Water Supply Engineering

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Water Supply Engineering

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Sanitary Engineering

- Introduction of Sanitary Engineering
- Quantity of Waste Water
- Characteristics and Examination of Sewage
- Design and Construction of Sewers
- Sewer Appurtenances
- Sewage Disposal
- Sewage Treatment
- Sludge Treatment and Disposal
- Disposal of Sewage from Isolated Buildings
- Solid Waste management
- WASH and Ecosan

Introduction of Water Supply Engineering

- **Importance of Water**
- Water is vital for our daily lives. In absence of water, there will be no life in the world.
- Next to air, water is the most important requirement for the not only for human life but also for animals and plants
- In cells, water content can found from 40% in certain species of plants (generally 80%)to more than 95% in cells of jellyfishes.
- The brain becomes unable to work properly without water in a day and one can die in 5 to 7 days without water.
- The human body contains about **50%-65%** of water.
- Unlike many other raw materials, there is no substitute for water in many of its uses.

Definition of water

Pure and Impure Water

Pure water is pure H_2O. It contains **two hydrogen and one oxygen atoms in a water molecule and nothing else.**

Pure water is a non-conductive substance that is toxic to life and not used for drinking purpose.

Wholesome Water

The water, which is not chemically pure but does not contain anything that may be harmful to human health, is called wholesome water.

Our body requires certain elements and if they are present in water, there removal is not desired. Therefore, we remove impurities only up to certain extent so that they may not be harmful to human health.

Definition of water

- **Palatable water**

The water that is tasteful for drinking and aesthetically pure is known as palatable water.

- **Potable water**

The potable water has characteristics of both palatable and wholesome water. It should be clear and free from suspended matter and smell.

It should not contain any bacteria and excess of dissolved inorganic matters. The water that is fit for drinking, safe and agreeable is called potable water.

- **Polluted water**

The water that contains **undesirable substances that make it unfit for drinking and for other domestic uses** is known as polluted water.

History of water supply system in Nepal

- In Kathmandu valley, the Kirat regime constructed rain-fed ponds and springs over 2000 years ago.
- Lichhavi Kings linked the ponds to stone spouts and dug wells to provide water to the cities.
- These structures expanded during the Malla regime, when elaborated networks of canals, ponds, and water conduits were constructed.
- The history of still available stone spouts (Hiti) start when Lichhavi King Mandev- I, built the first Hiti in Hadi Gaun of Kathmandu in 550 A.D.

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History of water supply system in Nepal

- Major expansion of Hitis' took place in between 14th to 16th century during the Malla period.
- Similarly, Nepal has history of ponds also. The main function of the ponds was to recharge the shallow aquifers during dry seasons.
- There was excellent water supply management system with public participation at that time. Guthis (local community groups) were formed to maintain the overall water supply system.
- Once a year, on the Sithi Nakha festival, the guthis worked together to clean up the ponds, wells, and water canals.

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History of water supply system in Nepal

- The first piped system was developed by Bir Shamsher in 1895 AD by establishing Bir Dhara.
- He also established Pani Goswara Adda and developed private and community taps.
- The history of planned development of water supply and sanitation started from fourth plan (1970-1975) with starting "Department of Drinking Water Supply and Sewerage" (1972)
- "National Drinking Water Quality Standard (NDWQS)" has implemented from 2006.

Institutions in Water Supply Sector

- The "Ministry of Water Supply (MWS)" is the leading authority for water supply and sanitation sector
- It is responsible for the planning, implementation, regulation, and monitoring of the sector.
- The Department of Water Supply and Sewerage (DWSS) is the lead implementing agency of the sector.
- Province Government
- Local Government

Institutions in Water Supply Sector

- Department of Water Supply and Sewerage
- Nepal Water Supply Corporation
- Kathmandu Upatekya Khanepani Limited
- Small Town Water Supply and Sanitation Project
- Rural Water Supply and Sanitation Fund Development Board
- Water Supply and Sanitation Users' Committee
- Department of Local Infrastructure (DoLI)
- Metropolitan, Sub metropolitan Areas and Municipalities, Rural Municipalities
- NGO
- INGO

Schematic Diagram of Water Supply System

- Source of water supply
- Intake
- Transmission line
- Pumping system
- Water treatment
- Break pressure tank
- Distribution pipe line
- Hydrants for fire fighting
- Public stand post
- Reservoir
- Miscellaneous

Schematic Diagram of Water Supply System

- Urban →source/intake/pump/water treatment plant/reservoir/distribution network/fire hydrants and house hold connection

- Rural →source/intake/sedimentation tank/break pressure chamber/reservoir/public stand post

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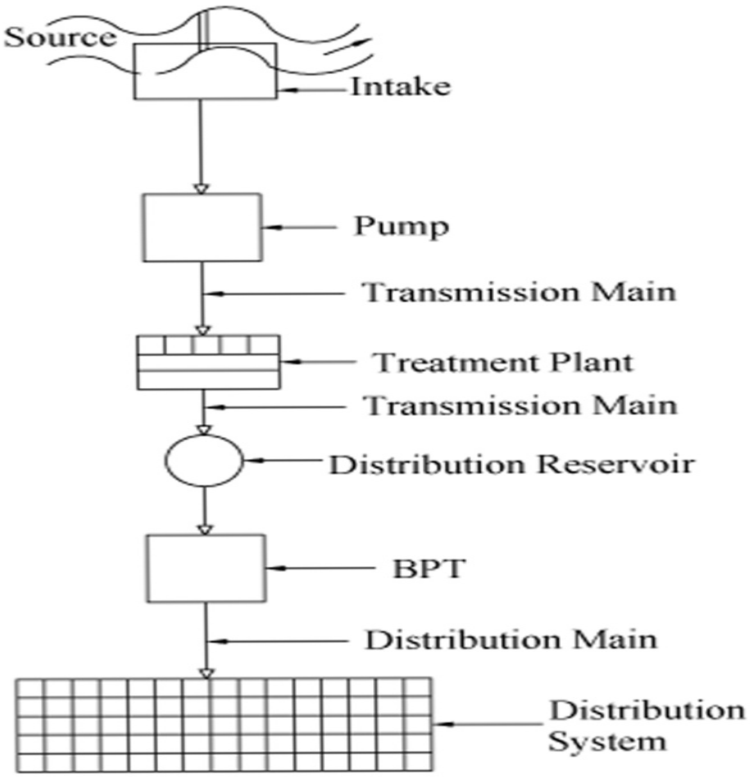

Fig 1.1 Schematic Diagram of Urban Water Supply System(Source at Lower Elevation)

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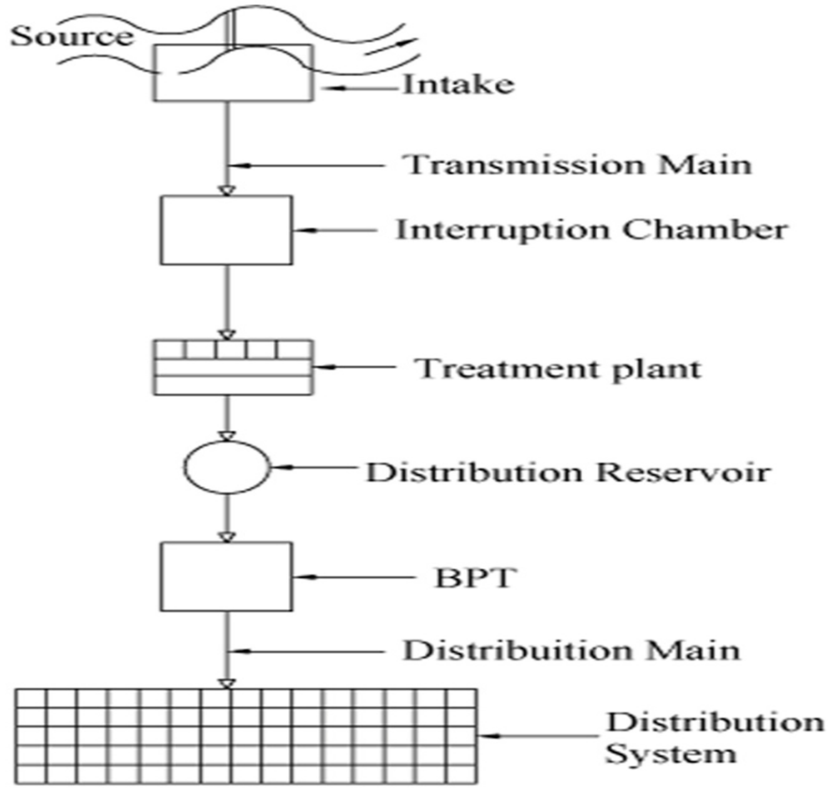

Fig 1.2 Schematic Diagram of Urban Water Supply System(Source at Higher Elevation)

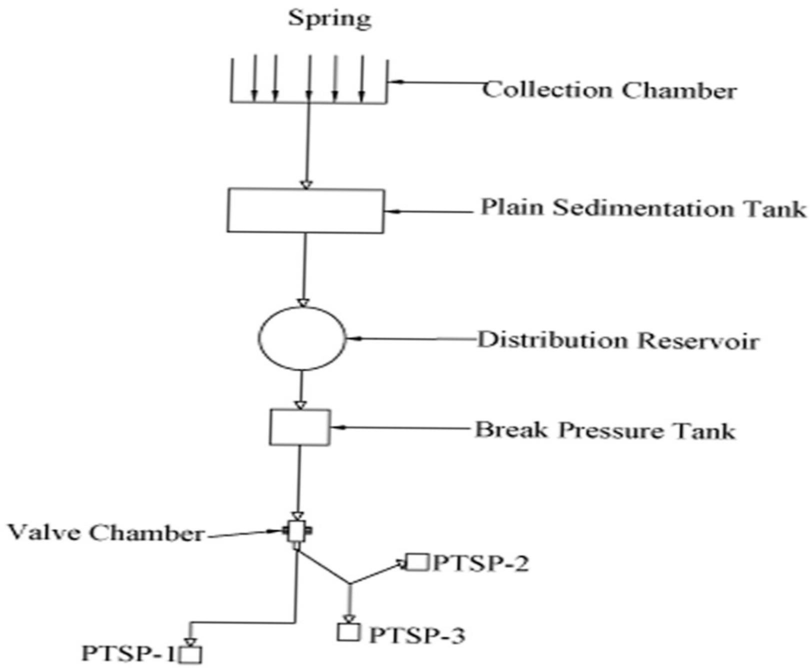

Fig 1.3 Schematic Diagram of Rural Water Supply System(Source at Hilly Area)

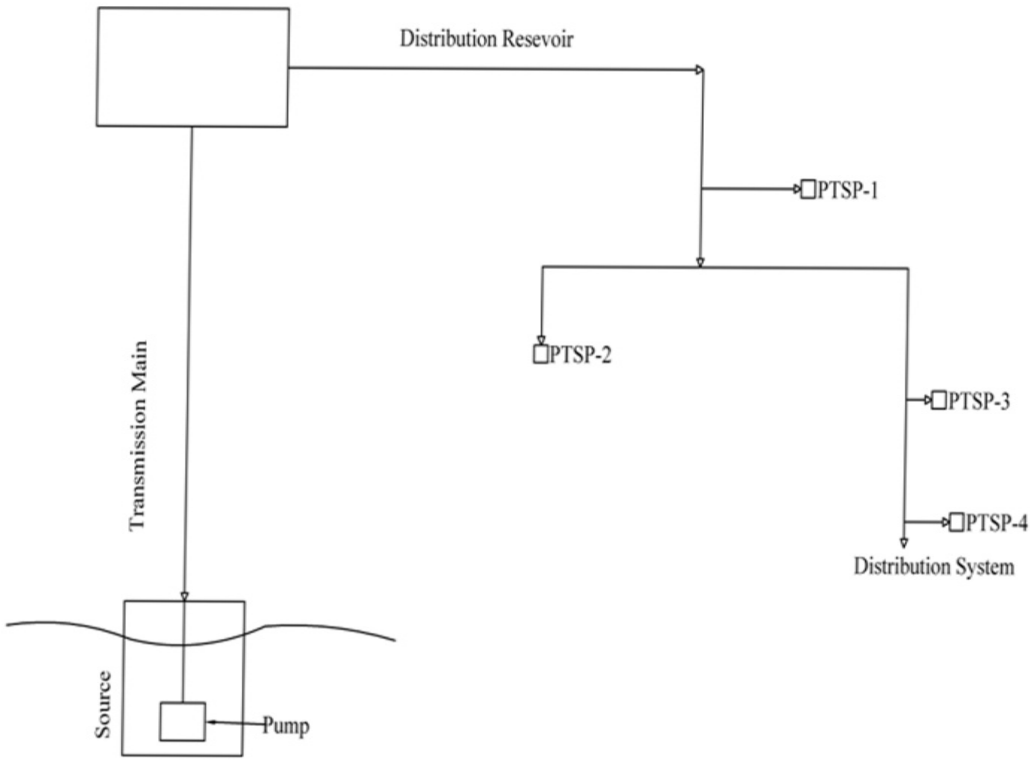

Fig 1.4 Schematic Diagram of Water Supply System
(Source Ground Water)

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Components of Water Supply Systems

- Collection Work
  - Source
  - Intake
  - Collection Chamber
  - Pump
- Transmission Work
  - Transmission Main
  - Interruption Chamber
  - Distribution Chamber

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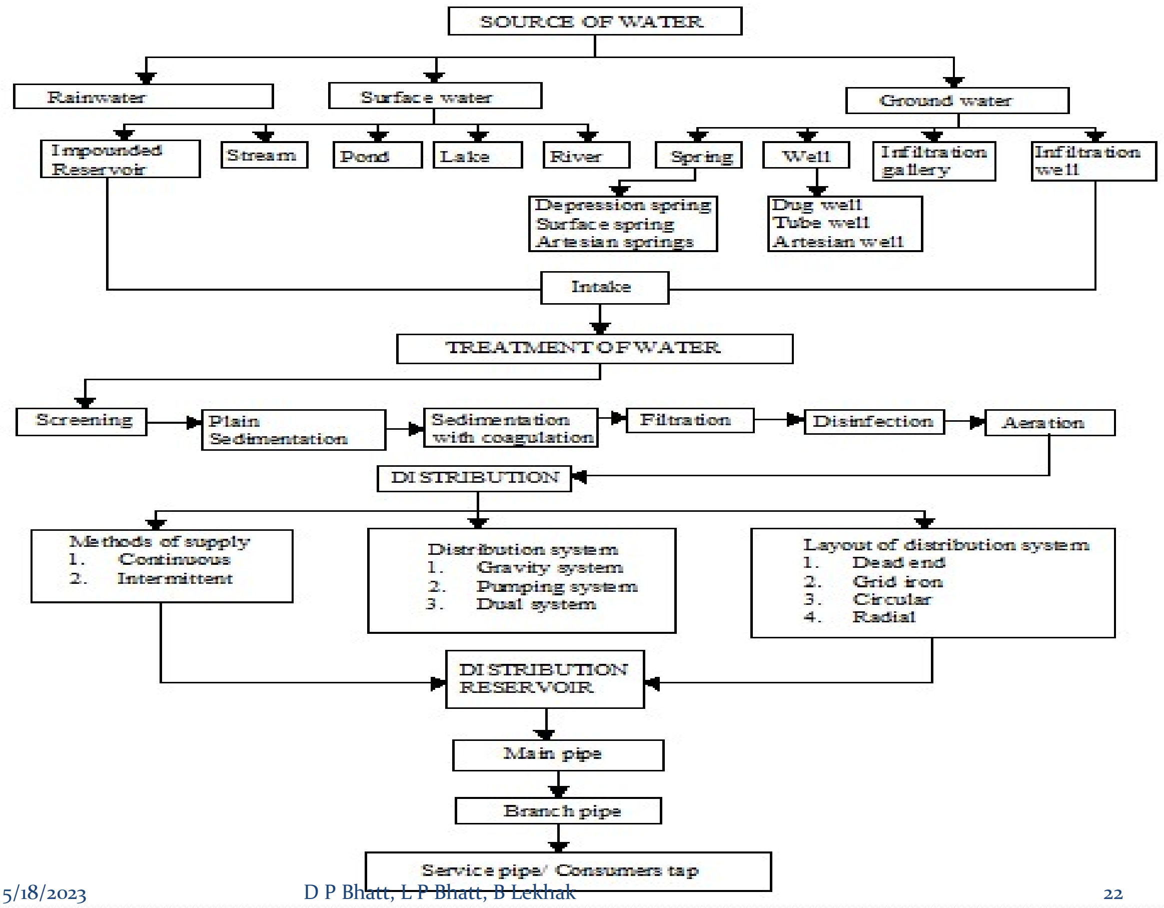
- **Treatment Work**

(screening, aeration, sedimentation, sedimentation with coagulation, filtration, softening, disinfection and demineralization)

- **Distribution Work**
  - **Reservoir**
  - **Distribution Pipelines**
  - **Break Pressure Chamber**
  - **Public Tap Stand Post**
  - **Valve and Valve Chamber**



1. Department of Water Supply and Sewerage (DWSS) was formally established in **1972 A.D.**
2. National Drinking Water Quality Standard (NWDQS) of Nepal came into effective in **2005 A.D.**
3. The water which is not chemically pure not does not contain anything harmful to human health is known as **wholesome water.**
4. Human's body consists about **50 to 60 % of water.**

Sources of water

How much ? Where ?

- Water covers 75% of the earth surface.
- About 97.3% of water is contained in sea that is saline and not useful.
- Similarly, 2.14% is in icecaps glaciers in the poles, which is also not useful.
- The remaining 0.56% found on earth is in useful form for human beings.

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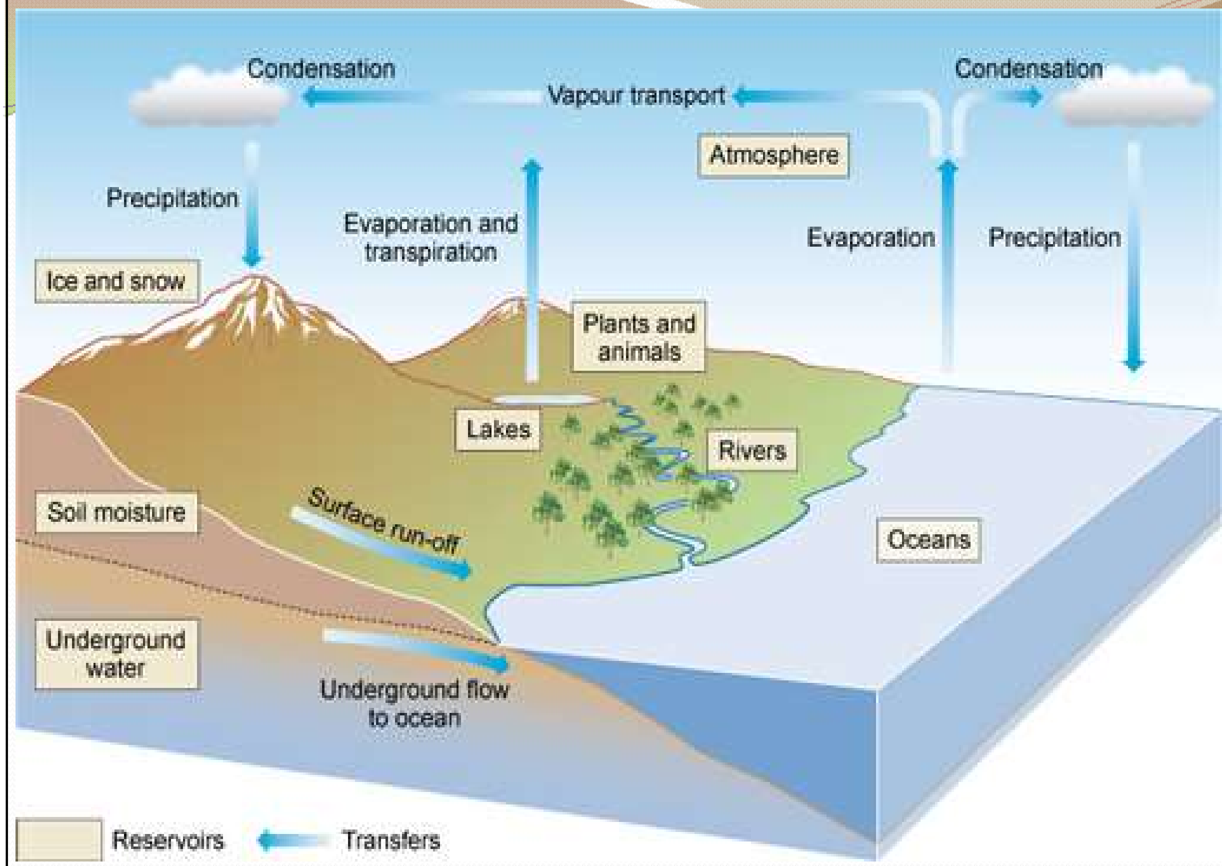

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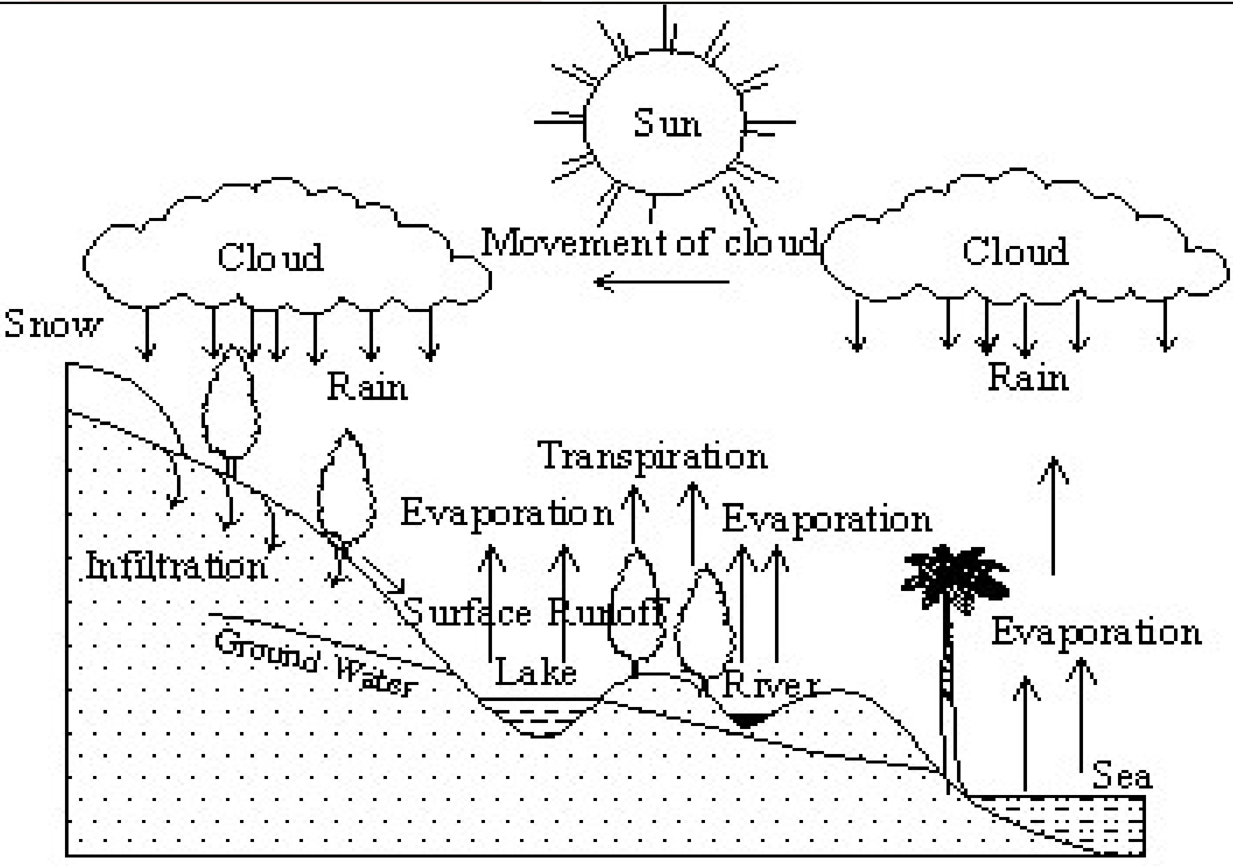

Figure 2.1 Water Cycle

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SOURCES OF WATER

- **Surface Water**
  - Streams Lake Ponds Rivers
  - Impounded reservoirs
- **Ground Water**
  - Springs Wells
  - Infiltration Gallery Infiltration wells
- **Rainwater**
- ***Grey water recycling***
- ***Fog water Harvesting***

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Surface Water

- Surface water is found in surface of the earth and get available as runoff from catchment area, during rainfall or precipitation.
- Some sources are feed by snow in higher mountains.
- Water coming from ground sources also contributes to surface water.

Streams

- Streams are formed by runoff.
- Some streams are feed by snow in higher mountains.
- Water coming from ground sources also contributes to streams.
- Streams are natural channels carrying the discharge collected by its small catchment.
- In streams, there is more discharge in rainy seasons then other seasons.
- Streams those dry in summer are known as rainy streams and are not practical for water supply projects.

Streams

- Quality of streams water is good except first runoff when it carries many floating and dissolved materials.
- Stream water some time contains clay sand and minerals while flowing over ground.
- Suspended impurities are removed in sedimentation tank up to certain extend.
- Dissolved impurities require special treatment.
- If upstream is farming areas and chemical fertilizers are used they polluted by pesticides and fertilizers.
- Upstream villages with open defecation practice also have impact on water quality.
- These are sources of water supply in hilly village and towns near them.

Rivers

- Rivers are natural channels carrying the discharge collected by its large catchment.
- Rivers are formed when the discharges of large number of springs and streams combines together.
- Initially, quantity of water is low in river that increases as it moves forward as more streams, springs and small rivers from more catchments area get combines.

Rivers

- Rivers have maximum quantity in comparison to other sources therefore most of cities are developed and situated near rivers from ancient times.
- Rivers may be perennial or non-perennial
- Rivers those have water throughout the year are known as perennial rivers and are directly used as source of water for water supply projects.
- Rivers those dry in summer are known as non-perennial rivers and are not practical for water supply projects without storage facility for summer.

Rivers

- River water in mountains close to their origin is normally pure.
- However, as river passes from more settlements, urban centers, towns, cities it get polluted.
- Most cities discharge their sewage and industrial wastewater in rivers.
- In Nepal, it is usual for dead bodies to be burnt on the banks of the river.

Rivers

- In monsoon, the runoff water also carries clay, sand, silt etc.
- Therefore, rivers get contaminated and river water should be used after necessary treatments.
- River water has self-purification action and it automatically becomes clean after some distance travel.

Lakes

- Lakes are natural depression basins formed with impervious beds with water.
- Lakes get filled by water from surface runoff from catchment, springs and streams flows, rainwater
- The **quantity of lake** water depends upon
  - capacity of basin
  - total catchment area
  - characteristics of catchments
  - geological formations of lake,
  - annual rainfall and
  - porosity of the ground.

Lakes

- The quality of lake water depends upon characteristics of catchment and lake basin.
- The quality of lake is good if its catchment is uninhabited and its basin does not contain soluble salts.
- Generally, large lakes are good in quality then small lakes as small lakes have high chances of having more algae, weeds etc.
- Again, higher altitude lakes have better quality than that of lower due to less settlements and habitats in their catchments.
- Low altitude lakes with residential area nearby are polluted.
- Lake water is used nearby cities for water supply purposes with necessary treatments.

Ponds

- Ponds are depressions in plains in which water is collected during rainy seasons.
- Normally these are man made by digging of ground.
- Sometime ponds are generated due to excavation done for construction, embankment for road and manufacturing of brick.
- The quantity of pond is small with number of impurities.
- Pond water is not used for water supply purposes.
- However, it is used for washing clothes and animal bathing in backward communities.

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Impounded Reservoirs

- Impounded reservoir or storage reservoir can be defined as an artificial lake developed by construction of a dam or other structure across river or stream.
- There is a great variation in the quantity of river water during monsoon and summer season.
- The discharge in some rivers remains sufficient to meet hot weather demand. However, in some rivers, it cannot meet hot weather demand than it becomes essential to store the water for summer season.
- The excess flow of water during monsoon needs be stored in the river by constructing a bund, a weir or a dam.

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Construction of reservoir is not feasible

- When the average flow is lower than average demand (can not fulfill water demand)
- When the rate of flow in the streams in dry season is more than the demand (no need to store water).

Size determination of Tank/ Reservoir

CASE I: Total Inflow > Total Outflow:

- Tank capacity = Maximum cumulative surplus (MCS) + Maximum cumulative deficit (MCD) – total inflow (TI)+ total demand (TD).

CASE II: Total Inflow ≤ Total Outflow:

- Tank Capacity = Maximum cumulative surplus (MCS) + Maximum cumulative deficit (MCD)

Site selection

- The reservoir site should have narrow river channel - length of dam -construction cost.
- Rapidly widening upstream -more capacity
- Sufficient quantity of water
- Higher elevation -gravity flow
- Near the distribution area -transmission
- Important infrastructures should not be submerged
- Deep reservoir must be formed-evaporation loss - weed growth.

Site selection

- Bed soil should not contain soluble salts, minerals
- The geological conditions - percolation -leakage
- There should not be deep fissures in bed rocks - percolate
- Watershed should be free from swampy area - microorganism growth occurs- treatment cost is increased.
- Availability of construction materials.
- Topography should be favorable for site of spillways and construction of aqueducts or pipelines.

Ground Water

- Water accumulated below the surface of the ground
- The largest available source of fresh water
- The main source of ground water is also precipitation and its surface runoff
- The process of infiltration and percolation of water into the ground until it reaches to impervious stratum and joining to the natural stores of ground is known as ground water recharge.
- The groundwater is held in voids of saturated porous strata and cracked and fissured rocks that acts as ground reservoirs.

Ground Water

- The surface of ground water exposed to atmospheric pressure beneath the ground surface is known as ground water table.
- The water table falls and rises according to precipitation and withdrawal.
- With the rapid urbanization and growing demands of water supply, the ground water resources are depleting in Nepal especially in Kathmandu valley.

Ground Water

- The following are the major reasons for ground water depletion in Nepal.
  - Increasing demand
  - With drawing more than recharge
  - Reducing of recharge area due to buildings, paved paths and roads
  - Diminishing surface water bodies
  - Uncertain rainfall

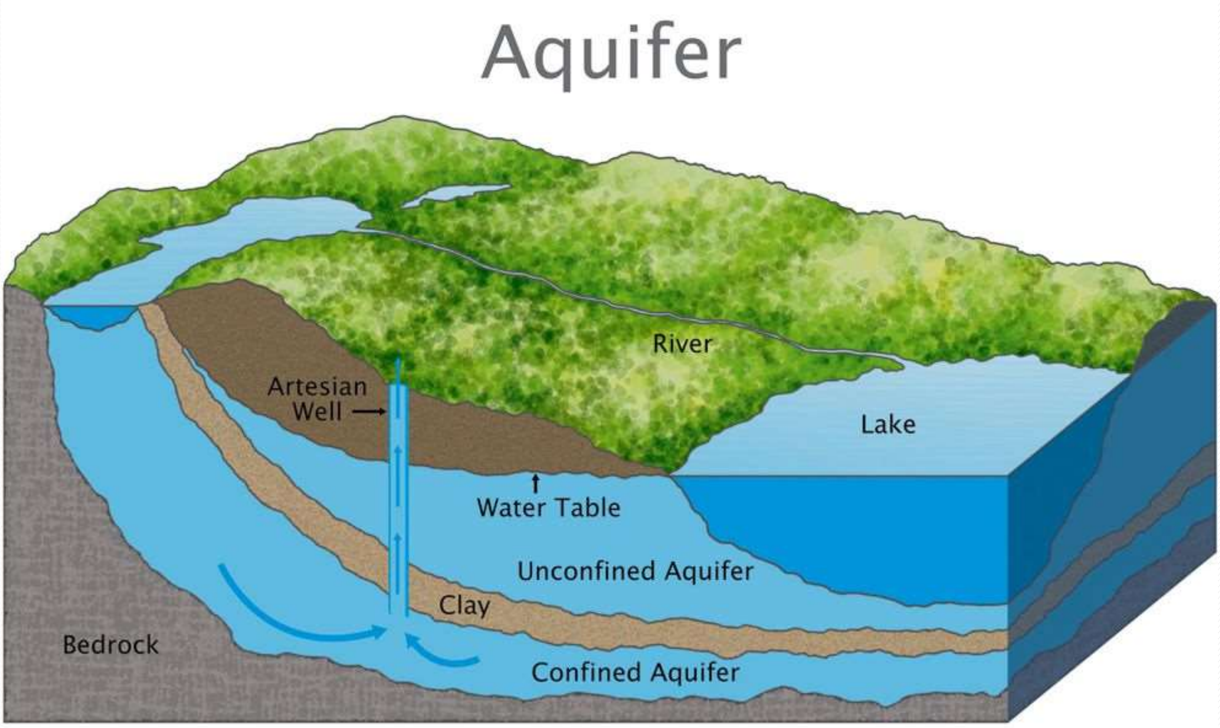
Definition of basic terms

Infiltration and percolation

- The entrance of rainwater or snow into the ground due to hydraulic permeability of soil is known as infiltration.
- The movement of water after entrance is known as percolation.
- The amount of infiltration depends on
  - rainfall characteristics such as rainfall intensity,
  - soil characteristics such as porosity,
  - type of soil cover and compaction of soil cover.

Water Bearing Stratum(Aquifer)

- Aquifer is **geological formation of permeable matters that acts as natural storage of underground water.**
  - Example-Unconsolidated sand and gravels
- Aquifer can store as well as transmission of water.
- The amount of water that an aquifer may yield is dependent upon the porosity and permeability of the material .
- Aquifers are further classified as confined and unconfined aquifer.



Confined Aquifers

- In confined aquifer, ground water is confined under pressure greater than atmospheric pressure by overlaying relatively impermeable strata.
- When a confined aquifer is tapped by a well, water can rise up above the top of the aquifer, sometimes rising above the surface of the ground.

Unconfined Aquifers

- An unconfined aquifer is one that does not have a confining layer above it.
- In unconfined aquifer water table forms the upper surface of the zone of saturation.
- Pores below the water table are full of water.
- In unconfined aquifer water table rises and falls according to change in water volume.
- When tapped by a well, the water level in the well will be the same as the water level of the aquifer,
- They have porous layers of sediment above them and may also be easily contaminated.

- **Aquiclude:-** Aquicludes are underground geological formation that contains water. However, do not allow draining of water from there. Example of aquicludes is clay layer.

- **Aquifuge:-** Aquifuge are impermeable underground geological formation that neither contains nor transmit water. Example of aquifuge is granite bed.

Classification of ground water

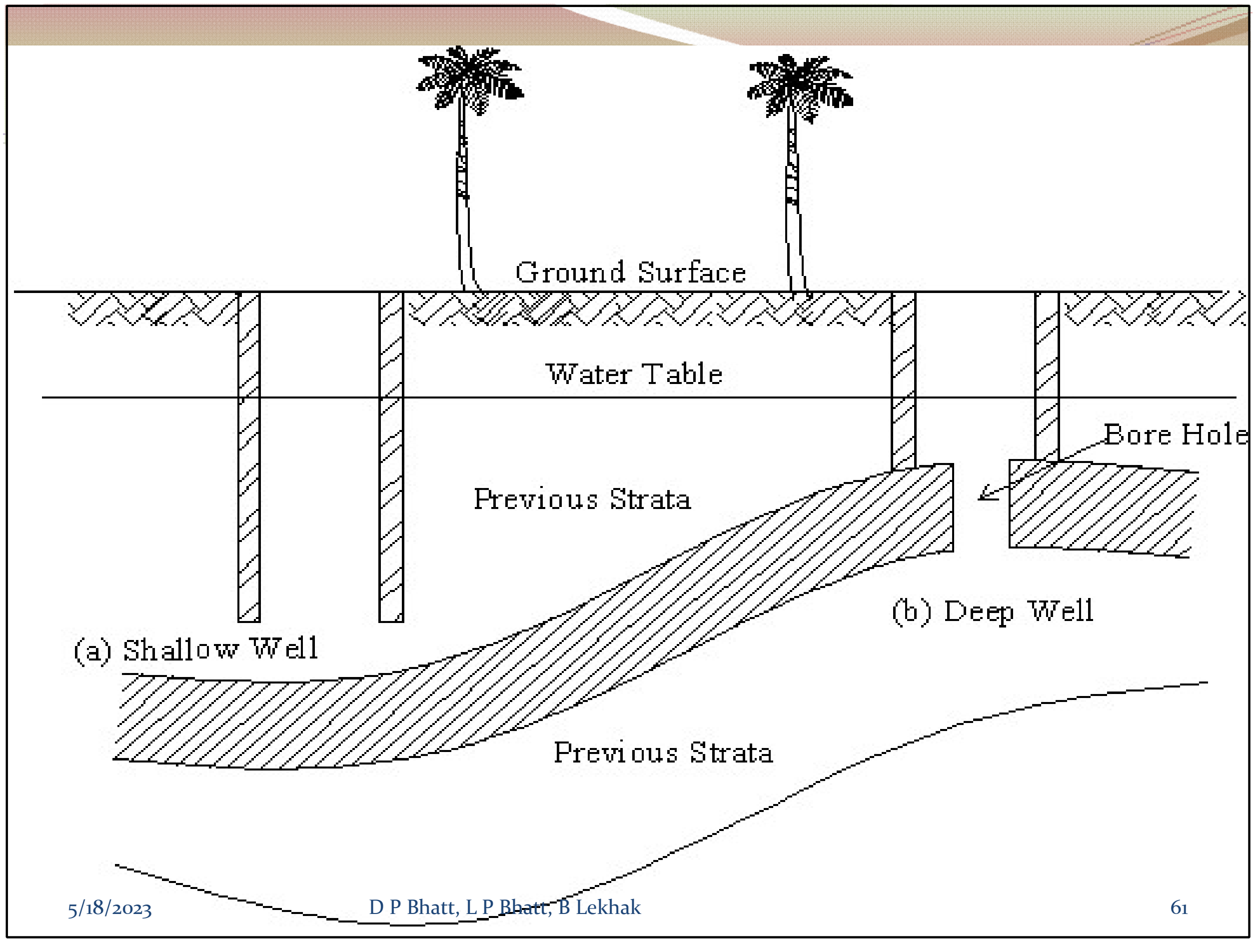
- Groundwater sources have their origin in the water cycle and are stored in aquifers beneath the ground surface.
- To gain access to groundwater sources there is need of digging or drilling through the ground up to an aquifer.
- Sometimes ground water reappears at the ground surface in the form of springs also.
- Sources of groundwater can be broadly classified as springs, wells, infiltration gallery and infiltration wells.

Springs

- If the water from aquifer comes out to earth automatically, than it is known as spring.
- Quantity of spring water is less hence it cannot be used as source for big cities and towns but well developed spring can be used for small towns in hilly region.
- In hilly area of Nepal, springs are major sources of drinking water supply for rural people, as spring water is relatively pure and these are mostly available.
- Some springs discharge hot water due to presence of sulphur and useful only for the treat of certain skin disease patients.
- Springs can classify as gravity and non-gravity springs.

Well

- A well is defined as **an artificial hole or pit made in the ground for the purpose of tapping water from aquifer.**
- Water well is an excavation in the ground by digging, driving, boring or drilling to access the groundwater in underground aquifers.
- The well water is drawn by an electric submersible pump, trash pump, vertical turbine pump, hand pump or mechanical pump.
- Wells can vary greatly in depth, water volume and water quality.
- Well water typically contains more minerals than surface water and may require treatment to remove minerals such as arsenic, iron and manganese.
- In Terai and valleys most of population has to depend on wells for their water supply.
- Wells may be classified as open well (shallow well and deep well), tube well and artesian well.


Ground Surface
Water Table
Bore Hole
Previous Strata
(b) Deep Well
(a) Shallow Well
Previous Strata
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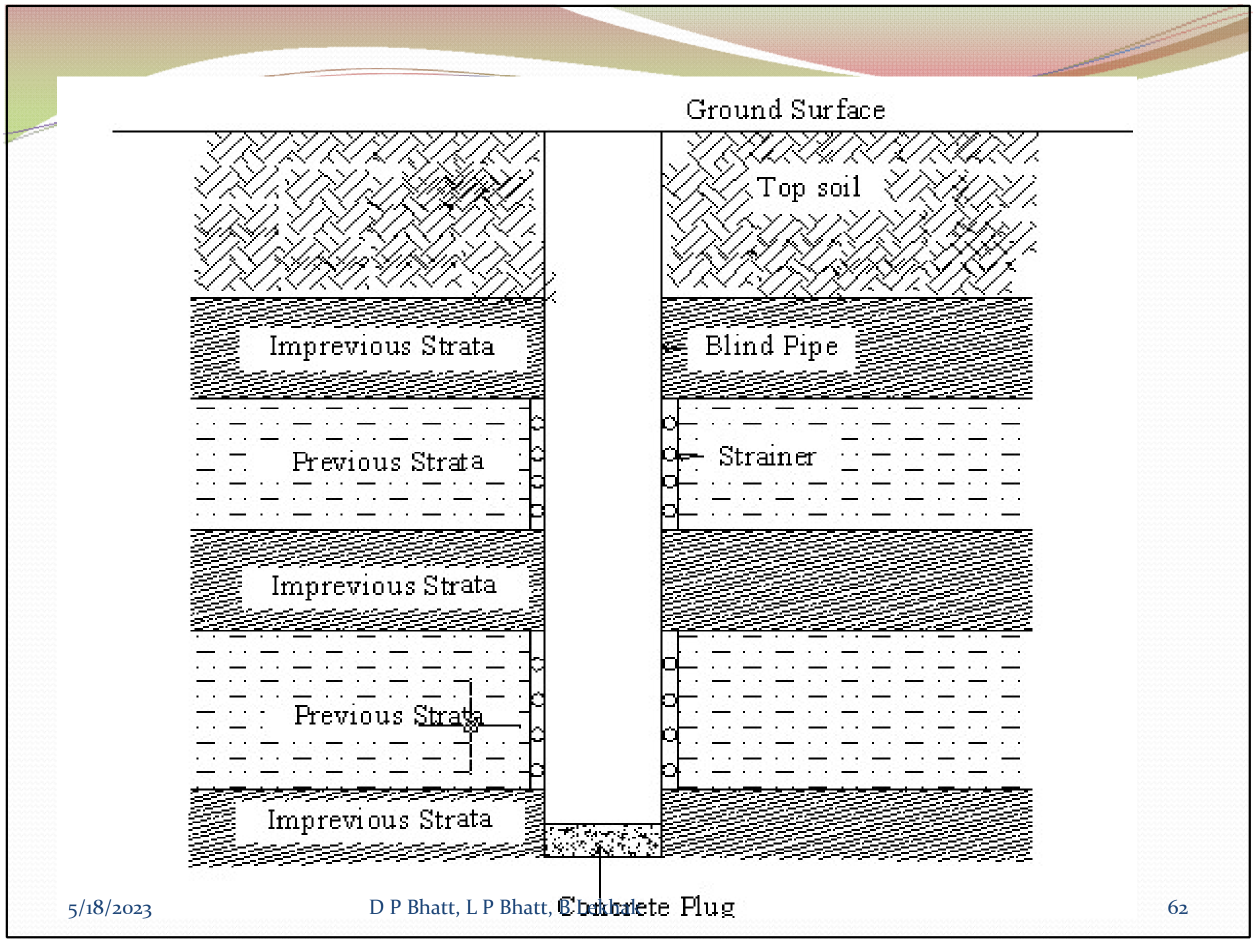
Ground Surface
Top soil
Imprevious Strata
Blind Pipe
Previous Strata
Strainer
Imprevious Strata
Previous Strata
Imprevious Strata
Concrete Plug
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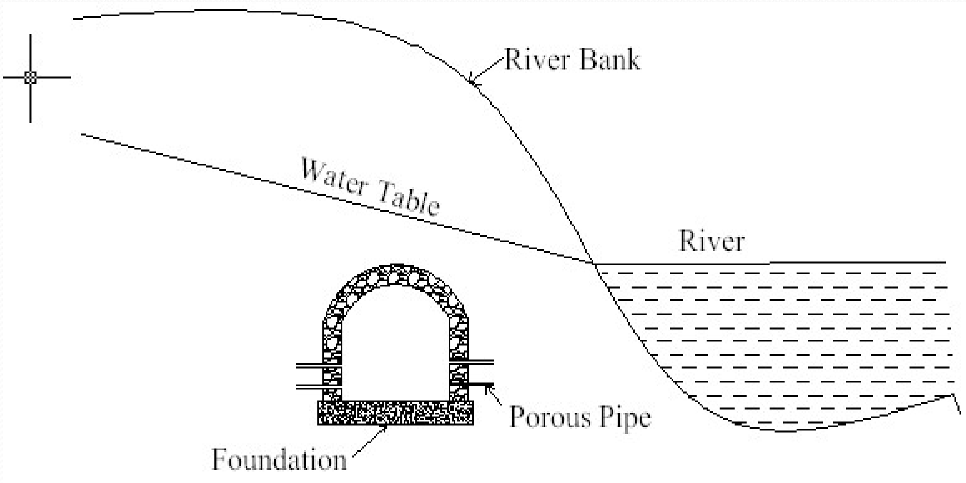
- Maximum discharge from open well is too low.
- To obtain more yields, now a day's tube wells are commonly used.
- A tube well is long pipe sunk into the ground intercepting one or more water bearing strata.
- Diameter of tube well is extremely less than open well.
- To construct a tube well a hole is dug by machine in to the ground and pipe is inserted.
- Tube well water may contains dissolved minerals like iron, magnesium etc.
- Tube well may be classified as shallow tube well (upto 30m) and deep tube well (30 to 600m).

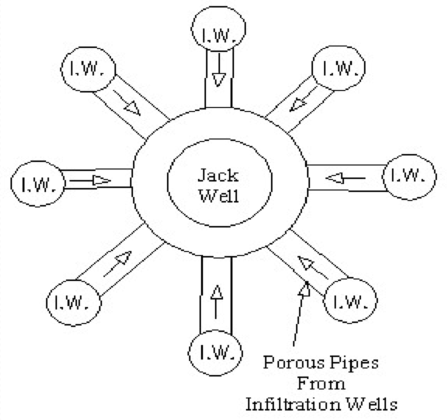
Infiltration Gallery

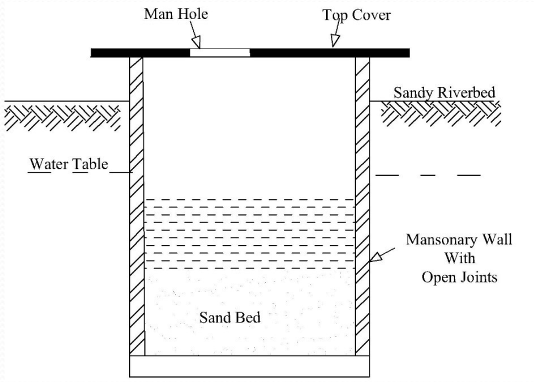
- Ground water travels towards lakes, rivers or streams, as they are located at lower elevation than other areas.
- This ground water can be tapped by digging a trench or constructing a tunnel on side right angle to flow direction of ground water and is known as infiltration gallery.
- It is also known as **horizontal well.**
- Infiltration gallery should constructed near the bank of river or other seepage area.
- Infiltration gallery is constructed by **cut and cover method.**
- To construct infiltration gallery a tunnel or trench is carried below minimum ground water table.



Infiltration Well

- Infiltration wells are the shallow well constructed in series along the bank of the river to collect the water seeping through the banks of river.
- They also work on same principal of infiltration gallery.
- As shown in Figure these wells are constructed of stone, bricks, and R.C.C rings with open joints.
- The wells are closed at top and open at bottom.
- For the purpose of inspection manhole is provided in the top cover of the well.





Selection of Water Sources

- Location
- Quantity of Water
- Reliability of the Source
- Quality of Water
- Water Right Problems
- Cost

Other factors

- **Technical Criteria:**
  - Construction cost
  - Operation costs
  - Complexity of the commissioning and the maintenance
  - Availability of spare parts
  - Use of local or imported materials

Environmental Criteria

- Water quality
- Potential contaminations
- Sustainable and safe
- Reliability

Socio-economic Criteria

- Ability to pay
- Willingness to pay
- Organization capacity and motivation.
- Financial capacity to pay for the maintenance

Institutional Criteria

- Design and model validated by the national policy and relevant ministries
- Technical skills availability
- Capacity of the local authorities to assist the community.
- Available technical assistance and follow-up.
- Available budget.

1. Most common surface water supply source is **River.**
2. The water obtained from tube wells is known as **Subsurface water.**
3. The vertical wells provided along the banks of river to draw ground water in dry seasons is called **infiltration wells.**
4. The earth's water circulatory system is known as **hydrological cycle.**
5. Ground water is usually free from **suspended impurities.**
6. As compared to shallow wells, **deep wells have more discharge.**

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- **Aquiclude:-** Aquicludes are underground geological formation that contains water. However, do not allow draining of water from there. Example of aquicludes is clay layer.

- **Aquifuge:-** Aquifuge are impermeable underground geological formation that neither contains nor transmit water. Example of aquifuge is granite bed.

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Occurrence of Ground water

- Groundwater is water which exists in the pore spaces and fractures in rocks and sediments beneath the earth's surface or found beneath the surface of earth
- Groundwater makes up about 1% of the water on the Earth (most water is in oceans)
- Groundwater makes up to 35 times the amount of water in lakes and streams.

OCCURRACNCE OF GROUND WATER DEPENDS ON

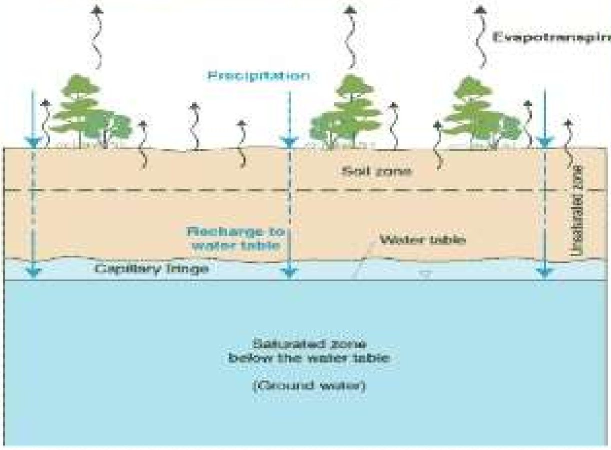
- Porosity of soil / rock
- Saturated and unsaturated zones
- Permeability
- Aquifer

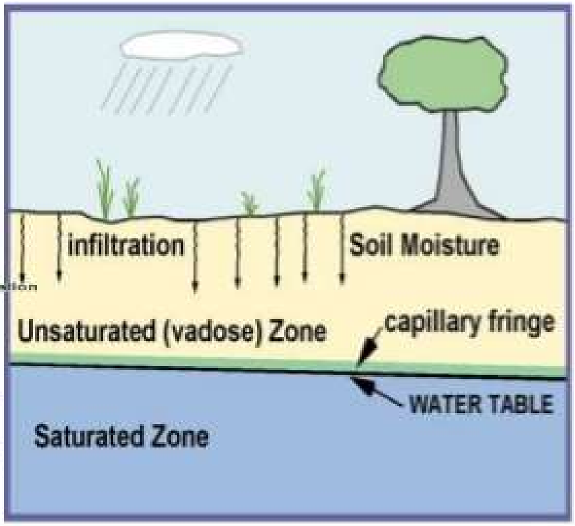
Vertical distribution of GW

The vertical distribution of ground water mainly divided into two zones:

Zone of Aeration

Zone of Saturation





Groundwater prospecting

- Groundwater prospecting involves various methods to locate suitable quality and quantity groundwater for extraction.
- Groundwater prospecting and extraction can both be part of general water resource management strategies to increase supply, or respond to climate change induced water scarcity or variability.
- Prospecting and extraction methods depend on the desired water quality and its final utilization,
- It include hydrogeological investigations, geophysical surveys, remote sensing assessments, and the more simple method of investigating already existing well sites in the area and their depths and characteristics.

Chemical characteristics

- Chemical characteristics of GW depends on geological strata
- The chemical constituents in groundwater determine its usefulness for industry, agriculture, and the home.
- Total dissolved solid
- Organic Constituents- Carbon is the key element.
- The species H_2Co_3 , Co_2 , HCo_3^-, and Co_3^{2-}, which are important constituents in all groundwater, however, are not classified as organic compounds

Chemical characteristics

- Dissolved Gases- The most abundant dissolved gases in groundwater are N_2 , O_2 , CO_2 , CH_4 (methane), H_2S, and N_2O.
- The first three make up the earth's atmosphere and CH_4 , H_2S, and N_2O can often exist in groundwater in significant concentrations because they are the product of biogeochemical processes that occur in non-aerated subsurface zones.
- Iron and Manganese-Found in deep aquifer
- Arsenic
- Sodiun
- Nitrate

Chemical characteristics

- Chloride- it is the dominant anion (negatively charged ion) in acidic groundwater.
- It is not harmful to human beings until high concentrations are reached.
- Fluoride is a very important constituent of teeth and bones in the human body.
- Fluorides at high levels are toxic to human.
- The high fluoride rich water affects dental enamel and may cause skeletal damages.

Properties of ground water

Characteristic	Ground Water
Temperature	relatively constants
Turbidity, SS	Low or nil (except in karst soil)
Colour	Due above all to dissolved solids
Mineral content	Largely constant--higher than in surface water from the same area
Divalent Fe and Mn in solution	Usually present
CO_2	Often present

Silica	Level often high
Mineral and organic micro-pollutants	Usually none but any accidental Pollution lasts a very long time
Living organisms	Iron bacteria frequently found
Chlorinated solvents	Often present
H_2S	Often present
NH_4	Often found
Nitrates	Level sometimes high

Recharge of ground water

- Ground water recharge is a hydrological process by where water moves downwards from surface water to ground water through pores or interstices or fractures of soil or rocks
- Rainfall is the main source for replenishment of recharge of ground water
- Recharge of ground water can be done either by natural or artificial methods

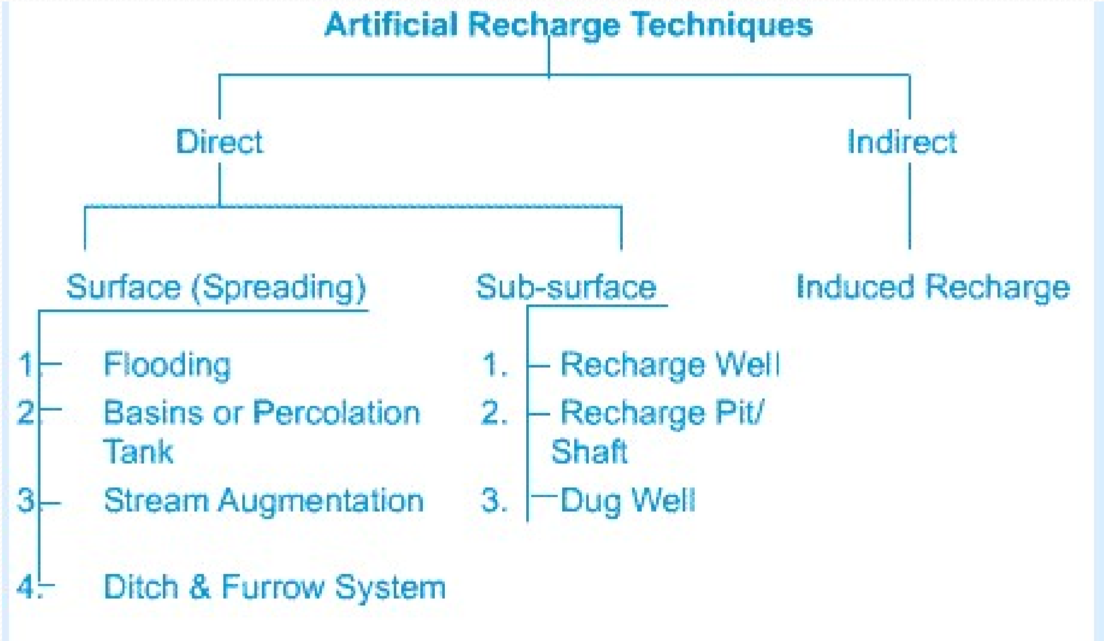
Natural recharge

The process of recharge of groundwater from the direct infiltration of rainfall or from the water percolation of adjacent water bodies,

- Following are the favorable conditions for natural recharge:
  - High permeable soil or sandy strata
  - Rocky strata with fractures
  - Perennial river
  - Forest land
  - Comparatively level land with less slope

Artificial recharge

- The process of artificial obstructing of flowing rainwater and inducing its infiltration by human activity such as irrigation, pounding, construction of injection boreholes or river spreading to increase the ground water reservoirs
- Due to continuous extraction of ground water, aquifer are not recharged at the same rate of extraction then artificial recharge is done to maintain water table
- Artificial recharge improves:
  - To improve the quality of GW
  - Conversion of GW for future
  - To maintain level of ground water table
  - To minimize the dry off water sources due to effect of climate change



Flooding

- This method is suitable for relatively flat topography
- In this water is spread as a thin sheet
- This methods required a distribution system for spreading of water
- More efficient in thin vegetation covering and sandy soil strata

Basin or percolation tank

- Area is divided into small basin by constructing small embankments
- The basin or tank is filled with water having depth 1.25m for effective recharge
- For effective discharge water should keep flowing in the basin or tank and flow should be along the diagonal
- Water enter to the basin or tank by supply ditch and return to stream through outlet

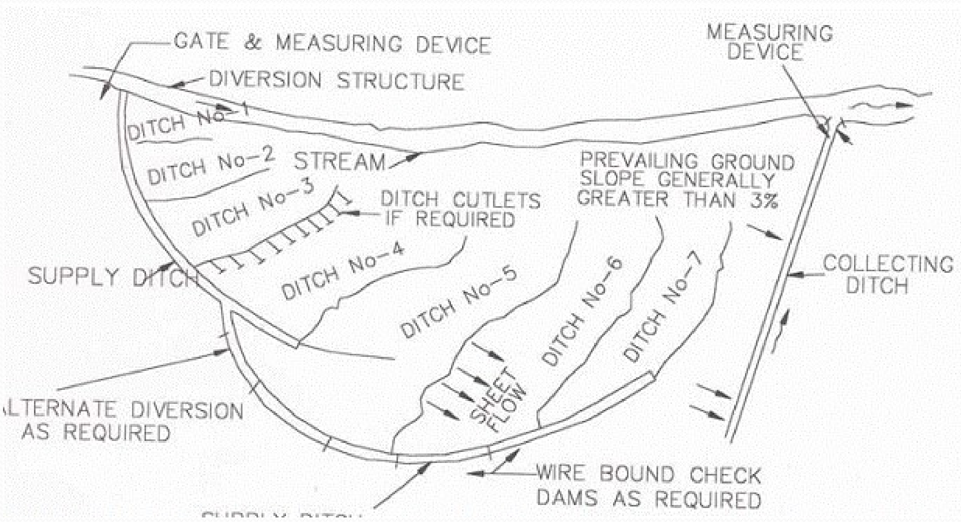
Stream augmentation

- In this method seepage through the stream is artificially increased by putting series of check dam across the stream
- Placing of check dam spread the water in the stream through the large area hence increase the infiltration area
- Placement of check dam is done on the area of sufficient thick permeable bed

Ditch and furrow system

- In areas with irregular topography, shallow, flat-bottomed and closely spaced ditches or furrows provide maximum water contact area for recharge water from source stream or canal.

- This technique requires less soil preparation than the recharge basins and is less sensitive to silting.



Recharge well

- In this methods water is recharged directly to the aquifer
- These are similar to the pumping well, it is suitable for recharging of single or multiple well
- Water is filled in the well which will be percolate to the ground
- This method is suitable when
  - Area available for recharge is small
  - Aquifer is located at great depth
  - Spreading method is not suitable

Recharge pit/ shaft

- This method is suitable for less permeable soil
- In this method a pit is dig to a depth to penetrate the less permeable strata
- This method is also used when surface folding method is not suitable
- Recharge shaft is similar to recharge pit having less cross sectional area compared to recharge pit

Induced recharge

- In this method natural water table around the surface source such as stream, river or lake is lowered down by pumping out of water from well or galleries constructed parallel to surface source
- Due to pumping a reverse gradient is formed and water from surface source enter in to the aquifer and recharge the aquifer
- This methods improve the quality of surface water due to the filtration of surface water through soil strata removes impurities of surface water

Groundwater Recovery

- **Groundwater Recovery** is the direct injection of surface water supplies such as potable water, reclaimed water (i.e. rainwater), or river water into an aquifer for later recovery and use.

Water Pollution

- Water pollution may be defined as alteration of physical, chemical and biological characteristics of water.
- Water pollution may cause harmful effects on human, aquatic life and environment
- Water pollution is addition of any pollutants or substance (often chemicals or microorganisms) which affects its quality and make unfit for its purpose

Types of water pollution

- Surface water pollution
- Ground water pollution
- Nutrients Pollution
- Oxygen depleting
- Microbiological
- Chemical water pollution
- Oil spillage

Sources of Water Pollution

- Domestic effluents or Sewage
- Industrial effluents
- Agricultural effluents
  - Uncontrolled spreading of manure
  - Disposal of animal dip
  - Ploughing of the land
  - Use of pesticides and fertilizers
  - Accidental spills from milk dairies

Sources of water pollution--

- Oil Pollution
  - Loss from storage facilities
  - Leakage during delivery and;
  - Disposal of waste oil to drainage systems
- Radioactive Substances
  - Radioactive substances are used in nuclear power plants, industrial, medical and other scientific processes.
  - They can be found in watches, luminous clocks, television sets and x-ray machinery.
- Domestic solid waste
- Thermal pollution
- Acid rain

Sources of water pollution--

- Water is uniquely vulnerable to pollution as a "universal solvent"
- Water is able to dissolve more substances than any other liquid on earth.
- Toxic substances from farms, towns, and factories readily dissolve into and mix with it, and cause water pollution.

Point source

- When contamination originates from a single source, it's called point source
- Examples include
  - Effluent from wastewater treatment facility
  - Contamination from leaking septic systems
  - Chemical and oil spills, and illegal dumping
  - A factory outlet/ city storm outlet
- While point source pollution originates from a specific place, it can affect miles of waterways and ocean.

Nonpoint source

- Nonpoint source pollution is contamination derived from diffuse sources.
- These may include agricultural or storm water runoff or debris blown into waterways from land.
- It is difficult to regulate, since there's no single, identifiable culprit.

Common water pollutants

- Sewage—Domestic, Hospital, animal and human excreta
- Metals- mercury and other heavy metals from industries
  - Lead
  - Cadmium
  - Arsenic
- Bacteria, virus, parasites
- Plastic, detergents, oil, gasoline

Common water pollutants

- Inorganic chemicals- acid, base, salts
- Plant nutrients
- Thermal pollution
- Animal manure and plant residue
- Fertilizer and pesticides

Effects of pollution

- Disturbance of food chain-when toxins and pollutants in the water are consumed by aquatic animals (fish, shellfish etc.) which are then consumed by humans.
- Death of aquatic animals
- Destruction of ecosystems -Water pollution can cause an entire ecosystem to collapse if left unchecked.
- Disease on human and death -In humans, drinking or consuming polluted water in any way has many disastrous effects on our health.
- Contamination of water source

Eutrophication

- Eutrophication, the gradual increase in the concentration of phosphorus, nitrogen, and other plant nutrients in an aging aquatic ecosystem such as a lake.
- Chemicals in a water body, encourage the growth of algae.
- These algae form a layer on top of the pond or lake.
- When these dense algal blooms eventually die, microbial decomposition severely depletes dissolved oxygen, creating a hypoxic or anoxic 'dead zone' lacking sufficient oxygen to support most organisms.
- This severely affecting the aquatic life there.

Groundwater Pollution

- Groundwater pollution occurs when pollutants are released to the ground and make its way down to the ground water
- It also occurs naturally due to presence of minerals in geological formation
- Groundwater gets polluted when contaminants

  Pesticides and fertilizers

  Waste leached from landfills and septic systems

Make their way into an aquifer, rendering it unsafe for human use.

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Groundwater Pollution

- Eradication groundwater of contaminants can be difficult to impossible, as well as costly.
- Once polluted, an aquifer may be unusable for decades, or even thousands of years.
- Groundwater can also spread contamination far from the original polluting source as it seeps into streams, lakes, and oceans.

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Quality of water

Drinking Water Quality Guidelines

SN	Parameters	WHO	NDWQS
1.	Turbidity, NTU	5.00	5.00(10)**
2.	Colour, TCU	15	5 (15)**
3	Taste	Unobjectionable	Unobjectionable
4	Odour	Unobjectionable	Unobjectionable
5	pH	6.5 - 8.5	6.5 - 8.5
6	Iron, mg/l	0.30	0.3 (3)**
7	Manganese, mg/l	0.10	0.20
8.	Total hardness as $CaCO_3$, mg/l		500
9.	Ammonia, mg/l		1.50

SN	Parameters	WHO	NDWQS
10	TDS, mg/l	1000	1000
11	Nitrate, mg/l	50	50
12	Chloride, mg/l	250	250
13	Residual Chlorine, mg/l	0.20 - 0.60	0.10 - 0.20
14	Arsenic, mg/l	0.01	0.05
15	Aluminium, mg/l	-	0.20
16.	Lead, mg/l	0.01	0.01
17	Cadmium, mg/l	0.003	0.03
18	Boron, mg/l	0.30	-
19	Chromium, mg/l	0.05	0.05
[illegible]	Fluoride, mg/l	[illegible]	[illegible]*

SN	Parameters	WHO	NDWQS
21	Nickel, mg/l	0.02	-
22	Hydrogen Sulphide, mg/l	0.05	0.10
23	Sodium, mg/l	200	200
24	Copper, mg/l	1.00	1.00
25	Zinc, mg/l	3	3
26	Mercury, mg/l	0.001	0.001
27	E Coli (Thermo tolerant or faecal coliform), CFU/100	Nil	Nil

Characteristics of Water for Domestic Use

- It should be free from disease causing micro-organism.
- It should be colorless and sparkling.
- It should be reasonably soft.
- It should be tasty and odour free.
- It should be free from objectionable dissolve gases like hydrogen sulfide.
- It should not contain salts and minerals such as iron, manganese, arsenic and other poisonous metals more than recommended in quality standards.
- It should be free from radio-active substances.
- It should not corrode pipes.
- It should have dissolved oxygen and free from carbonic acid so that it may remain fresh.
- It should not lead to scale formulation.

Impurities in Water and Their Effect

- Pure water is colorless, tasteless, and odorless.
- As universal solvent, water can dissolve every naturally occurring substance on the earth
- Water is not available in its pure state as it dissolves substances with which it comes into contact.

1. According to characteristics of the impurities present in water
   i. Physical impurities
   ii. Chemical impurities
   iii. Bacteriological impurities
2. According to state of solute or impurities in water, there are three types of impurities in water.
   i. Suspended impurities
   ii. Colloidal impurities
   iii. Dissolved impurities

Impurities in water

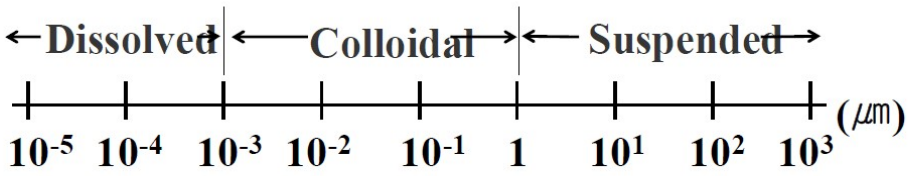
- All the impurities of water can be divided like this ;

-Suspended impurities

- Colloidal impurities

- Dissolved impurities

By size of particle



Suspended Impurities

- Suspended impurities are those, which normally remain in suspension in water due to its turbulence.
- These impurities include bacteria, algae, protozoa, fungi, silts, clay, vegetable, dead animals, organic and inorganic matters, mineral matters.
- They are large enough to see by naked eyes and can be removed by filtration and settling.
- They cause turbidity in water.
- Some impurities impart colour, odour and taste in water.
- Some bacteria causes disease - threat for public health.
- The concentration of suspended matter in water is measured by its turbidity.

Colloidal Impurities

- Colloidal impurities are finely divided dispersion of particles (size 1 micron to 1 mili micron)
- They cannot be visible by naked eyes and cannot be removed by ordinary filtration methods.
- As these particles are electrically charged particles, they are always in motion and cannot be settled by plain sedimentation.
- Such impurities cause color in water hence their quantity is calculated by color test.
- Sometimes these colloidal impurities are associated with organic matters containing bacteria and are chief sources of epidemics.

Dissolved Impurities

- Some impurities are dissolved in water during the water flow from rock and soil because water is a good solvent.
- These impurities may be in the form of solid, liquid or gas and may be organic or inorganic.
- They get in liquid phase after being dissolved in water.
- Therefore, physical methods like sedimentation, filtration etc. cannot remove dissolved impurities.
- Chemical methods those can alter phase like sedimentation with coagulation, precipitation, adsorption, distillation should be used to remove colloidal impurities.
- They are invisible.
- The concentration of dissolved impurities is measured in terms of ppm and is obtained by weighing the residue after evaporation of water sample from a filtered sample.

Impurities and their Effects
Suspended impurities

Constituents	Effect
Bacteria	Some cause diseases
Algae, protozoa	Odour, colour, taste and turbidity
Silts	Murkiness and turbidity
Clay	Turbidity
Vegetable	colour, taste and acidity
Dead animals	Harmful disease causing organism

Dissolved impurities

a) Salts		
Calcium and and Magnesium	Bicarbonate	Alkalinity , Hardness
	Carbonate	Alkalinity , Hardness
	Sulphate	Hardness
	Chloride	Hardness, corrosion
ii) sodium	Bicarbonate	Alkalinity ,softening effect
	Carbonate	Alkalinity ,softening effect
	Sulphate	Foaming of boilers
	Fluoride	Molten of enamel of teeth
	Chloride	Taste

b) Metal and compounds	
Iron oxide	Taste, red colour, corrosiveness, hardness
Lead	Cumulative poisoning
Arsenic	Heavy toxic, defects skin
Barium	Effects heart and nerves
Cadmium	Toxic and illness
Cyanide	Highly fatal
Boron	Effects nerves system
Nitrate	Excessive nitrate brings disease to small babies called blue baby disease
Silver	Discolors skin
Manganese	Black or brown colour
Selenium	Highly toxic to animals, fish

c) Gas	
Oxygen	Excessive amount brings corrosion
CO_2	Acidity and corrosiveness
H_2S	Strong odour, acidity and corrosiveness
d)Organic impurities	
Vegetable	Produce bacteria
Dead animal	Harmful disease causing organism and water pollution

Hardness of water

- The presence of carbonates, sulphates, chlorides and nitrates of magnesium, calcium and strontium in water causes hardness of water.
- These materials react with soap, causing a precipitation, which appears as scum, and no lather can be formed until enough soap has been dissolved to react with all these.

Effect of Hard Water

- It leads more consumption of soap to produce lather
- It leads to modification of colors in dyeing industry
- It causes serious difficulties in manufacturing process for example paper making, canning, ice manufacture etc.
- It causes choking and clogging problems in house plumbing.
- It makes food tasteless and tough.
- It forms scales in boiler plant so consumption of fuel is more.

Types of Hardness

- Carbonate hardness or temporary hardness
  - The hardness caused due to presence of carbonates of calcium, magnesium and strontium is known as temporary hardness and is usually called carbonate hardness (CH).
  - Temporary hardness can be removed by boiling or addition of lime in water.

NCH or Permanent Hardness

- Hardness caused due to presence of sulphates, chlorides and nitrates of calcium, magnesium and strontium in water is called permanent hardness, - also called non-carbonate hardness (NCH).
- Permanent hardness can be removed by lime soda process, zeolite process.
- The total hardness is sum of carbonate hardness and non-carbonate hardness.

$$\mathbf{T.H = C.H + N.C.H}$$

Determination of Hardness

- The hardness of water is usually expressed in ppm or mg/l as $CaCO_3$.
- The hardness of water is determined by following expresson
- $$TH = \frac{\text{Concentration of } Ca^{++} \times 50}{\text{Equivalent weight of } Ca^{++}} + \frac{\text{Concentration of } Mg^{++} \times 50}{\text{Equivalent weight of } Mg^{++}} + \frac{\text{Concentration of } Sr^{++} \times 50}{\text{Equivalent weight of } Sr^{++}}$$

Determination of Hardness

- As the equivalent weight of $CaCO_3$ is 50 and equivalent weight of Ca^{++} , Mg^{++}, Sr^{++} is 20, 12.2,43.8 respectively mathematically the expression can be expressed as bellow.

$$TH = \frac{C_{Ca} \times 50}{20} + \frac{C_{Mg} \times 50}{12.2} + \frac{C_{Sr} \times 50}{43.8}$$

Alkalinity in Water

- When acids or alkalis get dissolved in water, they creates acidity or alkalinity in water.
- When concentration of H^+ ions are less than OH^- then the water becomes alkaline.
- Alkalinity can be defined as the capacity to neutralize a standard solution of acid.
- In water alkalinity is due to presence of bicarbonate, carbonate and hydroxyl ions in water.
- Alkalinity caused by hydroxyl ions is called hydroxide alkalinity or caustic alkalinity.
- Alkalinity caused by bicarbonate ions is called bicarbonate alkalinity.
- Alkalinity caused by carbonate ions is called carbonate alkalinity.

Alkalinity in Water

- Mostly drinking water is alkaline due to sweeping of salts during its flow and decaying of organic matter in water.
- Bicarbonate alkalinity is major form of alkalinity as they are formed in considerable amounts from the action of carbon dioxide upon basic materials of soil.
- Surface water with booming algae contains carbonate and hydroxide alkalinities.

Determination of Alkalinity

- The alkalinity of water is usually expressed in ppm or mg/l as $CaCO_3$. The alkalinity of water is determined by following expression.
- Carbonate alkalinity in $\frac{mg}{l}$ as $CaCO_3$ $=$
$$\frac{\text{C of } CO_3^{--} \text{ ions} \times \text{Eq.W. of } CaCO_3}{\text{Eq.W. of } CO_3^{--} \text{ ions}} = \frac{\text{C of } CO_3^{--} \text{ ions} \times 50}{30}$$
- Bicarbonate alkalinity in $\frac{mg}{l}$ as $CaCO_3$ $=$
$$\frac{\text{C of } HCO_3^{-} \text{ ions} \times \text{Eq.W. of } CaCO_3}{\text{Eq.W. of } HCO_3^{-} \text{ ions}} = \frac{\text{C of } HCO_3^{-} \text{ ions} \times 50}{61}$$
- Hydrooxide Alkalinity $=$
$$\frac{\text{C of } OH^{-} \text{ ions} \times \text{Eq.W. of } CaCO_3}{\text{Eq.W. of } OH^{-} \text{ ions}} = \frac{\text{C of } OH^{-} \text{ ions} \times 50}{17}$$

Relation between Hardness and Alkalinity

- If total hardness is more than total alkalinity than carbonate, hardness is equal to total alkalinity and difference between total hardness and total alkalinity is non-carbonate hardness.
$$\text{TH} > TA \text{ than } CH = TA \text{ and } NCH = TH - CH$$
$$= TH - TA$$
- If total hardness is equal to or less than total alkalinity than the entire hardness is carbonate hardness and non-carbonate hardness is absent.
$$\text{TH} < TA \text{ than } CH = TH \text{ and } NCH = 0$$

Numerical

Living Organism in Water

- The natural water contains various types of living organisms. Some organisms born in water and remain in it due to their natural habits.
- Some organisms are introduced in the water by man during disposal of sewage, solid waste etc. in water.
- Some of the living organisms such as bacteria, viruses and protozoa are infectious to humans and are responsible for the serious outbreak of fatal water born diseases.
- However, majority of living organism in water are beneficial to humans and important for ecosystems.
- All the organisms can be broadly classified as macroscopic and microscopic.

Algae

- Algae are a photosynthetic plant life with unicellular organs of reproduction.
- They are self- cultivating by deriving energy from simple inorganic substances like gases and salts in presence of sun light.
- Their nutrients are phosphorous, sulphates etc. and they produce oxygen during photosynthesis.
- In fresh water, they are generally microscopic size. However, in salty waters, algae may be of several hundred meters in length.
- It develops colors, odour, turbidity and taste in water, clogs the filter, and can trouble in treatment plants.

Viruses

- Viruses are unicellular infectious organism.
- They can be plant as well as animal lives.
- They are ultramicroscopic in size rages from 10 to 500 milli-micron.
- Most of virus are harmful and communicate disease from one person to other.
- Water may contaminate with virus due to sewage disposal in water source.
- All viruses are parasitic and cannot grow outside the body of other living organisms.
- Viruses cause infections such as jaundice, hepatitis, yellow fever and variety of gastro intestinal disease.

Worms

- Worms or helmiths are animal life both unicellular as well as multicellular.
- They are visible to naked eyes. However, ova and larva of worms may not be visible.
- Worms are parasitic in nature and hence create different problems if inside the human body.
- The types of worms that have been found in tap water are midge larvae, flatworms, roundworms and rotifers.
- Round worms, hookworm, whipworm and tapeworm are mostly responsible for different type of diseases.

Bacteria

- Bacteria were the first forms of life on Earth. Bacteria are unicellular microorganisms with a simple nucleus.
- Their reproduction occurs through binary fision, which is the splitting of bacterial cell after it reaches certain size.
- They can also multiply outside the body also.
- Bacteria present in water vary from 1 to 4 micron in size.
- Bacteria may be harmful and beneficial also.
- Some bacteria are pathogenic and cause intestinal diseases like cholera, dysentery, typhoid, diarrhoea etc.
- Bacteria spreads in optimum temperature. At low temperature they remain in dormant state and survive for long durations. They die in high temperature above 78 degree.

Classification of Bacteria

According to shape

- **i. Cocci bacteria**:- Cocci are bacteria that are spherical, round or ovoid in shape.
- **ii.Spiral bacteria:-** Spiral bacteria are spiral shaped or curved rods or comma shaped or helical.
- **iii. Bacilli bacteria:-**Bacilli are straight or rod shaped with square or round end bacteria.

According o diseases cause

- **i. Pathogenic Bacteria:-** Pathogenic bacteria have capacity to cause disease.
- **ii. Nonpathogenic Bacteria :-** Nonpathogenic bacteria do not have capacity to cause disease.

Classification of Bacteria

According to method of obtaining nutrition

- **i.Photoautotrophic Bacteria:-**They synthesize their own food from organic matter, light, energy and carbon-dioxide.
- **ii.Chemoautotrophic Bacteria:-**They synthesize their food with the help of energy obtained from chemical sources.
- **iii.Heterotrophic Bacteria:-** They obtain their food from other living organisms, as they cannot synthesize it on their own.
- **iv. Symbiotic Bacteria:-**They obtain nutrition from host organism by offering something in return. They establish a mutual give-and-take relationship with host.

Classification of Bacteria

Based on survival temperature

- **i. Thermophilic Bacteria:** - Those bacteria which can resist high temperature (between 40 to 65°C) are known as Thermophilic bacteria.
- **ii. Mesophilic Bacteria:-** Those which require moderate temperature conditions to survive (between 20 to 40°C) are known as mesophilic bacteria.
- **iii. Psychrophilic bacteria:-** Those which can survive in extremely cold conditions (between 10 to 20°C) are known as psychrophilic bacteria.

Examination of Water

Purpose / Objective of Water Analysis/ Examination

- To determine various impurities and their concentration
- To design the treatment plant and outline of purification process
- To ascertain the quality of water after treatment
- To ascertain the water quality standard
- To operate the treatment plant
- Quality follows daily and seasonal variation. Therefore, it is necessary to find the quality of water at regular interval.

Type of Water Test

- **Physical Test**
- **Chemical Test**
- **Biological Test**

Physical Examination

- The physical examination of water involves the tests those are carried out to find the physical properties of water.
- Physical examination includes temperature, color, turbidity, taste and odour.

Temperature

- Temperature of water can be measured by digital or ordinary thermometer in ^oC or ^oF or ^oK.
- Temperature plays a vital role in viscosity, surface tension, density, vapor pressure, saturation value of dissolve gases etc.
- The rate of chemical reactions and biological activity are also affected by temperature.
- The temperature of surface water is generally at atmospheric temperature, while that of ground water may be more or less than atmospheric temperature

Colour

- Color produced by 1mg of platinum cobalt in 1 liter of water is 1 unit of platinum cobalt scale.
- Color is also measured in ^{o}Hazen. 1.245 gm of potassium chloroplatinate and 1gm of cobalt chloride dissolved in in 1 liter of distilled water produces 500 ^{o}Hazen.
- The platinum cobalt method is not convenient for field
- Therefore, colourimeter method is used in field.
- In this method, the water sample is compared with special properly calibrated glass colour discs instead of standard coloured water.
- For domestic water 5 unit in platinum cobalt scale is permissible. However, it should not exceed 20 units. Color is not harmful object but it is objectionable.

Turbidity

- Turbidity is the property that resists light to pass through the water.
- Turbidity is created due to presence of suspended matters such as clay, silt, finely divided organic and inorganic matter etc. in water.
- Ground waters are less turbid than the surface water.
- Turbidity is an important consideration because of three major reasons those are aesthetic, filterability and disinfection.
- Turbid water has muddy or cloudy appearance and aesthetically unattractive.

Turbidity

- Filtration of water is more difficult and costly with the increase in turbidity.
- In case of turbidity due to sewage solids, the disinfection may be affected because pathogenic organism may be encased in the particles and protected from the disinfectant.
- It is measured in the terms of ppm (parts per million), mg/l, NTU (Nephelometric Turbidity Unit) or JTU (Jackson Turbidity Unit).

Turbidity

- Drinking water should not have turbidity more than 10 N.T.U.
- Turbidity rod or tape and Jackson turbidity meter are common standard methods to find out the turbidity of water.
- However, nowadays digital turbidity meters are more popular.

Turbidity Rod or Tape

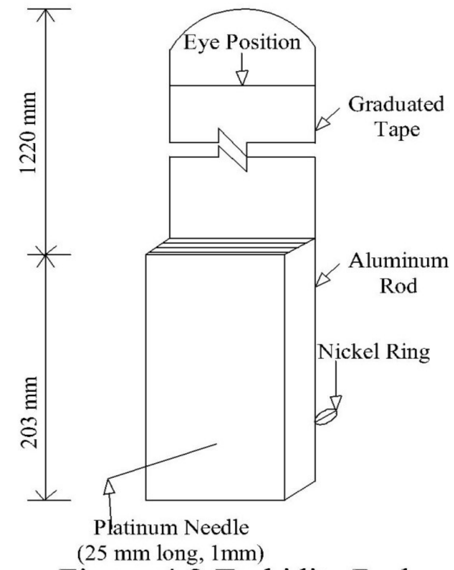


Figure:4.2 Turbidity Rod

Jackson Turbidity Meter

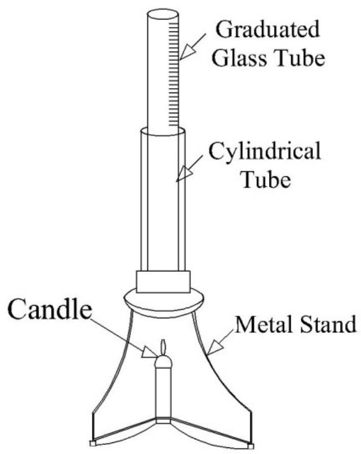


Figure:4.3 Jackson Turbidimeter

Taste and Odour

Flavor threshold number (FTN) can be defined as

$$\mathbf{FTN} = \frac{(\mathbf{A+B})}{\mathbf{A}}$$

Threshold odour number (TON) can be defined as

$$\mathbf{TON} = \frac{(\mathbf{A+B})}{\mathbf{A}}$$

A = volume of water sample in ml

B = volume of odour free water (dilute) added in ml to make water odour/ taste free

- If A was a 100 ml sample and 200 ml of water had to be a dded to not detect the odor , then TON would be 3.

TON = (100 + 200)/ 100

Chemical Examination

- Chemical examination are tests carried out to find the chemical properties of water.
- The chemical examination includes total solids, hardness, pH value, chloride content, residual chlorine etc.

Total Solids

- Total solids in water means the sum of solid in suspension, colloidal and dissolved forms. Total solids (TS) are obtained by evaporating a sample of water to dryness and measuring the mass of the residue.
- $Total\ solids\ (mg/l) or\ ppm$

$$= \frac{weight\ of\ residue\ (mg)\times 1000}{volume\ of\ sample\ water\ (ml)}$$

- $Total\ solids\ (mg/l) = Sudpeded\ solids (mg/l) + Total\ dissolved\ solids\ (mg/l)$

Hardness

- Hardness is measured in mg/liter or ppm. Generally, a hardness of 100 to 150 mg/liter is desirable.
- Hardness of water is determined by EDTA method. In this method, hardness is determined by titrating the water sample against Di –Ethylene diamine tetraacitic acid (EDTA) solution, using Eriocrome black T as indicator which changes the color of water sample from wine red to blue showing the end point of titration.
- $\text{Total hardness (mg/l)} = \frac{\text{ml of EDTA used} \times 1000}{\text{ml of water sample}}$

pH Value

- It is determined by calorimetric method or electrometric method.
- In calorimetric method, the color of sample water is compared with standard color disc or color-coded photograph, after addition of recommended indicator. Comparison may be done with standard colures of the solutions of known pH value.
- In electrometric method, pH can read directly read on scale or by digital display using digital pH meter. The electrometric method is more fast and reliable.

Other Chemical Test

- **Alkalinity** The alkalinity of water can be determined by titrating water sample with the standard N/40 or N/50 H_2SO_4 solution.
- **Chlorides** The amount of chloride present can be found by titrating the sample against Silver Nitrate (N/35.5 $AgNO_3$) using Potassium Dichromate ($K_2Cr_2O_7$) as indicator.
- **Chlorine**. Its content is determined with the help of starch iodide test. Potassium iodide and starch solution are added to the water sample which gives blue color. This sample titrated against N/100 Sodium thyo-sulphate and then quantity of chlorine is determined.

Bacteriological Examination

- Bacteriological examination of water is analysis of water for the presence of microorganism.
- It is important from public health point of view because pathogenic microorganism are responsible for many disease and epidemics.
- Many of the bacteria found in water are derived from air, soil and vegetation.

Bacteriological Examination

- Some of these are able to multiply and continue their existence while the remaining dies out in due course of time.
- The selective medium that promote the growth of particular bacteria is used in the lab to detect the presence of the bacteria. Again, suitable environment is provided by controlling temperature in incubator.

Indicator Organism

- It is difficult to detect pathogenic bacteria and other organisms in a water supply as they are in small numbers.
- Pathogens may be present rarely or at irregular intervals even in sewage effluent or polluted river water.
- The evidence of presence of the pathogenic bacteria in the water is obtained by testing the water for indicator organisms.
- Indicator organisms are numerous in sewage and water that has been contaminated by excreta.
- The number of coli-form organism in human excreta is estimated to lie between 10^{11} to10^{13} per capita per day.

Total Count or Agar Plate Count

- In this method, total number of bacteria presents in a water sample is counted.
- To count bacteria they are grow and developed in particular culture medium agar of gelatin at a temperature of 37°C for 24 hours in incubator or 20°C for 48 hours.
- Under above conditions, bacteria multiply and forms cluster or colonies those are visible to eyes.
- After incubation period, the sample will be taken out from the incubator and colonies of bacteria are counted by means of microscope to give number of bacteria present in water sample.

Multiple Tube Fermentation Technique

- In multiple tube fermentation technique, several number of standard fermentation tubes called Durham tubes are used for test presence of coliform bacteria including E-coli. This test is also known as E- coli test.
- The test is carried out in three phases.
- The results of the examination are reported in terms of the Most Probable Number (MPN).
- This number is based on probability formulas and is an estimate of the mean density of coliforms in the sample.
- MPN tables are based on the assumption of a Poisson distribution.

Membrane Filter (MF) Technique

- The Membrane Filter (MF) Technique was introduced in the late 1950's as an alternative to the MTF.
- In the MF test, a known volume of water sample is passed through a sterile membrane filter having pore size 0.45 µm.
- Bacteria are retained on the filter, as they are of larger than the size of the pores of the membrane filter.
- The membrane filter containing bacteria is then placed in a plate containing M-Endo as nutrient.
- After incubation of the plate containing membrane filter at 37°C for 24 hours, the colonies formed on the surface of the filter can be counted with a low power (10-15 magnifications) binocular or wide-field dissecting microscope or other optical device.

Water Related Disease

- The disease that are spread by contaminated water or by a lack of water for hygiene are known as water related disease.
- In developing countries, large portion of the population are often dependent on untreated water for drinking purposes.
- An estimated 80% of all diseases and over one-third of death in developing countries are due to the consumption of contaminated water.
- Again, one-tenth of each person's productive time is give up to water-related diseases.
- Studies have shown that improving the quality of water supply and sanitation significantly reduces morbidity

Water Borne Disease

- Waterborne diseases are caused due to consumption of the drinking water contaminated by human or animal excreta that contain pathogenic microorganisms or chemical impurities.
- They are also known as water quality disease.
- The major water borne diseases are cholera, typhoid, paratyphoid, diarrhoea, dysentery etc.

Water Washed Disease

- Water washed diseases are also called water hygiene disease.
- Theses diseases are developed due to poor sanitation.
- Poor sanitation may be due to lack of awareness or due to scarcity of water for proper hygiene.
- The major water washed diseases includes trachoma, conjunctives of eyes, scabies, leprosy, tuberculosis, whooping cough, tetanus, and diphtheria.

Water Based Disease

- Water based or water contact diseases are due to contact with dirty water.
- They are transmitted through aquatic animals that spend part of their life cycle in the water and another part as parasites of animals.
- Water based diseases include guinea worm (dracunculiasis), paragonimiasis, lung flukes, clonorchiasis, and schistosomiasis (bilharzia)

Water Vector Disease

- Water vector diseases are transmitted through biting of mosquitoes etc., those are developed near water bodies.
- Vectors like mosquitoes transfers parasites (virus, bacteria, protozoa, worms) in human body.
- Common diseases of this group are malaria, yellow fever, filariasis.etc.

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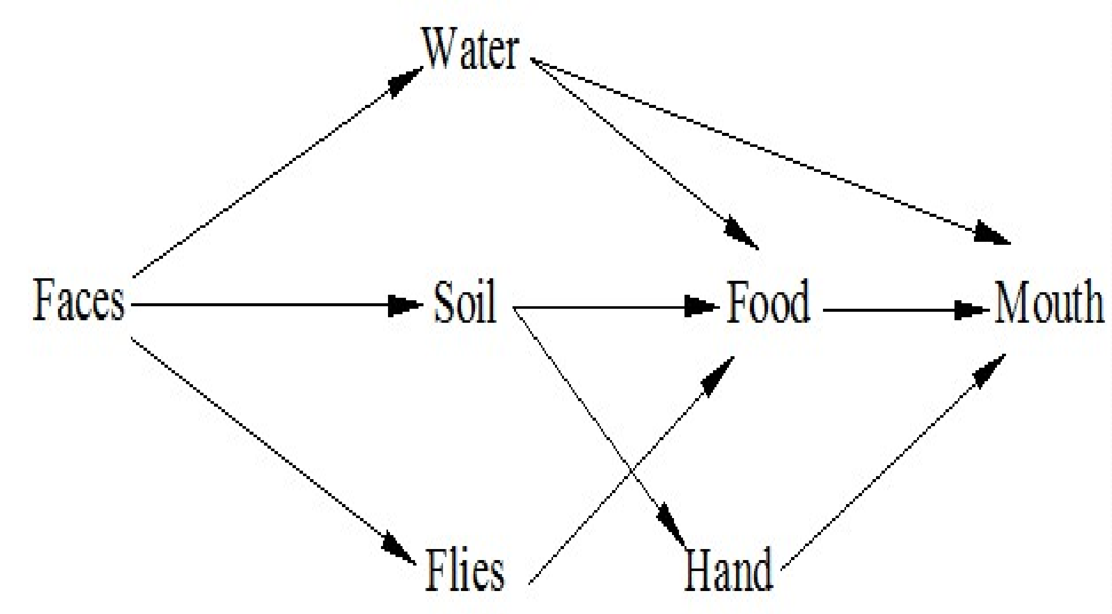
Transmission Routes



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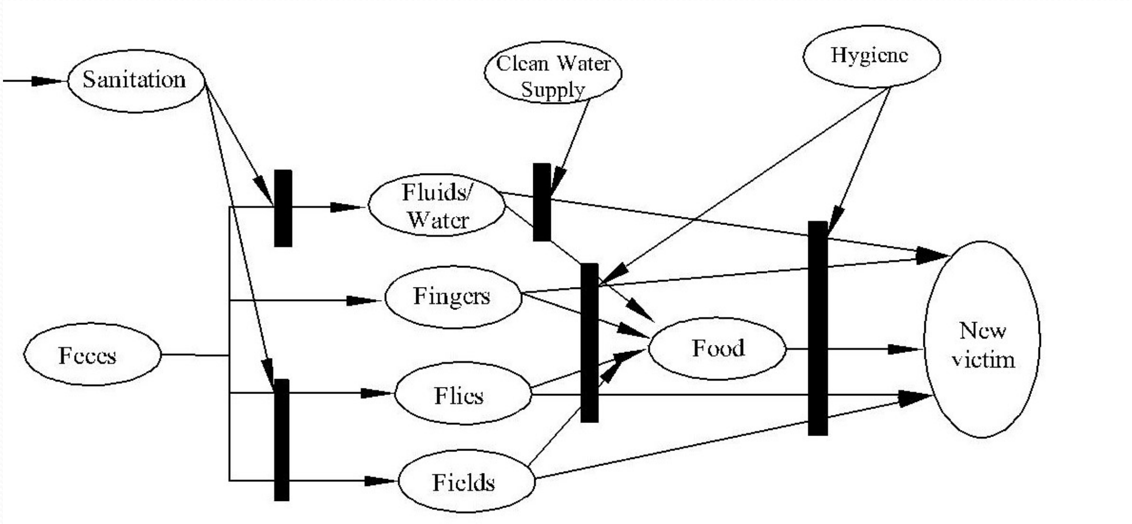
Transmission Routes with Preventive Measures



QUANTITY OF WATER

Q = 100 l/day , P = 4 persons

per capita demand, b = $\frac{100}{4}$ = 25 l/day.

Per Capita Demand of Water

- It is also termed as the rate of demand.
- It is defined as the total annual average daily consumption including all demands of water for a person. It is expressed in liters per capita per day (lpcd).
- In Nepalese context, for rural water supply system per capita demand is taken as 40 – 45 lpcd and for urban water supply system per capita demand is taken as 100-160 lpcd.
- If Q be the quantity of water required per year by community with population P, then per capita demand of water is given as:
- **Per capita demand of water** = $\frac{Q}{P * 365}$ (lpcd)

Base Period

- Base period is the period required ***for survey, design and construction of water supply system***.
- In Nepal 2 years construction period after the detailed design is recommended.
- Usually, base period of **two to three years** is recommended for small scale projects.
- For large project like Melamchi is more.

Base year = Survey year + Base period

Design year = Survey year + Base period + Design period

= Base year + Design period

2021 2024 2044

Base period (3 years)

Design period (20 years)

Survey year Base year Design year

Base Year

- After the completion of the water supply system, water is delivered to the community.
- The year in which the water is delivered to the community is called the base year.

Base year = Survey year + Base Period

Design Period

- Design period is defined as the future period for which a provision is made while planning and designing the water supply programs.
- The number of future years for which the project have to supply water and fulfill the demand of the people is known as design period.
- Typical design period in **Nepal is 15 to 20 years in rural areas** and **25 to 30 years in urban areas.**
- Mostly water works are designed for design period of 20 – 30 years.
- For developing community where population growth rate is high, the population estimation may not be accurate so a low design period is taken. For the developed community where population growth rate is low, high design period can be taken.

Design Year

- The year up to which the water supply project has to supply water and fulfill the water demand of the people is known as design year.

Design Year = Survey year + Base Period + Design Period

Design Year = Base Year + Design Period

Selection Basis

- Population growth rate
- Growth pattern of the area.
- Present and future settlement plan
- Anticipated rate of growth of population, including industrial, commercial developments and migration-immigration
- Potential for development
- Life of pipe and other structural materials considering obsolescence, wear, tears, etc
- Availability of water.
- Availability of fund.
- Expandability aspect.
- Rate of interest on loans
- Availability of materials

Types of Water Demand

- Domestic Demand
- Live stock demand
- Commercial demand
- Municipal demand
- Industrial demand
- Fire demand
- loss and wastage

Domestic Demand

- The quantity of water required **at household level for drinking, bathing, cooking, washing, toilets flushing, gardening, individual air conditioning** etc is called domestic water demand.
- Domestic water demand mainly depends upon the habits, social status, climatic conditions and customs of the people. Domestic water demand is denoted as **liter per capita per day (lpcd)**.

Domestic Demand

S.No.	Population	Per capita demand(lpcd)	Tap status
1	<2000	45	Public tap
2	2000-20000	75-100	Private tap
3	20000-100000	100-150	Private tap
4	>100000	150-200	Private tap

Domestic Demand

However, For design purpose, domestic demand can be calculated as following.

- 110 lpcd for fully plumbed house
- 65 lpcd for partially plumbed house and
- 45 lpcd for people served through public tap and no private connection in rural areas.

- Melamchi- 135lpcd

Livestock Demand

- Quantity of water required for domesticated animal is known as livestock demand.
- Livestock demand is generally not considered for **urban areas.**
- However, it should be considered in **rural area**, as livestock is an important component of the rural economy.
- Livestock demand **should not exceed 20% of the design domestic water demand.** Livestock demand is classified in to three categories.

Livestock Demand

S. No.	Category	Animals	Demand
1	Big animals	cows, buffaloes, horse	45l / animal / day
2	Medium animals	sheep, goats, pig	20 l / animal /day
3	Small animals	duck, hen, parrots	20 l /100 birds/ day

Institutional and Commercial Demand

- Institutional demand refers to the water required for offices, schools and health posts etc.
- Quantity of water required for commercial purposes is known as commercial demand.
- It depends on type of commercial establishment.
- Universities, institution, commercial buildings and commercial centers including office buildings, stores, hotels, shopping centers, health centers, schools etc. comes under this category.
- This demand should be considered **for rural and urban water supply schemes.**

Institutional and Commercial Demand

S.No.	Type	Demand	Remarks
1	Educational institution (school/campus)	10 lpcd	Day school
		65 lpcd	Boarders
2	Hospital	500 l / bed / day	With bed
		2500 l/day	Without bed example health centers
3	Hotel	200 l /bed /day	with bed(Lodge)
		500-1000 l/ day	Without bed (restaurants)
4	Offices	500-1000 l/ day	Depends on public mobility

Municipal/Public Demand

- The quantity of water required for public utility purpose like **street washing, sewer cleaning, gardens, public parks, fountains etc.** is known as municipal demand.
- This demand is considered in **urban water supply projects** only. To meet this demand **5% to 10% of total demand** is added at the time of design.

Municipal/Public Demand

S.No.	Item	Water demand
1	Street washing	1 to 1.5 liter / m^2 / day
2	Sewer cleaning	4 to 5 liter / person / day
3	Parks	1.4 liter / m^2 /day

Industrial Demand

- Quantity of water required for various industries is known as industrial demand.
- The water required in the industries mainly depends on the type of industries existing in the city.
- Industrial demand is taken **20% to 25% of total demand in urban areas** and **in not calculated in rural areas.**

Fire Demand

- Fire may take place due to faulty electric wires by short circuiting, bursting of LPG cylinder or other cooking stoves, fire catching materials, explosions, bad intension of criminal people or any other unforeseen mis-happenings or accidents.
- Water required for firefighting is usually known as fire demand
- All the big cities have full fire fighting squads.
- During fire break down large quantity of water is required for throwing on fire to extinguish it.

Fire Demand

- Fire hydrants of 15 to 20 cm diameter are normally provided on street corners at suitable intermediate points (100 to 150m apart).
- When fire occurs, fire brigade trucks installed with pumps are rushed to the site.
- They are connected to fire hydrants from where they throw jet of water under very high pressure. There are several empirical formulas to calculate fire demand.

Fire Demand Formulas

- National Board of Fire Water Under Writer's Formulas: Q = $4637\sqrt{P}\,(1 - 0.01\sqrt{P})$
- Freeman's Formula: Q = $1136\,(\frac{P}{5} + 10)$
- Kuichling's Formula: Q = $3182\sqrt{P}$
- Buston Formula : Q = $5663\sqrt{P}$
- DWSS Formula

Fire Demand Formulas

- National Board of Fire Water Under Writer's Formula

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

- Freeman's Formula

$$Q = 1136(P/5 + 10)$$

- Kuichling's Formula

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

- Buston Formula

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

Where, Q= the quantity of water required to meet fire demand in liters per minute.

P=population in thousands.

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DWSS Formula

$$Q = 100 \times P^{0.5}$$

Where,

Q= the quantity of water required to meet fire demand in kiloliters per day.

P= is the population of the service area in thousands.

If it results more than 1 liter per capita per day, for small cities and towns 1 liter per capita per day can be adopted as fire fighting demand.

Only one third of this volume should be added as fire demand storage while determining the capacity of the service reservoir.

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Loss and Wastage

- While estimating the total quantity of water of a town or community, an allowance of **15% of total quantity of water** is made to compensate for losses and wastage of water because all the water, which goes in the distribution pipes, do not accounted in metering system of consumers due to following reasons.
  - Leakage and over flow from service reservoirs
  - Losses due to defective pipe joints, cracked and broken pipes, faulty valves and fittings
  - Leakage and losses on consumers premises when they get un metered water supply
  - Under registration of supply meters
  - Losses from consumers when they keep open taps of public taps even when they are not using the water and allow the continuous wastage of water
  - Losses due to unauthorized and illegal connections

Total water demand

Total water demand= Domestic water Demand +Live stock demand +Commercial demand+ Municipal demand+ Industrial demand+ Fire demand+ loss and wastage

$TD = DD+LD+CD+MD+ID+FD+LW$

Population Forecast

- **Factors Affecting Population Growth**
  - a)Birth, b)Death,
  - c)Migration, d)Immigration
- In Nepal, illiteracy, poverty, early marriage, poly gamy, religious factor, open boarder, agriculture as main occupation and desires of having son.
- Other some factors that increase the population of urban area are transportation facilities, job opportunity, presence of institutions and economic activities.

Methods of Population Forecast

i. Arithmetical increase method
ii. Geometrical increase method
iii. Incremental increase method
iv. Decrease rate of growth method
v. Simple graph method
vi. Comparative graph method
vii. The master plan method

Arithmetical increase method

$$P_n = P_o + nI$$

Where,

- P_n = future population at the end of n decade
- P_o = Last known population/ present population
- n = No. of decades
- I = average increment for a decade

- This method gives low results and it is to be adopted for large cities which have practically reached their maximum development.

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Geometrical Increase Method

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

Where,

- P = population at present or Last known Population
- G = average percentage of growth of 'n' decades

- This method usually gives **higher results** as compared to **arithmetical increase method.**
- The geometrical increase method is generally considered **suitable for old cities which are not undergoing further development.**

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Incremental Increase Method

$$P_n = P + nI + n(n+1)R/2$$

- R = average incremental increase
- The results obtained is **between** arithmetical increase method and the geometrical increase method and hence the results given by this method are considered **quite satisfactory.**

Decrease Rate of Growth Method

- $P_n = P_o \left(1+\frac{Gn-1D}{100}\right)\left(1+\frac{Gn-2D}{100}\right)\left(1+\frac{Gn-3D}{100}\right)\left(1+\frac{Gn-4D}{100}\right).....\left(1+\frac{Gn-nD}{100}\right)$
- Where, Gn = Percentage increase in population at last known decade
- D = average decrease in percent increase in population per decade

This method is considered suitable **for large cities** for which the **population is approaching the saturation limit** and in case where the rate of growth is showing a **downward trend.**

Variation in Demand of Water

- The rate of demand of water does not remains constant but it varies with the season or month of the year, with the days of the week and with the hours of the day.
- These variations in the rate of demand of water are termed as:
    i. Seasonal or Monthly Variation
    ii. Daily Variation
    iii. Hourly Variation

Variation in Demand from Average

- Seasonal or monthly variation
    - Maximum Seasonal Demand= Seasonal peak factor × average demand
    - *Seasonal peak factor is 1 for Nepal and 1.4 for India*
- Daily variations
    - Maximum Daily Demand= Daily peak factor × Average Demand
    - *Daily peak factor adopted for Nepal is 1.1 and 1.8 for India*
- Hourly variations
    - Maximum Hourly Demand= Hourly peak factor × Average Demand
    - *Hourly peak factor adopted for Nepal is 3 and 1.5 for India.*
- **Peak Demand and Peak Factor**
    - Peak factor= Seasonal peak factor * Daily peak factor * Hourly peak factor
    - Peak factor of **2 to 4** is adopted in Nepal for **continuous system of supply** and **4 to 6** for **intermittent system of supply.**
    - $Q_{max} = \text{Peak factor} \times Q_{average}$

Effects of Variations in Design

Source of Water Supply

The source of water supply should have sufficient capacity to meet the maximum daily demand if impounded reservoirs are not used.

Transmission Lines

Transmission lines should have capacity to carry maximum daily demand of water.

Distribution Lines

Main lines carrying water from the distribution reservoir to distribution system should be designed to carry maximum hourly demand of maximum daily demand and fire demand.

Effects of Variations in Design

Pumps

Pumps should be designed for two to three times of maximum daily demand of water because the should have capacity for electricity cutoff also. If pumps are not operated for 24 hours, then the design rate of pumps should be multiplied by the ratio of 24 hours to the number of hours for that the pumps are in operation.

Treatment Plant Units

The treatment plant units should be designed for the maximum daily demand and reserve for break down and repairs.

Distribution Pipes

The Distribution pipes should be designed to full fill peak demand and fire demand.

Service Reservoir

Service reservoir should be designed to store water for hourly fluctuation, emergency reserve, fire demand and demand may be required at the time of maintenance.

Factors Affecting Demand of Water

- Size of Town or City
- Standard of Living
- Climatic Condition
- Industrial and Commercial Activities
- Quality of Water
- Pressure in Pipe Line
- System of Supply
- System of Sanitation
- Metering
- Cost of Water
- Age of Community
- Efficiency of Water Works Administration

INTAKES

Introduction

- In every water supply system, there is need to collect water from the source
- The main function of the intakes is to collect water from source and then discharge water by means of pumps or directly under gravity to supply line.
- Intakes are structural device to draw water from source and built at/near water source.
- Intake structure should have sufficient factor of safety against external forces such as heavy currents, water pressure, wave action, wind, floating materials, submerged bodies, landslides, ice pressure etc.
- They should have sufficient self-weight so that it does not float by up thrust of water and must be watertight.

Components of Intakes

- In general, an intake consists conduits, screens, valves and housing.
- Conduits or pipes are needed to convey water.
- In conduits, there must be screen at inlet end to stop large objects from entering in intake chamber.
- In each conduit, there must be provision of valves to regulate the flow of water.
- A housing and structure is needed to support conduits, valve operation, pumps etc. and to permit withdrawal of water from source.
- Housing and structure may be constructed from stone masonry, brick masonry, PCC or RCC and concrete blocks.

Site Selection of an Intake

- Intake site should be selected where water quality is good. This reduces the treatment cost. -up stream of city before sewage and industrial waste disposal.
- Quantity of water is sufficient throughout the year
- Intake site should be safe from landslides and other external forces that can damage intake.
- Intake site should be located near the community or treatment plant to reduce cost of transmission of water.
- There should not be heavy current of water
- Intake should not be on the way of navigation channel Where there is no alternative than navigation channel should be reported by piles.

Site Selection

- The intake should be on good and strong foundation.
- There should be sufficient space for future expansion.
- In the case of a meandering river, the intake should not be located on the curves. However, if the intake is to be located on the curve, it should be located on the concave bank (outer bank).
- The intake site should remain easily accessible during floods and should not get flooded. The flood water should not be concentrated in the vicinity of the intake.

Types of Intake

- Intakes are classified under following three heads.
- **Based on level of top and water level**
  - Submerged intake
  - Exposed intake
- **Based on level of water retention in housing**
  - Wet intake
  - Dry intake
- **Based on source**
  - River intake
  - Reservoir intake
  - Lake intake
  - Canal intake
  - Spring intake
  - Stream intake

Water Treatment

Water available in various sources cannot be directly used for several purposes as it contains various types of impurities.

The water treatment is required to make water suitable for its intended use by removing impurities contained up to levels prescribed in standards.

In general, ground water requires less treatment than surface water because surface water is exposed to more contaminants.

Water Treatment Process

S.No.	Name of Unit	Objective
1	Screening	To remove large suspended and floating matters
2	Aeration	To remove taste, odour, dissolve gases, iron, manganese etc.
3	Plain sedimentation	To remove suspended impurities such as silt, clay, sand etc.
4	Sedimentation with Coagulation	To remove fine suspended and colloidal matter
5	Filtration	To remove microorganism, very fine suspended and colloidal matter
6	Disinfection	To remove pathogenic microorganism
7	De-chlorination	To remove excess chlorine
8	Softening	To remove hardness of water
9	Miscellaneous treatment plants	To remove dissolved metals and gases as indicated by water test or analysis

Screening

- Water derived from surfaces source may contain large suspended as well as floating matters that may be debris such as sticks, branches, dead animals, leaves, etc.
- If they are not removed, they may clog pipes, damage pumps, form unsightly scum and sludge in sedimentation tank.
- Screens are fixed in the intake works and at the entrance of treatment plant to remove large suspended as well as floating matters.
- Screening is a process of removing large suspended and floated objects by passing water through screens.
- Screens acts as protective device for other treatment plants.

Types of Screens

Following are types of screens.

- Bar screen
  - Coarse screen
  - Medium screen
- Fine screen

Bar Screen

- Bar screen are placed in front of fine screens to intercept larger floating and suspended materials of size greater than size of spacing between two bars.
- They are mostly in the form of bar grill of rectangular or circular shape.
- Generally, circular bars are of 25 mm diameter and rectangular bars are of 10mm x 50mm in size.
- The screens are known as coarse or medium size depending upon the opening space between the bars.
- The screen is called coarse screen if spacing between bars is 50 mm to 150 mm and is called medium screen if spacing between bars is 20 mm to 50 mm.

Bar Screen

- Mostly bars are kept inclined so that they can be cleaned easily and increase flow area of opening.
- Generally, they are placed on a slope 3 to 6 vertical to 1 horizontal.
- The cleaning of inclined bar is done mechanically as well as manually.
- However, sometimes bars are kept vertically. Vertical bars should be cleaned mechanically.

Fine Screen

- Fine screen are used to intercept smaller floating and suspended materials of size lesser than intercepted in coarse screens. Fine screens are generally made of wire mesh.
- They are used at water intake sometimes alone or sometimes subsequent to a bar screen so that fine screen do not begin clogged rapidly.
- Generally, for ground water they are used alone and for surface water with coarse screen.
- There is need of a device to clean fine screen continuously otherwise, they get clogged.
- If fine screens are arranged as endless bonds or drums of material perforated with holes about 6mm diameter, the process is known as automatic straining.

Sedimentation

- Sedimentation is the removal of suspended particles by gravitational settling.
- Sedimentation tanks are designed to reduce the velocity of flow of water so that it permits suspended solids to settle out of the water by gravitational force.

Types of Sedimentation

  - Plain sedimentation
  - Sedimentation with coagulation

Plain Sedimentation

- If suspended particles settle down due to force of gravity only and no chemicals are added, this type of sedimentation is called plain sedimentation.

Types of Sedimentation Tanks

- Depending upon the method of operation
  - Fill and Draw type sedimentation tanks
  - Continuous flow type sedimentation tanks
- Depending upon the direction of flow
  - Horizontal flow tanks
  - Vertical flow tanks
- Depending upon the shapes
  - Rectangular tanks
  - Circular tanks
  - Hopper bottom tanks

Equation of Settling Velocities

S. No.	Equation used	Reynolds Number	Diameter
1	Laminar –Stoke's law $V_s = \frac{gd^2(S-1)}{18\nu}$ $V_s = 418(S-1)d^2(3T+70)/100$	Up to1	Up to 0.1mm
2	Transition- Hazen's law $V_s = \sqrt{\frac{4gd}{3C_D}(S-1)}$ $C_D = \frac{24}{R_e} + \frac{3}{\sqrt{R_e}} + 0.34$	>1-1000	0.1 to 1mm
3	Turbulent- Newton's law $V_s = \sqrt{3.33gd(S-1)}$	1000-10000	Greater than 1mm

Design Aspects of Plain Sedimentation Tanks

1. **Velocity of Flow:** For settlement of discrete particles, the particle should reach in the sludge zone before water leaves the tank. It is generally adopted in the range of 15cm to 30cm per minute.

2. **Capacity of Tank:** Capacity or volume of tank is calculated by detention period and rate of discharge. The capacity of tank is calculated by

$$V = Q \times T$$

Detention Period: Detention period is the theoretical time taken by a particle of water to pass between inlet and outlet of a sedimentation tank. The detention period is found to vary from 3 to 8 hours.

$$\text{Detention period (T)} = \frac{V}{Q} = \frac{LBH}{Q}$$

$$\text{Detention period (T)} = \frac{H}{SOR} = \frac{H}{Vs}$$

Surface Overflow Rate(SOR)

- Quantity of water passing per hour per unit area is known as surface overflow rate or simply overflows rate or surface loading.
- It is known that the settlement of a particle does not depend on the depth of tank and depends upon the surface area of the tank.
- For design of sedimentation tank surface overflow rate is taken in the range of 15 to 30 $m^3/day/m^2$

Inlet and Outlet Arrangements

- The inlet is a device provided to distribute the water inside a tank, and the outlet is a device provided to collect outgoing water.
- These arrangements should be properly designed and located in such a way that they do not cause any obstruction or disturbance to the flowing water.

Design criteria adopted in Nepal

S.N.	Parameters	Value
1	Detention Time	1-3 hr
2	Surface Overflow Rate	0.625-1.25 $m^3/m^2/h$ (0.625-1.25 m/h)
3	Water Depth	1.5-2 m
4	L/B ratio for rectangular tank	3-8
5	Sludge Zone depth	0.3-1m (as per cleaning interval)
6	Free Board	0.25m
7	Bottom Slope	2-5 %
8	Horizontal flow velocity	0.4cm/s
9.	Weir loading rate	4-12 $m^3/m/.h$

Sedimentation with Coagulation

- Fine suspended particles and colloidal impurities are not removed by plain sedimentation.
- Particle of 0.06mm size requires 10 hours to settle in PST and 0.002 mm particle will require 4 days for settling.
- This settling time is unfeasible from technical as well as economical aspects.
- Again, colloidal particles being charged particles and being in continuous motion do not settle in plain sedimentation.
- Therefore, we need certain chemicals to add in the water to remove such impurities, which are not removed by plain sedimentation. These chemicals are known as coagulants.

Common Coagulants

- The chemicals those when added to water makes an insoluble, gelatinous, flocculent precipitation and used to settle fine suspended and colloidal particles from raw water in the process of sedimentation with coagulation are known as coagulants.
- Following are common coagulants
  - Aluminum sulphate or alum
  - Iron salts
  - Ferrous sulphate and lime
  - Ferric Chloride
  - Chlorinated copperas
  - Sodium aluminate
  - Polyelectrolytes

Effective pH range for different coagulants

S.No.	Coagulant	Chemical formula	pH Range
1	Aluminum sulphates	$[Al_2(SO_4)_3.18H_2O]$	6.5-8.5
2	Chlorinated copperas	$FeSO_4.7H_2O + Cl_2$	3-9
3	Ferric chloride	$FeCl_3$	3.5-6.5 and >8.5
4	Ferrous sulphate	$FeSO_4.7H_2O$	>8.5
5	Sodium aluminate	$Na_2Al_2O_4$	5.5-8.5

Process of Sedimentation with Coagulation

- Sedimentation with coagulation involves following four operations
  - Feeding of the coagulants
  - Mixing of the coagulants
  - Flocculation
  - Sedimentation
- It can be divided in three operations also. The first operation is coagulation process that involves feeding and mixing of coagulants in water. The next is flocculation process that involves agitating of water with coagulants for 30 to 40 minutes. At last, sedimentation that involves clarifying of precipitate. The detention time required for sedimentation is 2 to 3 hours.

Filtration

- Sedimentation and sedimentation with coagulation removes large proportion of suspended as well as colloidal particles those have specific gravity more than water.
- There are some particles those have specific gravity less than or equal to water that cannot be settled in sedimentation process.
- For removing such particles, bacteria, taste, odor other operation is needed.
- The process of passing the water through beds of sand or other granular materials is known as filtration.
- Filters are used to remove bacteria, colour, taste, odours and to produce clear and sparkling water.

Theory of Filtration

- **Mechanical Straining**
- **Sedimentation and Adsorption**
- **Biological Action**
- **Electrolytic Action**

Types of Filter

- Slow sand filter
- Rapid sand filter
- Pressure filter

Slow sand filter

- Slow sand filters are the initial type of filters introduced in 1829 in England.
- The rate of filtration through slow sand filters is very slow (less than 1: 20) in comparison to other filters
- They are costly to install, as they need large area and large quantity of sand in comparison to other filters
- They are expensive to operate, as they need laborious methods to clean them. Slow sand filters are best suited when land, labour and sand are available at low cost.
- The water having low turbidity (less than 20 N.T.U) can be directly feed to slow sand filter without any pretreatment. The water having high turbidity needs plain sedimentation

Rapid Sand Filter

- Requirement of more land and sand led to find new ideas to increase rate of filtration that can be achieved by increase size of filter media OR pass water under pressure.
- Rapid sand filters evolved at the end of the 19th century in the United States and quickly gained popularity.
- Rapid sand filter had replaced the slow sand filters in water treatment works for municipalities because of high rate of filtration ranging from 3000 to 6000 $l/m^2/hour$ and smaller area of filter required.
- The raw water needs pretreatment from sedimentation with coagulation in rapid sand filters and needs chlorination as subsequent treatment.

Pressures filter

- Pressure filter is type of rapid sand filter in a closed watertight cylinder.
- In which water passes through the sand bed under pressure of 3 to 7 kg/cm^2 and developed by pumping.
- The operation of the pressure filter is similar to rapid sand filter, except that the coagulated water is directly applied to the filter without mixing and flocculation.
- These filters are used for industrial plants.
- However, these are not economical on large scale. Pressure filters may be vertical pressure filter and horizontal pressure filter.
- The rate of filtration is 6000 to 12000 $l/m^2/day$.

S.N.	Item	Slow Sand Filter	Rapid Sand Filter
1	Area	Needs very large area	Needs small area
2	Quantity of sand	More sand is required	Less sand is required
3	Filtration Rate	100 to 200 $l/m^2/hour$	3000 to 6000 $l/m^2/hour$
4	Filter media Sand	Effective size 0.25-0.35mm Uniformity coefficient 2 to 3 Depth 90 to 110cm	Effective size 0.35-0.6mm Uniformity coefficient 1.2 to 1.7 Depth 75cm
5	Base Material Gravel	Size 3 to 65mm Depth 30 to 75cm	Size 3 to 40mm Depth 60 to 90cm
6	Coagulation	Not required	Essential

S.N.	Item	Slow Sand Filter	Rapid Sand Filter
7	Size of one unit	Up to $180m^2$	$10m^2$ to $50m^2$
8	Loss of head	15 cm initially to 1m final	30cm initial to 2m final
9	Supervision	No skilled supervision is Required	Skilled supervision is Required
10	Cleaning of Filter	Scraping of 2-3cm sand from upper layer, Cleaning interval 1 to 2 months.	Back wash with clean water under pressure, cleaning interval 1 to 2 day
11	Flexibility on operation	Not possible	Possible
12	Amount of wash water	0.2-0.6% of filtered water	2-4 % of filtered water

S.N.	Item	Slow Sand Filter	Rapid Sand Filter
13	Cost of unit	Costly	Less costly
14	Efficiency	Efficient in bacteria and suspended impurities removal,	Removal colour taste, odour and turbidity are good. However, less removal of bacteria.
15	Quality of raw water	Without pretreatment or after plain sedimentation	Treatments with coagulation necessary
16	Penetration of suspended materials	Superficial	Deep
18	Supplementary treatment of water	Chlorination	Chlorination

Disinfection of Water

- Slow sand filter can remove, 99% pathogenic bacteria.
- However, this percentage is less in case of rapid gravity filter.
- Therefore, in order to neutralize the effect of remaining organisms, the water is passed through disinfection process.
- The killing of harmful bacteria is done with the help of chemicals or substances those are called disinfectant, and the process is called disinfection.

Requirements of Good Disinfectant

- The disinfectant should be able to remove all pathogenic organisms with in contact time
- It should not take long time for killing pathogens.
- It should be cheap and easily available.
- The operation and handling of disinfectant should not be complicated.
- The concentration should be determined by simply and quickly.
- The water should not become toxic or objectionable after addition of disinfectant.
- Residual amount of disinfectant should be there and should be safe to be left in water to prevent water from further contamination.

Methods of Disinfection

- **Physical Methods**
  - Boiling
  - Ultraviolet Rays
  - Sunlight
- **Chemical Methods**
  - Chlorination
  - Bromine treatment
  - Iodine treatment
  - Potassium Permanganate treatment
  - Ozone treatment
  - Excess Lime Treatment
  - Silver treatment

Chlorine Demand

- Chlorine and chlorine compounds first reacts with organic as well as inorganic impurities in water due to their oxidation power.
- After competition of oxidation the remaining chlorine starts to killing pathogenic microorganism.
- The amount of chlorine required for oxidation of organic and inorganic impurities as well as killing of pathogens is known as chlorine demand.
- Chlorine demand is defined as the difference between the amount of chlorine added to the amount of chlorine available at the end of contact period (residual chlorine).

Dose of Chlorine

- The quantity of chlorine required to be added to water that leaves required residual chlorine (generally 0.2mg/l) after contact period is known as dose of chlorine.
- To find chlorine dose in lab, different doses of chlorine is added in equal volume of water sample and tested after contact period of 10 minutes.
- The dose that leaves required residual chlorine after contact period is taken as dose of chlorine for that water sample.

Chlorine Dose = Chlorine Demand + Residual Chlorine

Dose of Chlorine

- **Chlorine dose depends upon the following factors.**
  - Time of contact
  - Nature and concentration of organism
  - pH value
  - Temperature
  - Variable conditions and others

Types of Chlorine

Chlorine is introduced into the water in solid, liquid and gaseous forms. Chlorine is used in the form of free chlorine or its compounds. The major chlorine compounds used for disinfection are as follows.

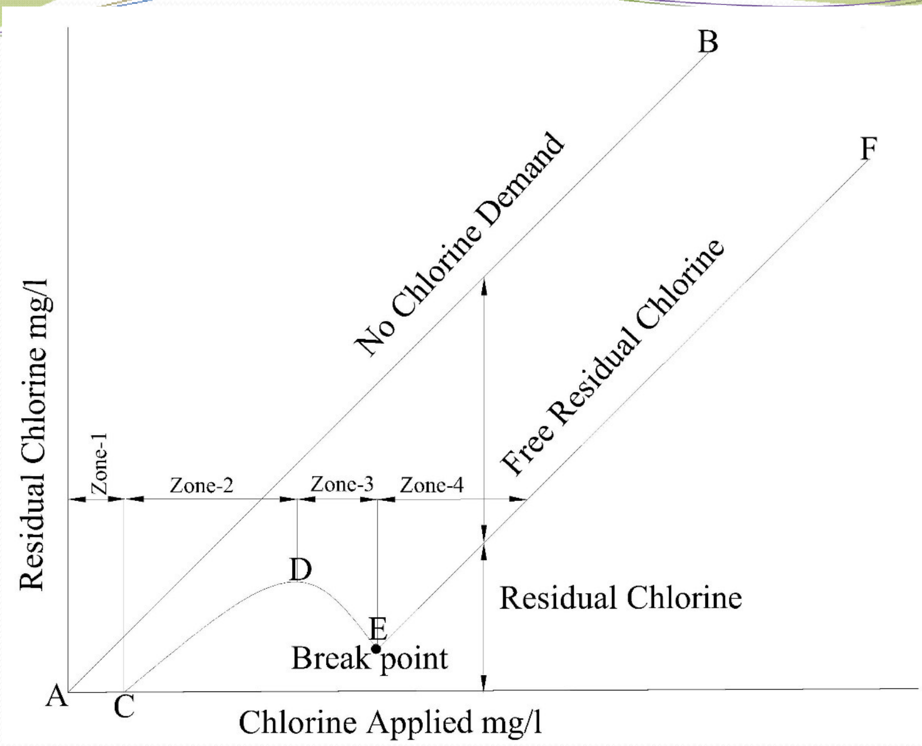
- Bleaching powder
- Chloramines
- Chlorine gas or liquid chlorine
- Chlorine dioxide gas

Forms of Chlorination

- Plain Chlorination
- Pre- chlorination
- Post Chlorination
- Double or Multiple Chlorination
- Break Point Chlorination
- Super Chlorination
- De-chlorination
- Re-chlorination

Break Point Chlorination

- When chlorine is added to water the following two actions takes place.
  - It kills bacteria present in water, thus disinfection is accomplished.
  - It oxidizes the organic matter present in water i.e. chlorine demand is satisfied
  - If water has no chlorine demand, any chlorine added to such water will appear as residual chlorine and hence relation between applied and residual chlorine will be as indicated by line AB having slope of 450.
  - However, water generally has some chlorine demand hence relation between applied and residual chlorine will be as indicated by curve CDEF.



Break Point Chlorination

- In the beginning, the amount of residual chlorine is less in as shown in zone 1, because it is expended to oxidize reducing agents in water like nitrates, iron, sulphides etc.
- Zone 2 shows increase of residual chlorine in the addition of chlorine to water. In this zone chlorine reacts with compounds such as ammonia etc. and forms chloramines and chloro-derivatives hence residual chlorine is obtained in form of combined available chlorine and is also recorded as residual chlorine along with free available chlorine.
- Therefore, with the increase in the applied chlorine, the residual chlorine also increase in portion CD of the curve and it reaches at the maximum residual chlorine.

Break Point Chlorination

- After point D further addition of chlorine suddenly drops the amount of residual chlorine as shown in zone 3 and curve DE. This sudden decrease is due to fact that the increased concentration of applied chlorine oxidize organic matter, chloramines and chloro-derivatives.
- Again, after point E further addition of chlorine increases the residual chlorine in water along EF having slope of 45^{o}, because entire applied chlorine a will appear as residual chlorine.
- The applied chlorine that results sudden increase of residual chlorine is called ***break point chlorine***.
- At this point the residual chlorine has its minimum value that is associated to true residual free chlorine since chlorine demand has satisfied.
- If applied dose is equal to break point chlorine dose than it is known as ***break point chlorination.***

Hardness Removal

Removal of Temporary Hardness

- Boiling
- Lime treatment

Removal of Permanent Hardness

- Lime soda process
- Zeolite method
- Deionization method

Aeration

- To remove tastes and odor caused by gases due to organic decomposition.
- To increase the dissolved oxygen content of water.
- To remove hydrogen sulphide in water and therefore removes the odor due to hydrogen sulphide.
- To decrease the carbon dioxide content of water and therefore reduces corrosiveness of water and increase the pH value
- To covert iron and manganese from their soluble form to insoluble form, so that iron and manganese can be participated and removed.
- To kill bacteria to some extent
- To mix required chemical with water

Methods of Aeration/Aerator

Aeration is done by following main types of aerators.

- Free Fall Aerators
  - Cascade aerator
  - Inclined aerator
  - Slat tray aerator
  - Gravel bed aerator
- Spray Aerators
- Air diffuser Aerators

Water Supply Engineering

RESERVOIRS AND DISTRIBUTION SYSTEM

- After the treatment of water, it is distributed to the target community for domestic, industrial and public uses.
- Water is to be stored temporarily and supplied to the consumers through the network of pipelines called distribution system.
- The distribution system also includes pumps, reservoirs, valve, water meter, pipe fittings, fire hydrants, service connections, instruments for measurement of pressures, flow leak detectors etc.

Systems of Water Supply

Water may be supplied by following two systems.

- Continuous system

This is the best system in which the water is supplied to the consumer during all 24 hours of a day. It is possible when there is adequate quantity of water in the source for the target community.

- Intermittent system

In this system, water is supplied to the consumer during some fixed hours of a day, generally morning and evening time. This system is adopted when adequate water is not available or sufficient pressure is not available. In this system, the whole community is divided into several zones and each zone is supplied water for a fixed hour in a day.

Disadvantage of intermittent system

- The public has to store water for non-supply hours. Public needs to construct or purchase storing devices.
- During the fire break down this system fails to supply the water in non-supply zone that may cause huge damage.
- Due to the surplus storage, the wastage of water becomes more.
- The pipe diameter should be bigger in this system to supply water for the whole day within few hours.
- Again, number of valves and fitting required will be more to separate different zones.

Disadvantage of intermittent system

- During non-supply period, the pressure in the pipe falls below the atmospheric pressure creating partial vacuum, which may promote suction of ground water and sewage.
- During non-supply period, the taps may be left open unknowingly or due to negligence, this may cause wastage of water.
- This system creates difficulty to the public since they have to form a long quee during the supply period and struggle for the collection of water.
- Pipelines are likely to rust faster due to alternate wetting and drying. This increases the maintenance cost.

Disadvantage of intermittent system

- Extra staff will be required to regulate flow in different zones.
- Besides the number of disadvantage, this system is usually adopted in the countries like Nepal due to lack of fund to be invested.
- It should be change to continuous system as soon as possible.
- However, some modification can be made in this system by dividing the city in to zones and supply system in a particular time.

Advantage of intermittent system

- The repair work can be easily done in the non-supply hours.
- The wastage of water due to leakage is low.

Reservoir

- Reservoirs are the tank or device in which water is collected and stored for different purpose.

Types of reservoirs

- According to use
  - Clear water reservoir

  The clear water reservoir is a tank or basin in which clear or treated water is collected and stored after water treatment.

  This is constructed with in treatment plant premises and located below the ground so that treated water from final treatment unit flow under gravity.
  - Distribution reservoir

  The reservoir, which stores the treated water from clear water reservoir for supplying water to distribution system, is called service reservoir or storage reservoir or distribution reservoir.

Distribution reservoir

- The reservoirs in which storage of water is done in order to meet the variation in demand of different hours of a day is called balancing reservoir.
- The reservoirs in which water is stored for the maintenance of the network or the failure of the pump is called break down reservoir.
- The storage tank where quantity of water stored for the fire fighting activity is called fire reservoir.
- However, it is better to achieve all these purpose in same distribution reservoir.
- The distribution reservoir should be located near the distribution area to supply water in shortest time. It also reduces pipe cost as transmission line pipes are of smaller diameter.

According to location

- Surface Reservoirs

Surface reservoirs may be circular or rectangular in shape. They are built at or below ground level and therefore they are called ground reservoir.

- Elevated Reservoirs

They are constructed above the ground level therefore also called overhead reservoirs. These reservoirs may be circular, rectangular, egg shaped, spherical, elliptical etc.

Sizing of reservoirs

- Mass curve method

The mass curve or consumption and yield can be used to determine the reservoir storage capacity.

- Analytical Method

i)When total inflow is more than total outflow, than capacity of balancing reservoir (CBR)

CBR = maximum cumulative sulplus (MCS) + maximum cumulative deficit (MCD) + total demand or total outflow – total supply or total inflow

ii) When total inflow is less than or equal to total out flow

CBR = maximum cumulative sulplus (MCS) + maximum cumulative deficit (MCD)

Methods of Distribution system

- Method of distribution depends upon the topography of the area. Depending upon the method of distribution, water distribution systems are classified as follows.
    - Gravity system
    - Pumping system
    - Dual system

Gravity System

- When the distribution reservoir is located at higher elevation then the target community then the water can be supplied with gravity flow.
- This method is much suitable when the source is river or impounded reservoir at sufficient height than the city.
- Usually pumping of water is not required at any stage of the distribution.
- This method is the most reliable method.

Gravity System

- The design of distribution system pipes is done in such a way that the water head at the consumer tap is exactly similar to the required one and remaining head is lost in frictional and other losses.
- This system also has the minimum leakage since the water flow under the gravity.
- However, in this system water has to be pumped during the firebreak down.

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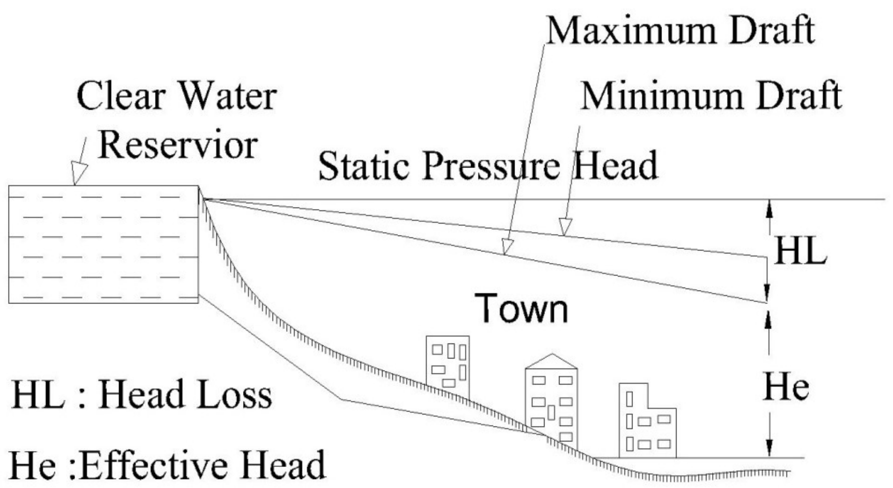

Figure:7.3 Gravity System

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S.N.	Advantage	Disadvantage
1	No energy requirement to operate the system as water is conveyed by gravity.	Not applicable in flat terrain like Terai, where an elevated source of water supply is not available.
2	No pump is required and there are very few moving parts.	Water loss by leakage and wastage is comparatively higher as the system remains under constant pressure.
3	Construction, operation and maintenance are	

Pumping System

- In pumping system, water has to be pumped and then directly send to the consumer.
- The pumps may be used at different speed to meet different demand of water.
- Generally, a number of pumps are established and only some of them are always used.
- Some other pumps are installed for the emergency cases like fire hazard, peak water demand etc.
- This method is suitable if the source is not at higher elevation than the target community.

Pumping System

- However, this system of distribution becomes very expensive for the long term use.
- Moreover, if electric pump are used, the water may be insufficient when the power fails. T
- herefore, commonly diesel pumps are managed for alternative.
- Nowadays solar energy is also used to pump the water.
- This method has no problem of the pressure and maintaining head at the consumer's tap.
- During fires, the water can be pumped in required quantity by the stand by units.

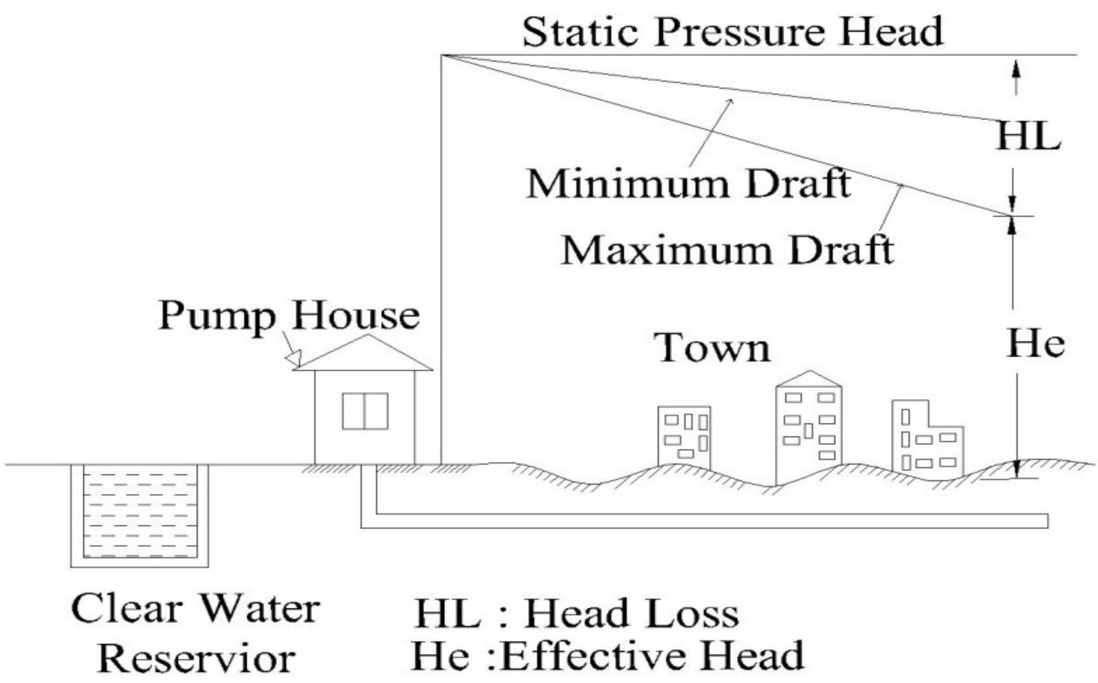

Figure:7.4 Pumping System

S.N.	Advantage	Disadvantage
1	Water can be pumped only when required.	Direct pumping at a uniform rate is not able to meet varying water demand and maintain required pressure under varying rates of consumption.
2	Low water loss due to system leakage.	Breakdown of the system occurs if power fails.
3	Water can be stored during non supply hours.	Maintenances and operation costs are high.
4		Inflow of water through leaks may cause water contamination during non-pumping hours.

Dual System

- The pump is connected to the mains as well as elevated reservoir.
- In this method of distribution, water is collected in the elevated water reservoir and water is supplied from there.
- When the water demand is low water is send directly from the reservoir and when the water demand increased the water is also pumped directly to the public.
- In this case two pumps, one to elevate the water and the other to distribute water, have to be installed.

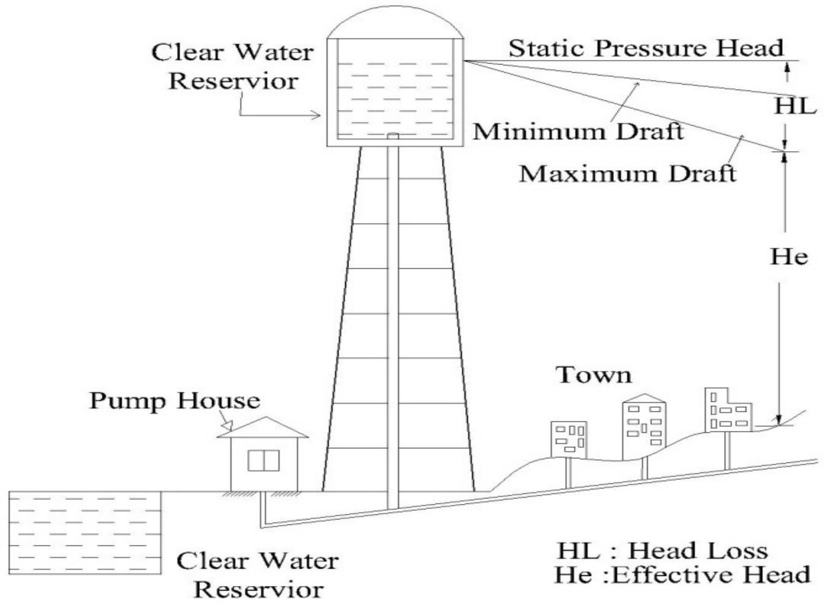

Figure:7.5 Dual System

S.N.	Advantage	Disadvantage
1	The system is more reliable and can manage fluctuation of water demand.	Relatively higher initial cost.
2	The pumps can be operated at rated capacity resulting in higher efficiency and economy of operation.	Comparatively higher loss due to leakage and wastage.
3	Reasonable pressure can be maintained with varying water demand and there is no possibility of inflow of polluted water in the system.	

Layout of the water supply system

Depending upon the layout of various pipes used for distribution of water, following four are major layout of distribution system.

- Dead End or Tree System
- Grid Iron System
- Circular or Ring System
- Radial System

Dead End or Tree System

- This system contains one main line and several service pipes branching form it.
- These sub mains can be connected at the both side of the main line and again other branches start from these sub mains.
- From branches service connections provided for individual buildings.
- The diameter of pipe decreases at every tree branch

Dead End or Tree System

- There are no cross connections between branches and sub-mains.
- Therefore, there are a number of dead ends in this system.
- This method is suitable for the irregular developed towns.
- It is the cheapest method and easy in determination of pipe diameter and valves.
- However, this method can create dead end and maintenance problem.
- This method of distribution system is not effective towards the fire demand.

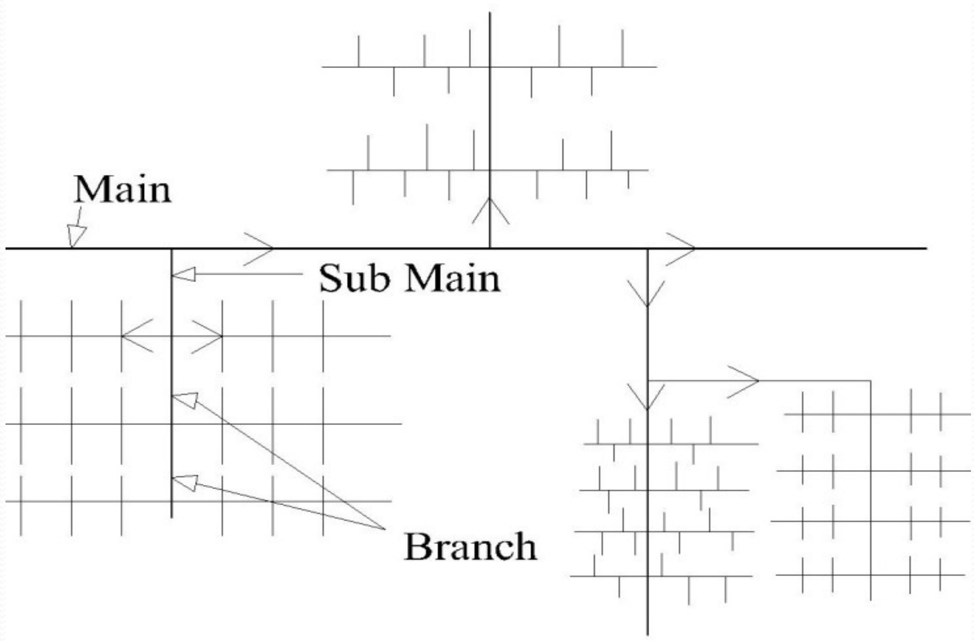

Figure:7.6 Tree/ Dead End System

Grid Iron System

- It is also called reticulated system.
- In this system of layout, the mains, sub-mains and branches are interconnected to each other.
- Main line runs along the major road through the center of area.
- From both side of main line sub mains are taken those are inter connected by branch to the side roads.
- Thus, water will get circulated through the entire distribution system and the disadvantage of the dead end system is eliminated.

Grid Iron System

- The water does not remain stagnant.
- In this system, only less area is affected during repairing works.
- During the firebreak, the water can be diverted towards the affected area from both direction.
- However, the distribution pipe required is longer and number of valves is more that increases overall cost.
- During the maintenance work, several numbers of valves have to be closed.
- This system is most convenient system for rectangular type of settlement with planned development.

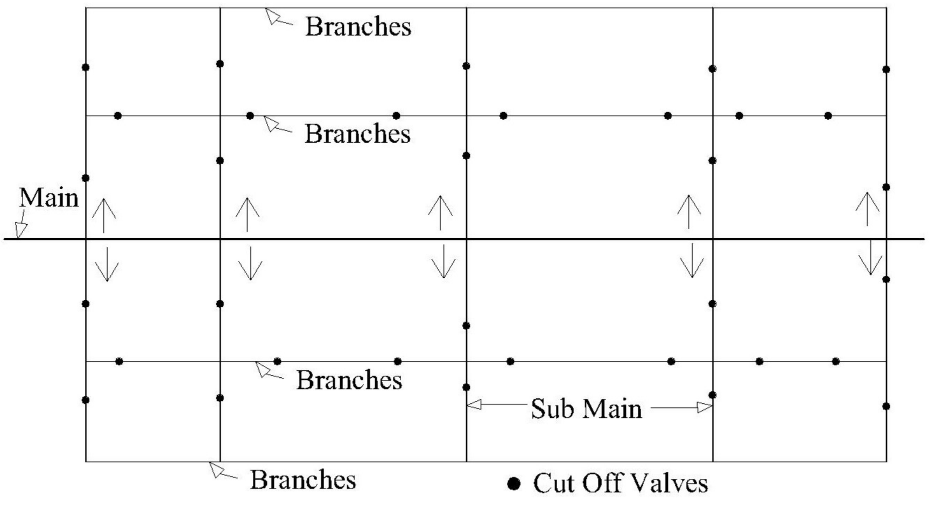

Figure:7.7 Grid Iron System

Circular or Ring System

- This system can be adopted in a well-planned city
- In this system, each locality is divided into numbers of square or circular blocks and the distribution mains are laid around the four sides of the block.
- The branches, sub mains etc, are laid in the inner road.
- In this system, every point of the city receives water form two direction.
- This system is the easier for laying but it involved too many numbers of valves and pipe lengths.
- The advantages and disadvantages are same as that of grid iron system.

Circular or Ring System

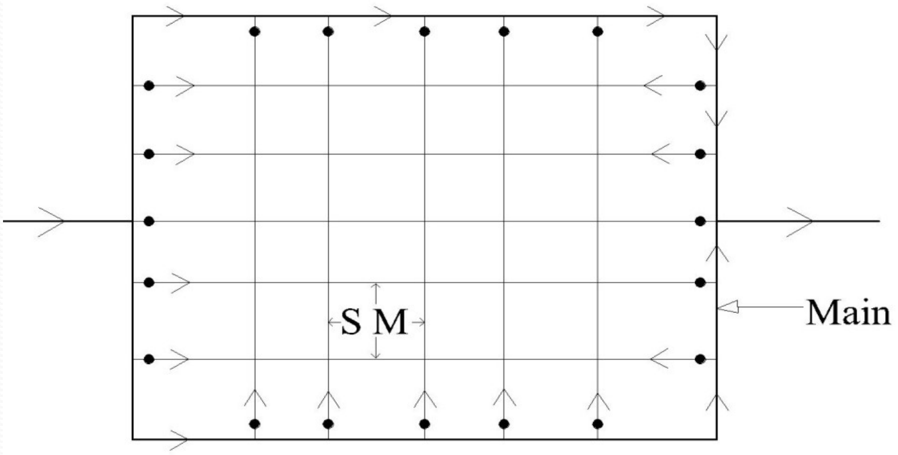

Figure:7.8 Circular Or Ring System

Radial System

- This method can be adopted if the city settlement is radial in nature.
- In this system, the water flows from a central reservoir to the outer periphery.
- The entire city is divided into the various zones and each of the zones has a central reservoir which distributes water in the corresponding zone only.
- This system gives very quick and satisfactory water supply and reliability during the maintenance period.

Radial System

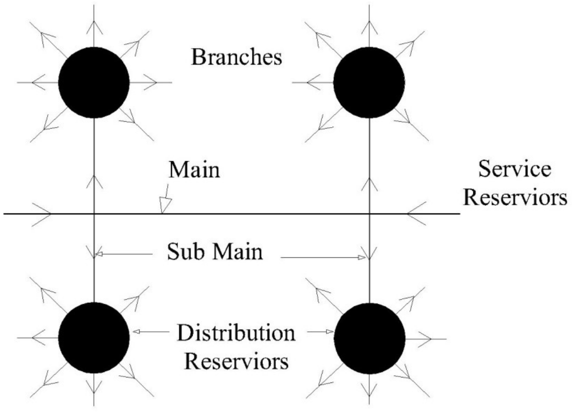

Figure:7.9 Radial System

Design of Distribution System and Design Criteria

- Design of distribution system involves hydraulic and structural design of pipes.
- Hydraulic design means to determine diameter of pipe that can carry required discharge of water under a known pressure difference between inlet and outlet sections.
- To design a distribution system knowledge of pipe hydraulics , design criteria and design steps is necessary.

Pipe Hydraulics

- To determine size of pipe continuity equation and Bernoulli's equation are basic relations that are used.

$$Q = A \times V = \text{constant}$$

$$A_1 \times V_1 = A_2 \times V_2 = \text{constant}$$

$$(\pi\, d^2{}_1/4) \times V_1 = (\pi\, d^2{}_2/4) \times V_2 = \text{constant}$$

$$Z_1 + P_1/\gamma + V^2{}_1/2g = Z_2 + P_2/\gamma + V^2{}_2/2g + H_L$$

$$V = \frac{Q}{\frac{\pi}{4}(d)^2}$$

Formula for friction head loss

$$H_f = \frac{flv^2}{2gd},\ H_f = \frac{flQ^2}{12.1d^5} \text{ Darcy Weisbach Formula}$$

$$H_f = \frac{6.843L}{D^{1.167}}\left(\frac{V}{C}\right)^{1.852} = \frac{10.68L}{d^{4.87}}\left(\frac{Q}{C}\right)^{1.852} \text{ Hazen Williams}$$

$$H_f = \frac{n^2LV^2}{0.157\ D^{4/3}} = \frac{10.294n^2LQ^2}{D^{16/3}} \text{ Mannings}$$

Minor Loss

Losses due to the local disturbances of the flow in the pipes such as changes in cross section, valves, bends, elbows, and similar items are called minor losses.

$$\mathbf{h_f = k\frac{v^2}{2g}}$$

h_f = Minor loss k = Minor loss coefficient

v = Velocity (m/s)

- Following are some minor head losses.
  - Loss of head due to sudden enlargement
  - Loss of head due to sudden contraction
  - Loss of head due to bends
  - Loss of head at entrance
  - Loss of head at exit

Minor Loss

Loss of Head due to Sudden Enlargement $H_e = \frac{(V_1 - V_2)^2}{2g}$

Loss of Head due to Sudden Contraction $H_c = 0.5\frac{V^2}{2g}$

Loss of Head due to Bends $h_b = k\frac{v^2}{2g}$

Loss of Head at the Entrance $H_E = 0.5\frac{V^2}{2g}$

Loss of Head due to Exit $= \frac{V^2}{2g}$

Design Criteria

- Velocity, pipe size, pressure and design discharge are important and mutually linked parameters that should be chosen tactfully to design distribution system.
- For efficient and smoothly operating pipelines these three criteria should be within prescribed limits.

Velocity

- The velocity of flow is most important parameter that should to neither high nor too low.
- Too low velocity will cause sedimentation in pipelines that will cause obstructions in flow and clog pipelines.
- Similarly, too high velocity will increase head loss or loss of energy due to friction.
- Again, it will cause abrasion on interior surface of pipes and that may damage pipes.
- In an average, the velocity of water in the distribution mains should not be less than 0.3 m /sec and not more than 3m/sec.
- Higher velocity is also related with pipe material and its strength.

Pipe size

- Pipes for water distribution are commercially available in various sizes but not all.
- Determination of suitable pipe size depends on water demand, pressure to be maintained and cost.
- Theoretical pipe size calculated by using formulas may not be commercially available size.
- In such case, nearest higher commercially available size should be recommended and head loss and available pressure should be calculated for recommended size.
- In Nepal 15,20,25,32,40,50,65,80,100,125,150, 200,250, 300, 350,400,450,500,600,700,800,900,1000, 1200,1400, 1600,1800,2000,2200,2400,2600,2800,3000 mm are commercially available sizes.

Pressure

- The pressure of flow is another important parameter that should to neither high nor too low.
- If there is too low pressure the water will not be able to reach up to consumers tap at upstairs and requires energy to operate pumps.
- Similarly, too high pressure will cause bursting of normal pipes and demand high rating pressure pipes that will increase project cost.
- Although the water is supplied to the public with greater pressure, a lot of it will be lost in the way of distribution.
- The head losses may occur due to friction in the pipeline, at the reducers at valves, bends, meter etc.
- Therefore, the net head available at the consumer's tap is the head of supply minus all types of losses.

Design discharge

- Design discharge is the maximum discharge that will be carried by pipe section.
- It is based on population to be served by pipe section and other demands in that area.
- Design discharge should consider peak factor also.
- The main line should contain 3 times the average demand of the city.
- The service pipe should have 2 times the average demand of that locality.

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Design Steps

- **Step1- Population Survey**

The population of a community to be served by the proposed water scheme needs to be accurately surveyed. From which population at the end of the design period is estimated.

- **Step2-Engineering Survey**

Engineering survey of the land lying between source and distribution reservoir as well as complete distribution area is accomplished with help of survey equipment's available.

- **Step3-Map preparation**

Detailed maps are prepared showing the positions of roads, streets, existing underground service lines like electricity, telephone, sewer lines, existing water lines etc. if exits.

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Design Steps

- **Step4-Tentative Layout**

A tentative lay is prepared showing source, intake, treatment plant, transmission mains, distribution reservoirs, distribution lines, valves and fittings, fire hydrants etc. Population to be served by each distribution line should be marked being based on step 1.

- **Step4-Calculation of Design Discharge**

Calculate the design discharge that will be carried by each section of distribution pipe based on population to be served by pipe section based on population and other demands. The pipes should be designed to carry peak demand that is 2 to 3 times more than average demand. Mark discharge of each pipe section.

Design Steps

- **Step5-Calculation of Pipe Diameters**

On the basis of discharge assume pipe diameters so that velocity of water flow ranging from 0.6 to 3m/s. Small velocity should be assumed for small diameter pipes and vice versa.

- **Step6-Calculate Head Loss**

Calculate head loss in each section of pipe using Darcy Weisbach or Hazen Williams or Manning's formula major (friction) head loss and other formulas for minor head loss.

Design Steps

- **Step7-Calculate Residual Pressure**

Calculate residual pressure and velocity in each pipe section. If residual pressure and velocity are in permissible range, the design is correct and if not in permissible range change pipe diameter and again start calculation.

If calculated velocity is more or residual head is less than required then increase the pipe diameter.

If calculated velocity is less or residual head is more than required then decrease the pipe diameter.

Conveyance of water.

- The process of carrying water from intake to distribution reservoir via treatment unit (transmission works) and from distribution reservoir to the public (distribution works) is called conveyance of water.
- For the conveyance of water different types of conduits are used like open channel, tunnels, aqueduct, pipeline etc.
- However, due to the convenience of workability, pipes are mostly used for the conveyance of water in distribution works in water supply projects. They also save water from contamination.
- Open channels are used to convey water from intake to treatment plants in few water supply projects.

Pipes

- Pipes are circular conduits that can carry water under pressure.
- Pipes are found in several diameters and of different materials.
- They are made of materials like cast iron, wrought iron, galvanized iron, ductile iron, steel, cement concrete, asbestos cement, timber, clay, copper, HDPE, PPR, and PVC etc.
- Similarly pipe of various diameter are used in same water supply system.

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Pipes

- The main pipe is a larger diameter pipe, sub mains are smaller and branch pipes are the smallest pipes.
- The pipelines used in the houses are the service pipes that are even smaller in diameter.
- Generally, in water supply projects, water is always under pressure in pipes, therefore the pipe material and the fixture should withstand stresses due to the internal pressure of water.
- Similarly, they must withstand vacuum pressure when the pipes are empty and water hammer when the valves are closed and temperature stresses.

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Requirements of Pipe Material

- It should be strong enough to withstand internal and external pressures.
- It should have facility of easy and watertight joints and fittings.
- It should be impervious.
- It should be available in all size range.
- It should be lightweight so that it is easy in transport and erection.
- It should be durable at least up to design period.

Requirements of Pipe Material

- It should be corrosion resistant.
- It should be abrasion resistant.
- It should not react with water to alter its quality.
- Cost of pipes should be less.
- It should be smooth so that frictional resistance or head loss will be low.
- The damaged units should be replaced easily.

Types of pipe

- Cast Iron Pipes
- Galvanized Iron Pipes
- Wrought Iron Pipes
- Ductile Iron Pipes
- Steel Pipes
- Cement Concrete Pipes
- Asbestos Cement Pipes
- Plastic Pipes
  - High Density Polyethylene Pipes
  - PVC Pipe
  - CPVC Pipe
  - Poly Propylene Random (PPR) Pipes

Cast Iron Pipes

- Cast iron pipes are widely used because of their resistivity against corrosion and their longer life up to 100 years.
- CI pipes when laid horizontally are 100% stronger than when laid vertical.
- These pipes are available in 2.5 m to 5.5 m lengths with various diameters.
- These pipes can be joints by the bell and spigot joint, threaded or flanged joints.
- However, the CI pipes are very inconvenient due to the heavy self-weight and brittleness.
- The pipes are coated with hot tar during the manufacturing process so the inner surface is made smooth to reduce the frictional losses.

Galvanized Iron Pipes

- These pipes are galvanized by providing a protective coating of zinc on inner and outer surface of steel pipes or WI pipes, which can resist corrosion better.
- These pipes are convenient to carry, connect with each other and lay on the ground.
- They are joined by screw joints.
- GI pipes are equally strong in with standing the water pressure and head loss is less.
- These pipes are used in house plumbing and small distribution systems.
- Generally,15, 20 and 25 mm pipes are used in house plumbing.
- They are available in 6 m length.
- The life span of these pipes is about 20 years.

Ductile Iron Pipes

- Ductile iron pipe is a pipe made of ductile iron commonly used for potable water transmission and distribution.
- This type of pipe is a development of cast iron pipe.
- DI pipes are manufactured from pig or grey iron.
- However, DI pipes are manufactured from ductile iron that has higher resistance against breakage and high tensile strength.
- Typically, DI pipe is manufactured using centrifugal casting in metal or resin lined molds.
- Protective internal linings and external coatings are applied to ductile iron pipes to reduce corrosion.

Ductile Iron Pipes

- The standard internal lining is cement mortar and standard external coatings include bonded zinc, asphalt or water-based paint.
- In highly corrosive environments, polyethylene encasement may also be used.
- Life expectancy of unprotected ductile iron pipes depends on the corrosiveness of soil present and tends to be shorter where soil is highly corrosive.
- However, a lifespan in excess of 100 years has been estimated for ductile iron pipelines installed using evolved laying practices, including use of properly installed polyethylene encasement.

Steel Pipes

- Steel pipes can withstand more water pressure, hence are used in the main line in the distribution system where pressure is high.
- They also have very high weight, moderate cost, easy to handle and easy to lay.
- However, the major demerit of such pipe is the inefficiency to bear the external load when the pipe is in partial vacuum.
- Similarly, the useful life of the steel pipes is also less about 25 to 50 years.
- Due to the problem in joints, steel pipes are not used in the distribution lines.

Cement Concrete Pipes

- These pipes are either pre cast or cast in situ and also known as Hume pipes.
- Again, they are PCC or RCC pipes depending upon the diameter of pipe and head.
- For heads up to 15 m PCC pipes may be used and for heads up to 60 m RCC pipes are used.
- For heads more than 60m pre-stressed RCC pipes are used.
- Normally concrete pipes are manufactured in the cement: sand: aggregate ratio at 1:2:2.

Cement Concrete Pipes

- The main advantage of using such pipes is that they are non-corrosive and longer life span.
- The maintenance cost of such pipes is almost nil and the joints are very simple.
- However, concrete pipes are inconvenient due to the heavy weight and less resistance towards the shock and impact.
- They are not suitable to provide service connections.
- Therefore they are rarely used in distribution systems.

Polyvinyl Chloride (PVC) Pipes

- It is the white plastic pipe commonly used for plumbing and drainage at household's level. It is developed from combination of plastic and vinyl.
- PVC is a thermoplastic material that is molded into different shapes to create pipes, fittings, valves
- PVC have made it one of the most widely used plastics in the world due to its strength, durability, easy installation, and low cost and had becomes a common replacement for metal piping.
- The main disadvantage of PVC is that it is brittle that can break easily.
- It cannot carry higher temperature more than 60°C.

Poly Propylene Random (PPR) Pipes

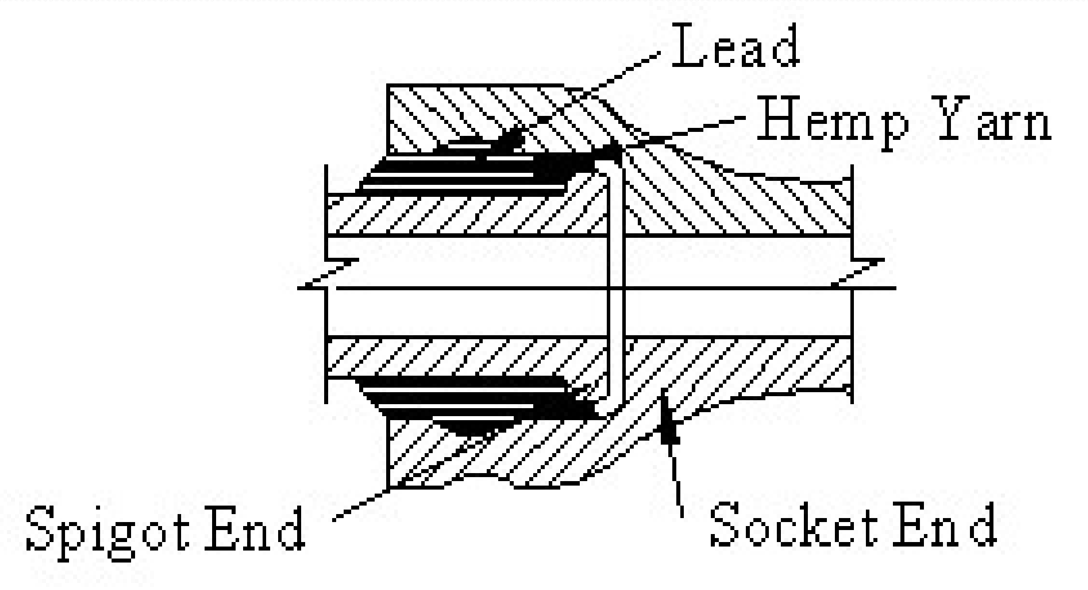
- Poly Propylene Random pipe and fittings are developed in Germany in 1995.
- They are thermoplastic resigns produced by polymerization of propylene with ethylene.
- Presently PPR pipes and fittings are most reliable in plumbing and water supply plants, due to their chemical features and fusion welding, which ensures the a perfect seal tight system.
- They are eco-friendly and recyclable.
- They are applicable for hot and cold waters.

Pipe Joints

- The pipes are available in limited length for ease of handling, placing in position and transportation.
- They are joined together to made the pipeline of required length.
- The joints should be of equal strength as the strength of pipe as joints also have to bear same hydraulic pressure.
- Major type of pipe joints.
  - Spigot and socket joint
  - Flanged joint
  - Collar joint
  - Expansion joint
  - Screwed and socket joint

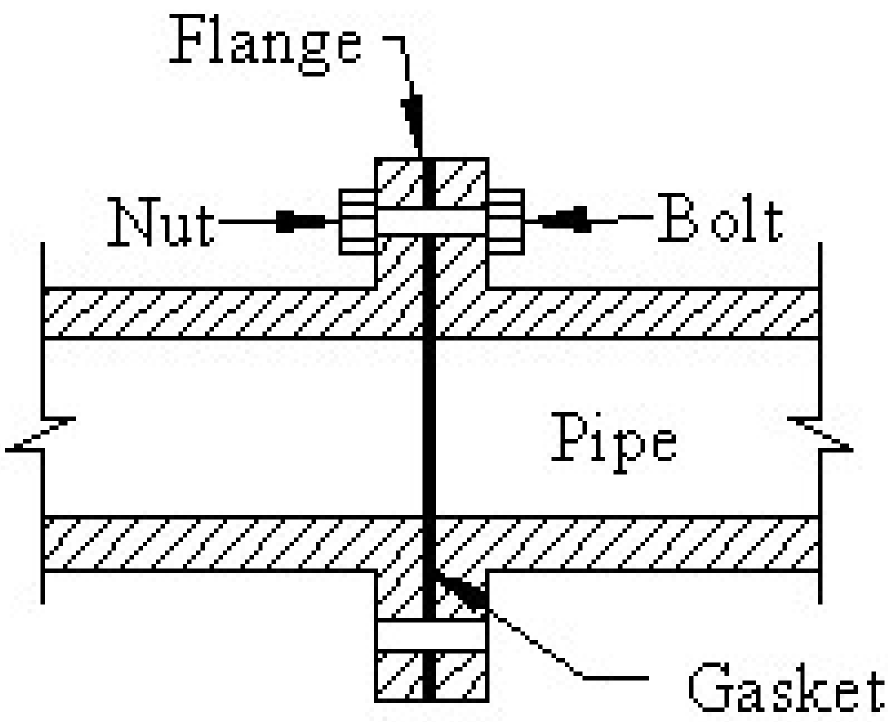
Spigot and Socket Joint

- This type of joint is also known as bell and spigot joint and mostly used for cast iron and ductile iron pipes.
- In this joint, one end of pipe is enlarged to form special shape socket and is known as socket or bell end.
- Other end of pipe is left normal and known as spigot end.
- In this joint, normal (spigot) end of one pipe is slipped in socket or bell end of other pipe until contact is made.
- The hemp yarn or jute is used to maintain the alignment.
- The space between socket and bell end is wrapped with molten lead at 400°C.
- After cooling the lead gets solidified and makes joint watertight.



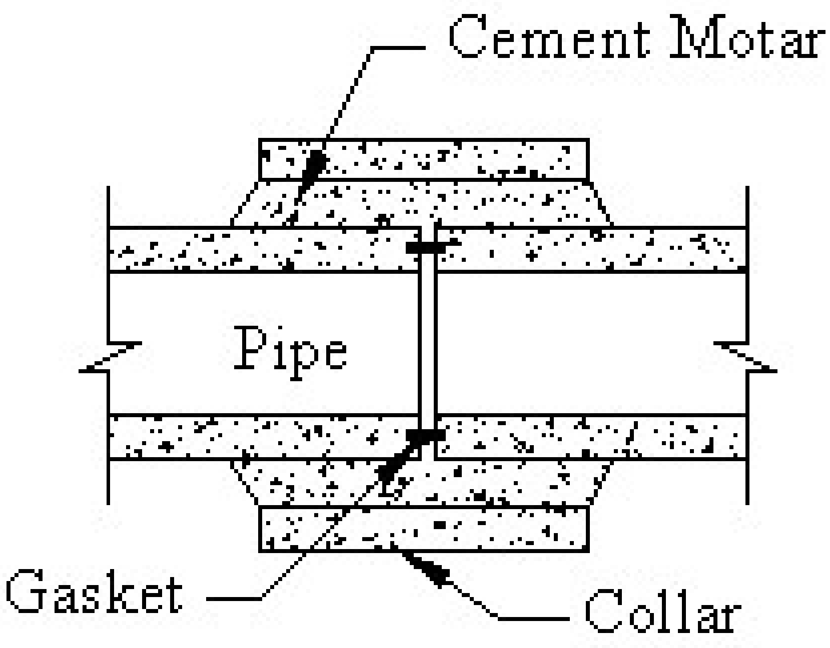
Flanged Joint

- This type of joint is used in pipes of CI,DI, GI, WI and steel pipes with flanges at both ends that can be screwed.
- The flanges are casted during manufacturing process.
- This joint is easy to assemble and dismantle.
- Therefore, they are generally used for temporary pipelines.
- As shown in Figure in flanged joint, the pipes are aligned and flanges are pulled together so that holes in two flanges are aligned with each other.
- Then rubber washer is placed between them for water tightness.
- Then flanges are bolted by nuts and bolts. Oil or grease should not be used. .



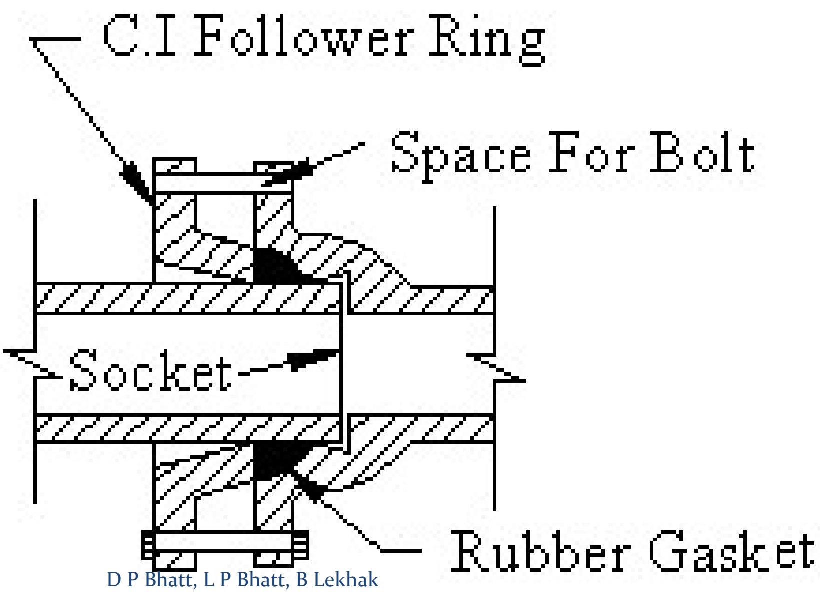
Collar Joint

- This type of joint is mostly used for concrete or asbestos cement pipes.
- As shown in figure to join the pipes, ends of pipes are brought at same level, then rubber gasket between steel rings or jute rope soaked in cement is kept in the groove and the collar is placed at the joint so that it should have the same lap on both pipes.
- Space between pipes and collar is filled with cement



Expansion joint

- There is need to get allow for free expansion and contraction of pipes for changing temperature.
- Expansion joints full fill the need by inserting elastic gaskets between free space of socket and spigot.
- As shown in figure, Socket end is flanged with cast iron follower ring which can be freely slide on the spigot end.
- The rubber gasket introduced will maintain itself for variation in length due to change in temperature.
- The expansion and contraction of pipe results slight movement of socket end in forward and back ward direction.
- The CI follower ring keep rubber gasket at its position and water tightness is also maintained



Screwed Joints

- This joint is mostly use to join small diameter CI, GI and WI pipes.
- The ends of pipes have threads on outside and socket or coupling has threads on inner side.
- The same coupling is screwed on ends of both pipes to join them.
- Application of jute or zinc may be used to make joint watertight.

Laying of Pipes

- Detail Design and Map Preparation
- Setting Out
- Excavation of Trenches
- Timbering of Trenches
- Preparation of sub grade
- Laying and Joining of Pipes
- Anchoring of Pipes
- Testing of Pipes
  - Pressure test
  - Leakage test
- Back filling of Trenches
- Disinfection of Pipeline

Valves and Fittings

- **Valves**

In water works practice, to control the flow of water, to regulate pressure, to release or to admit air, prevent flow of water in opposite direction valves are required.

- various types of valves

1. Sluice valves
2. Reflux valves
3. Air valves
4. Pressure Relief Valves
5. Drain valves
   1. Globe valve
   2. Ball valve

Sluice Valves

- These are also known as gate-valves or stop valves.
- These valves control the flow of water through pipes.
- The entire distribution system is divided into blocks by providing these valves at appropriate places.
- They are provided in straight pipeline at 150-200 m intervals.
- When two pipes lines interest, valves are fixed in both sides of intersection.
- When sluice valve is closed, it shuts off water in a pipeline to enable to undertake repairs in that particular block.
- The flow of water can be controlled by raising or lowering the handle or wheel.

Reflux Valve

- These valves are also known as check or non-return valves.
- A reflux valve is an automatic device that allows water to go in one direction only.
- Reflux valve is generally placed in water pipe, which obtain water directly from pump.
- When pump fails or stops, the water will not run back to the pump and save water in storage tank.

Pressure Relief Valves

- These valves are also known as safety valve or cutoff valve.
- They are positioned at the points where pressure is supposed to be maximum and pipes are expected to be burst.
- When the pressure increases to the predetermined values, the valve automatically operates, the excessive pressure is released and pipeline is saved from being damaged.

Air Valves

- **Air inlet valves**
  - These valves open automatically and allow air to enter into the pipeline so that the development of negative pressure can be avoided in the pipelines.
  - The vacuum pressure created in the down streamside in pipelines due to sudden closure of sluice valves.
  - This situation can be avoided by using the air inlet valves.
- **Air relief valves**
- Sometimes air is accumulated at the summit of pipelines and blocks the flow of water due to air lock.
- In such case the accumulated air has to be removed from the pipe lines.
- This is done automatically by means of air relief valves.

Drain Valves

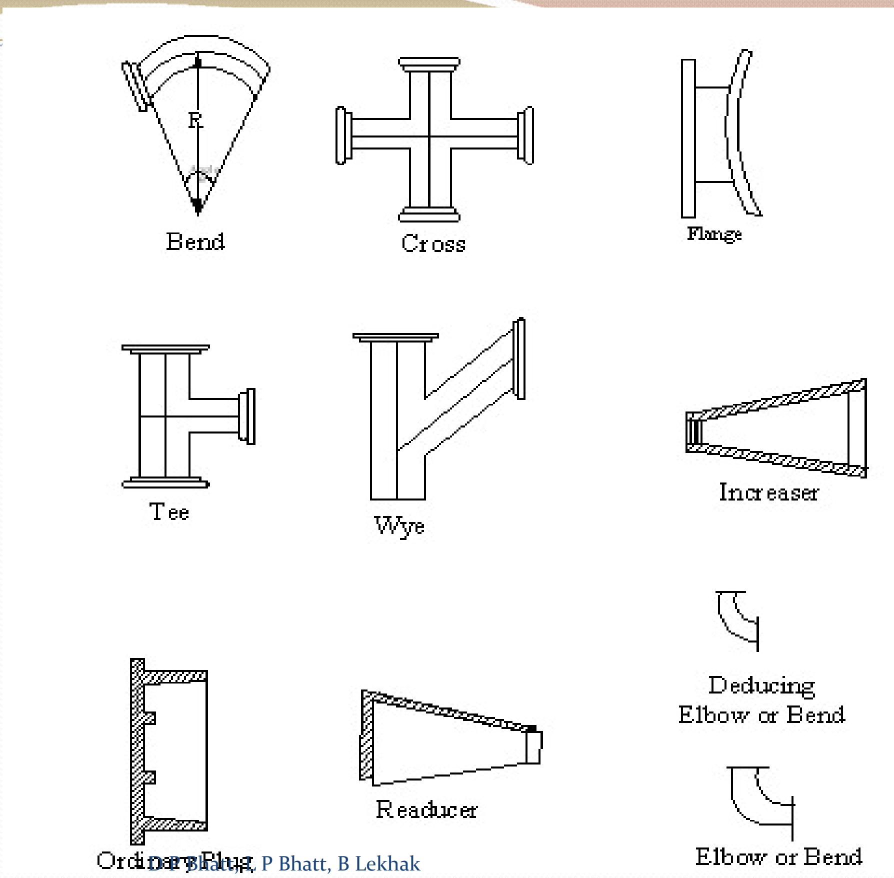
- Drain valves are also called wash out or blow off or scour valves.
- They are provided at all dead ends and depression of pipelines to drain out the water and accumulated silt and sand.
- A branch is taken from lowest point of the pipeline and drain valve is placed in branch.
- When drain valve is opened the water comes out from valve removing all.
- After the complete removal of silt, sand and clay, the value is to be closed.
- These are ordinary sluice valves operated by hand.

Pipe Fittings

1. In addition to the pipes, joints and valves various types of fittings are used during laying and plumbing of pipes.
2. Pipe fittings are piping component that helps in changes the direction of the flow such as bends, crosses, elbows, tees, wye etc.
3. They also changes the size of the pipe such as reducers, reducing elbow etc.
4. They are also used to connect different components such as couplings, unions and stop the flows such as caps, plugs etc

Purposes of fittings

- They connect pipes of different sizes.
- They connect different pipe sections.
- They connect different appurtenances.
- They change direction and gradient of pipes.
- They maintain and regulate flow.
- They close or seal pipes.



Thank You