-main for distribution.

FREE FLOW SYSTEM

- In this system, the surface of water in the conveying section flows freely due to gravity. In such a conduit the hydraulic gradient line coincide with the water surface and is parallel to the bed of the conduit. It is often necessary to construct very long conveying sections, to suit the slope of the existing ground. The sections used for free-flow are: Canals, flumes, grade aqueducts and grade tunnels.

PRESSURE SYSTEM

- In pressure conduits, which are closed conduits, the water flows under pressure above the atmospheric pressure. The bed or invert of the conduit in pressure flows is thus independant of the grade of the hydraulic gradient line and can, therefore, follow the natural available ground surface thus requiring lesser length of conduit.

CONT:

- The pressure aqueducts may be in the form of closed pipes or closed aqueducts and tunnels called *pressure aqueducts or pressure tunnels* designed for the pressure likely to come on them.

- Due to their circular shapes, every pressure conduit is generally termed as a *pressure pipe*. When a pressure pipe drops beneath a valley, stream, or some other depression, it is called a depressed pipe or an *inverted siphon*.

- Depending upon the construction material, the pressure pipes are of following types: Cast iron, steel, R.C.C, hume steel, vitrified clay, asbestos cement, wrought iron, copper, brass and lead, plastic, and glass reinforced plastic pipes.

HYDRAULIC DESIGN

The design of water supply conduits depends on the resistance to flow, available pressure or head, and allowable velocities of flow. Generally, Hazen-William's formula for pressure conduits and Manning's formula for freeflow conduits are used.

- Hazen-William's formula

$$U=0.85\ C\ r_H^{0.63}S^{0.54}$$

- Manning's formula

$$U={}^{1}/_{n}\ r_H^{2/3}S^{1/2}$$

where, U= velocity, m/s; r_H= hydraulic radius,m; S= slope, C= Hazen-William's coefficient, and n = Manning's coefficient.

- Darcy-Weisbach formula

$$h_L=(fLU^2)/(2gd)$$

SECTION D UNIT V–WATER DISTRIBUTION SYSTEM

The purpose of distribution system is to deliver water to consumer with appropriate quality, quantity and pressure. Distribution system is used to describe collectively the facilities used to supply water from its source to the point of usage.

Requirements of Good Distribution System

- Water quality should not get deteriorated in the distribution pipes.
- It should be capable of supplying water at all the intended places with sufficient pressure head.
- It should be capable of supplying the requisite amount of water during fire fighting.

CONT:

- The layout should be such that no consumer would be without water supply, during the repair of any section of the system.
- All the distribution pipes should be preferably laid one metre away or above the sewer lines.
- It should be fairly water-tight as to keep losses due to leakage to the minimum.

Layouts of Distribution Network

- The distribution pipes are generally laid below the road pavements, and as such their layouts generally follow the layouts of roads. There are, in general, four different types of pipe networks; any one of which either singly or in combinations, can be used for a particular place. They are:

CONT:

- *Dead End System*
- *Grid Iron System*
- *Ring System*
- *Radial System*

Distribution Reservoirs

Distribution reservoirs, also called service reservoirs, are the storage reservoirs, which store the treated water for supplying water during emergencies (such as during fires, repairs, etc.) and also to help in absorbing the hourly fluctuations in the normal water demand.

DISTRIBUTION RESERVOIR

Functions of Distribution Reservoirs:

- to absorb the hourly variations in demand.
- to maintain constant pressure in the distribution mains.
- water stored can be supplied during emergencies.

Location and Height of Distribution Reservoirs:

- should be located as close as possible to the center of demand.
- water level in the reservoir must be at a sufficient elevation to permit gravity flow at an adequate pressure.

Types of Reservoirs

- Underground reservoirs.
- Small ground level reservoirs.
- Large ground level reservoirs.
- Overhead tanks.

Storage Capacity of Distribution Reservoirs

The total storage capacity of a distribution reservoir is the summation of:

- *Balancing Storage:* The quantity of water required to be stored in the reservoir for equalising or balancing fluctuating demand against constant supply is known as the balancing storage. The balance storage can be worked out by *mass curve method*.
- *Breakdown Storage:* The breakdown storage or often called emergency storage is the storage preserved in order to tide over the emergencies posed by the failure of pumps, electricity, or any othe mechanism driving the pumps. A value of about 25% of the total storage capacity of reservoirs, or 1.5 to 2 times of the average hourly supply, may be considered as enough provision for accounting this storage.
- *Fire Storage:* The third component of the total reservoir storage is the fire storage. This provision takes care of the requirements of water for extinguishing fires. A provision of 1 to 4 per person per day is sufficient to meet the requirement.
- The total reservoir storage can finally be worked out by adding all the three storages.

Pipe Network Analysis

- Analysis of water distribution system includes determining quantities of flow and head losses in the various pipe lines, and resulting residual pressures. In any pipe network, the following two conditions must be satisfied:
- The algebraic sum of pressure drops around a closed loop must be zero, i.e. there can be no discontinuity in pressure.
- The flow entering a junction must be equal to the flow leaving that junction; i.e. the law of continuity must be satisfied.
- Based on these two basic principles, the pipe networks are generally solved by the methods of successive approximation. The widely used method of pipe network analysis is the Hardy-Cross method.

Hardy-Cross Method

- This method consists of assuming a distribution of flow in the network in such a way that the principle of continuity is satisfied at each junction. A correction to these assumed flows is then computed successively for each pipe loop in the network, until the correction is reduced to an acceptable magnitude.
- If Q_a is the assumed flow and Q is the actual flow in the pipe, then the correction d is given by
- $d=Q-Q_a$; or $Q=Q_a+d$
- Now, expressing the head loss (H_L) as
- $H_L=K.Q^x$

CONT:

we have, the head loss in a pipe

$=K.(Q_a+d)^x$

$=K.[Q_a^x + x.Q_a^{x-1}d + ...\text{negligible terms}]$

$=K.[Q_a^x + x.Q_a^{x-1}d]$

Now, around a closed loop, the summation of head losses must be zero.

$$SK.[Q_a^x + x.Q_a^{x-1}d] = 0$$

$$\text{or} \quad SK.Q_a^x = - SKx\ Q_a^{x-1}d$$

Since, d is the same for all the pipes of the considered loop, it can be taken out of the summation.

$$\Sigma\ K.Q_a^x = - d.\ SKx\ Q_a^{x-1}$$

$$d = -\Sigma H_L\ /\ x.\ \Sigma\ \lvert H_L/Q_a \rvert$$

CONT:

- The numerator in the above equation is the algebraic sum of the head losses in the various pipes of the closed loop computed with assumed flow. Since the direction and magnitude of flow in these pipes is already assumed, their respective head losses with due regard to sign can be easily calculated after assuming their diameters.
- The absolute sum of respective KQ_a^{x-1} or H_L/Q_a is then calculated. Finally the value of d is found out for each loop, and the assumed flows are corrected. Repeated adjustments are made until the desired accuracy is obtained.
- The value of x in Hardy- Cross method is assumed to be constant (i.e. 1.85 for Hazen-William's formula, and 2 for Darcy-Weisbach formula)