COUNCIL FOR TECHNICAL EDUCATION AND VOCATIONAL TRAINING

NARAYANI BAHUPRADHIK SHIKSHALAYA

BHARATPUR-10, CHITWAN

A COMPLETE NOTE OF

WATER SUPPLY ENGINEERING

Based on New Curriculum

ER. SATISH MISHRA

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Contents

Unit-1: Water Supply

1.1 Introduction

A branch of civil engineering concerned with the development of sources of supply, transmission, distribution, and treatment of water.

Objective of water supply system

The broad objective of the water system is to supply safe, wholesome, and potable water to the community in adequate quantity and required pressure. Apart from these objectives of water supply system can be summarized as.

- ✓ To supply safe, wholesome, and potable water to consumers,
- ✓ To supply water in adequate quantity in easy way,
- ✓ To supply water to domesticated animal, to the industry and many more,
- ✓ To save time on fetching(time to collect water) works,
- ✓ To Promote the personal and industrial cleanliness,
- ✓ To prevent the spread of epidemic disease,
- ✓ To enhance the economic development of country,
- ✓ To provide water supply facility for industrial, commercial, and domestic purposes.

1.2 Importance and necessity of water supply system

Next to air, the other important requirement for human life to exist is water. Human can survive without food, shelter, and clothes for several days but cannot without water is available in various forms such as river, lake, Streams etc. The water is required for various purposes which are as follows.

- For cooking and drinking
- For bathing and washing
- For growing crops
- For fire fighting
- For street washing
- For heating and air-cooling
- For watering lawns and gardens.
- For industrial use.
- For power generation and various industrial processes.
- For recreation in swimming pools, fountains and cascades.
- For Navigation (travel in water).
- For chemical purpose.

Hence, there is a need of systematic and well-organized water supply schemes to supply adequate quantity of safe and wholesome water to meet the demand of consumers for drinking and other purposes.

Different types of water

The rainwater is originally pure contains two third part of hydrogen and one part of oxygen by volume but absorbs various gases, dust and other impurities while falling on the way of moving on the ground it carries Impurities like silt, non-organic, organic, minerals Impurities, suspended matters etc. This substance not always be harmful but may be useful to human life. As per the impurities present in the water, it is termed as follows,

Pure water: It is the water containing two parts of Hydrogen and one part of oxygen only by volume. It is not good for health.

Potable water: The water suitable for drinking having pleasant taste and useable for domestic purpose is called potable water.

Polluted water (प्रदुषित): This water is like contamination but is the result of contamination. This water contains substances unfit or undesirable for public health or Domestic purpose.

Contaminated water (मिश्रीत): Contamination means containing harmful matter. It is always polluted and unfit for use Water consistency of micro-organisms, chemicals, industrial or other wastes, large numbers of pathogens that cause diseases are called contaminated Water.

Palatable water: Water which is well aerated but free from excessive temperature color, turbidity, taste, and odour and aesthetically acceptable is called palatable water.

***Wholesome water:** It is drinkable water which is neither chemically pure nor contain anything harmful mater to human health but contains useful minerals to the human health.

The following are the requirement of wholesome water.

i. It should be free from radioactive substance (micro-organism, harmful salts, disease causing bacteria and other poisonous metal.
ii. It should be colorless and sparkling.
iii. It should be tasty, odour free, soft, cool, and cheap in cost.
iv. It should not corrode pipes.
v. It should have dissolved oxygen and free from carbonic acid so that it remains fresh.

1.3 History of planned water supply system in Nepal

Following are the major historical achievement of planned water supply systems in Nepal:

- **Ancient and Medieval Periods**

  Lichhavi Period (400-750 AD): Development of traditional water systems like stone spouts (dhunge dharas), wells, and ponds.

  Malla Period (1200-1768 AD): Further advancements in water distribution through the construction of intricate stone spouts, ponds, and canals, particularly in the Kathmandu Valley.

- **19th Century**

  1891: Introduction of the first piped water system in Kathmandu by Bir Shumsher JBR, which sourced water from the Sundarijal area and distributed it via a network of pipes.

- **Early 20th Century**

  1920s: Establishment of the Department of Water Supply and Sewerage (DWSS) to oversee water supply and sanitation services.

  1930: Construction of the Pani Pokhari water reservoir in Kathmandu.

- **Mid-20th Century**

  1950s: post-1951 democratic changes in Nepal brought more attention to infrastructure development, including water supply systems.

  1960: Launch of the first Five-Year Plan, which included objectives for expanding and improving water supply systems.

- **Late 20th Century**

  1973: Introduction of the Integrated Development Project, which focused on water supply and sanitation as part of overall rural development.

  1980s: Initiation of several donor-funded projects, including those by the Asian Development Bank (ADB) and the World Bank, to improve urban and rural water supply systems.

  1989: Establishment of the Kathmandu Valley Water Supply Management Board to manage water resources in the Kathmandu Valley.

- **Early 21st Century**

  2000: Implementation of the Melamchi Water Supply Project (MWSP), aiming to divert water from the Melamchi River to Kathmandu Valley to address chronic water shortages.

  2006: Establishment of the Kathmandu Upatyaka Khanepani Limited (KUKL), a public company responsible for water supply and sanitation in the Kathmandu Valley.

  2013: The Nepal Water Supply Corporation Act was amended to decentralize water supply services and enhance local governance.

  2014: Initiation of the second phase of the Melamchi Water Supply Project.

- **Recent Developments**

2021: Completion and operationalization of the Melamchi Water Supply Project, providing significant relief to water scarcity issues in Kathmandu Valley.

2023: Ongoing efforts to expand and improve water supply infrastructure in urban and rural areas, with continued support from international donors and agencies.

- **Current and Future Plans**

  2024 Onwards: Focus on sustainable water management practices, climate resilience, and expanding access to safe drinking water for all communities across Nepal.

1.4 Impact of water supply

There are two types of impact due to water supply schemes they are.

a. Positive Impacts
b. Negative Impacts.

a. Positive Impacts:

Positive impact is further divided into and long-term impact and Intermediate impacts.

Intermediate Impacts:

- ✓ Fetching time is saved so that this time can be used for other productive work.
- ✓ Safe, reliable, adequate and expected supply is gained.
- ✓ Improves hygienic condition so that time and money expenses for medicine are saved.

Long term impact

- ✓ Increases the living standard of the people.
- ✓ Help in the economic growth of whole nation.
- ✓ Increases socio-economic activities of individuals, family and then community.

b. Negative impacts:

- ✓ Reduces downstream water and expects on aquatic life.
- ✓ Decrease ground water table May create dispute between downstream water users.
- ✓ Pollution due to decreased quantity of water of downstream may occur.

1.5 Water supply and its impact on public health, women, and environment

Impact on public health:

- ✓ Safe, potable, wholesome supply of water decreases the chance to transmit disease like Dysentery, cholera, Diarrhea, Roundworm etc.

- ✓ Improves hygienic condition so that personnel, community, and national good hygiene can be achieved.

Impact on women:

- ✓ Especially, fetching time can be saved so that this time can be used for other productive work.
- ✓ Health of women, especially during critical time will not ruin due to water supply system.
- ✓ Proper hygienic condition can be achieved.

Impact on Environment:

- ✓ Water from water supply can be used to maintain greenery.
- ✓ Proper sanitation can be achieved.
- ✓ Good water system reduces the chance to pollutant the water.
- ✓ Biodiversity can be achieved.

1.6 Components of water supply system (Rural and Urban) and their function

A. Rural/ Gravity water supply system

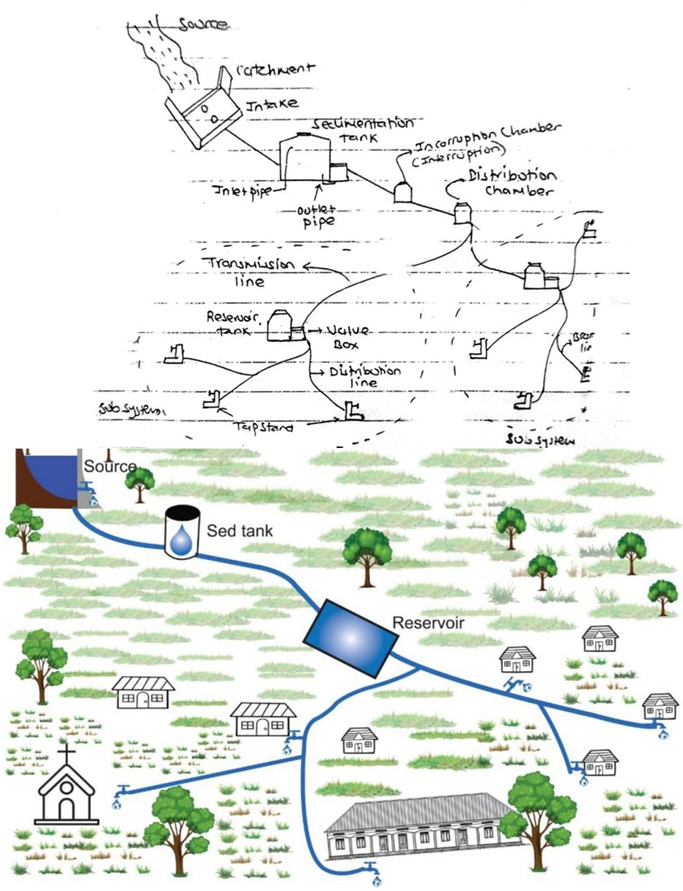


FIGURE:- RURAL WATER SUPPLY SYSTEM

1. **Intake:**

   Intake is the structure constructed to collect water from source. This may be either masonry or RCC. The water collected from intake is send to either collection chamber if water is collected from multiple sources or directly to transmission pipeline. The intake consists of inlet, outlet pipe, overflow pipe and washout.

2. **Collection Chamber(CC):**

   Collection chamber is constructed when water from two or more than two sources are to be collected. Collection chamber may be either attached with intake or made separately. Collection chamber includes inlet, outlet, overflow, and washout. Valve chamber is constructed to protect the fittings.

3. **Wash Out (WO):**

   Wash out valve is kept at the lowest point when the pipeline is going U profile. This is kept at valley and just after collection chamber. This is used to washout the sediments from the pipeline i.e., to remove suspended particles.

4. **Sedimentation Tank (ST):**

   Sedimentation tank is provided when the water contains high silt or sediments is high. ST helps water to remain stagnant and allows the sediments to settle down due to gravity. The fine suspended solid is removed from this chamber. It includes inlet, outlet, overflow, and valve chamber.

5. **Interruption Chamber (IC)/ Break Pressure Tank (BPT):**

   Interruption chamber and break pressure tank is provided when the head of water is more than sixty meters. Interruption chamber is provided in transmission line and break pressure tank is provided in distribution line. Both of this are used to reduce the pressure and prevents pipe from bursting. It consists of valve chamber, valves, outlet, inlet, overflow, and washout

6. **Air Valve (AV):**

   Air valve is provided to remove the air from the pipeline. If the air isn't removed from the pipe this air blocks the water flow. This is provided in summit and air is removed automatically.

7. **Distribution Chamber (DC):**

   If the water is to be distributed to reservoir tank located in different community, then distribution chamber is to be constructed. The construction of DC is same as that of collection chamber. It also contains inlet, outlet, and washout. Air vent is provided in outlet pipe.

8. **Pipeline:**

The pipeline is provided to flow water. In this purpose either HDPE or GI pipe is used. HDPE pipe is buried whereas GI pipe is not buried. Anchor block is provided to support GI pipe. The pipeline from intake to RVT is called transmission pipeline and from RVT to tap is called distribution pipeline.

9. Pipe Crossing:

Pipe crossings are provided when the pipeline is to be crossed from stream or George. Pipe crossing is either suspended crossing or non-suspended crossings.

10. Reservoir Tank (RVT):

Reservoir tanks are constructed to storage water therefore this is also known as storage tank. Reservoir is to be constructed near the community where water is to distribute. This RVT is either of Ferro cement, stone masonry or RCC tank depending upon the water to be collected. In Nepal rural water supply Ferro cement reservoir is highly used. RVT consists of valve chamber. Inlet, outlet, washout, air vent is provided reservoir.

11. Tap stand:

The last point of gravity system of water supply system is tap. The tap stand is either household or community tap stand. Community tap stand is provided at center of 5-6 household. The maximum distance between the house and community tap is one hundred meters.

B. urban/city water supply system

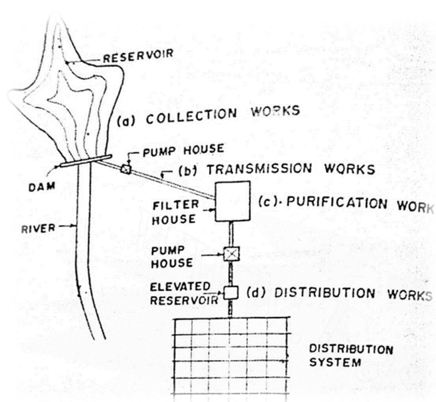


FIGURE :- CITY/ URBAN WATER SUPPLY SYSTEM

1. Collection works

It may include intake works and storage depending upon river, a dam and storage may be constructed, or direct intake can be made.

2. Transmission work

The water should be supplied to the city through transmission work. It is the connection between collection and purification works through conduits, pipes, and canal aqueduct etc.

3. Purification/treatment work:

The purification works is done to treat water to get required quality. The process depends upon the quality of source and quality to be required.

4. Distribution system:

It is required to convey purified water from clear water reservoir to the user by any system of distribution like dead-end pattern, grid iron pattern etc.

Unit-2 Sources of Water Supply

2.1 Hydrological Cycle and Sources of Water

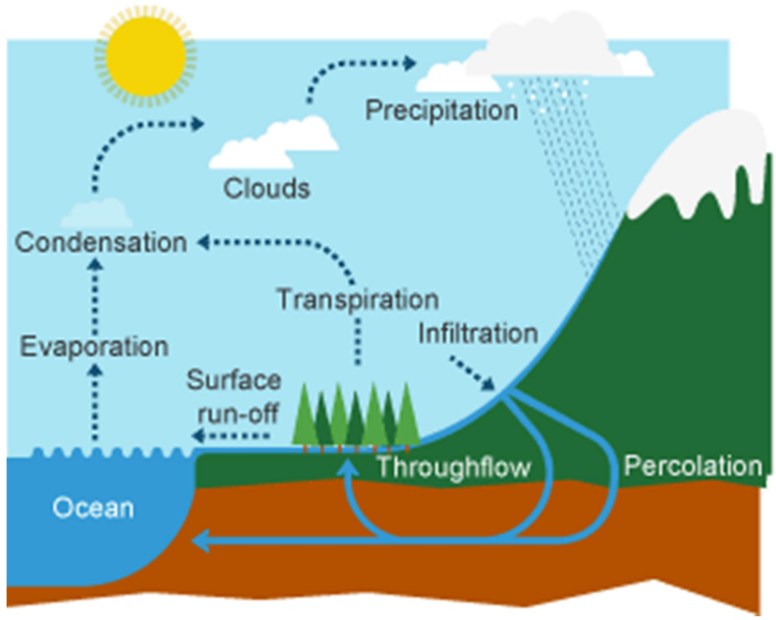


FIGURE:- HYDROLOGICAL CYCLE

Processes of the Hydrological Cycle:

1. **Evaporation:** Water from oceans, rivers, lakes, and other water bodies evaporates into the atmosphere due to solar heat.
2. **Transpiration:** Plants release water vapor into the atmosphere through transpiration.
3. **Condensation:** Water vapor rises and cools, leading to condensation and cloud formation.
4. **Precipitation:** Clouds produce precipitation, which falls back to the Earth's surface as rain, snow, sleet, or hail.
5. **Infiltration:** Some of the precipitation infiltrates the ground, replenishing groundwater supplies.
6. **Runoff:** The rest of the water flows over the surface as runoff, eventually returning to rivers, lakes, and oceans.
7. **Sublimation:** Ice and snow change directly into water vapor without first melting into water.
8. **Deposition:** Groundwater moves through soil and rock layers, recharging aquifers and feeding into water bodies.
9. **Percolation:** water moves through the soil and porous rock layers into underground aquifers.

Water Sources:

There are two types of water sources viz, surface sources and ground sources. In general, we have following types of sources of water

- Oceans and Seas: Largest reservoirs of water.
- Rivers, streams, and Lakes: Freshwater sources on the Earth's surface.
- Groundwater: Water stored in underground aquifers.
- Ice and Snow: Water stored in glaciers and polar ice caps.
- Atmosphere: Water vapor present in the air.

2.2 Surface Sources

Sources of water can be broadly classified into two types. They are

Sources of Water Supply

A. Surface Sources

1. River
2. Stream
3. Pond
4. Lakes
5. Impoundes reservoir

B. Ground Sources

1. Springs (Gravity, Artesian)
2. Wells (Shallow, Deep, Artesian, Tube)
3. Infiltration Galleries
4. Infiltration Wells

A. Surface Sources

Those sources from which water can be obtained easily on the surface of the earth. The quantity may be sufficient, and quality may be acceptable, and treatment may be required for surface sources.

1. River (नदी):-

Rivers are the large water course formed by the combination of discharge of large number of streams and springs from hill to low land and sea. Discharge is smaller in hills, and it becomes larger in lowland due to the increment of the catchment. Depending upon the water availability of Water River may be classified into perennial or non-perennial. Quantity of water available is very large and can be used as a source of water supply for towns and cities.

2. Stream (खोला):-

Streams are formed by the surface runoff and the discharge is maximum in rainy season. It is the main source of water to the villages of the hilly areas. The quality of water in streams is normally good expecting the water of first run-off. But sometimes run-off water while flowing over ground is mixed with clay, sand, and Minerals. Impurities and can be removed in settling tank while dissolved impurities requires special treatment.

3. Pond (पोखरी):-

Ponds are temporary type of surface source formed in small natural depressions and artificial depressions when the large quantity of excavation is done for constructing highway, bridge, building etc. Surface runoff and village wastewater flows towards pond so the possibility of contamination and quality may be very poor & high degree of treatment is required for pond water. It is not reliable Supply so used in animal bathing, irrigation purpose etc.

4. Lakes (ताल):-

Lakes are natural basin with impervious bed in the mountainous region. It is permanent type of surface source formed in high altitude in between mountains. The lakes situated in mountainous region are of good quality and quantity and may be used in water supply without or after certain treatment. The quality of water of lakes depends upon basin capacity, catchment area, annual rainfall, porosity of ground etc.

5. Impounded reservoir (जलाशय)

FIG: IMPOUNDED RESERVOIR

These are the artificial reservoir constructed to store water to meet demand at dry seasons. The water can be stored by constructing a bund, a weir, or a dam across the river where minimum area of land is submerged in the water and the reservoir basin remains off shaped having maximum depth of water. While deciding the site for the location of impounded reservoir, following point should be considered.

- Sites where enough water is available should be selected.
- Weir or dams should be constructed where the width of river is narrow.

- Cultivable land, highway, towns, railway should not submerge in its reservoir.
- At the site, bed soil should not contain soluble salts, minerals which may affect the quality of water.
- Watershed should be free from swampy areas.
- Site should be such that useful construction materials for the construction of dam are available nearby.

In the bottom of such reservoir area algae, weeds, vegetable and organic grass takes place which produce bad smell, taste and color in water. Therefore, water should be used after purification. It should be generated and chlorinated to kill the microscopic organisms which are born in water.

2.3 Ground Sources

Ground water is the water which percolates in the ground after rain fall. Therefore, the quantity of ground water directly depends on the rain fall. The quality of ground water is much better than surface water because surface contains large amount of suspended impurities, whereas ground water is free from it.

1. **spring:**

A spring is the natural outflow of ground water appearing at the earth's surface. Springs can supply small quantity of water so it can't be used as a source of water to the big town but may be suitable for water supply schemes in village area in hilly region of Nepal. The quality of water is good and may contain Sulphur in certain springs which discharge hot water which can be used for taking dips for the cure of certain skin diseases. Following are the types of spring.

A. Gravity spring
   i. Depression Spring
   ii. Contact springs
   iii. Artesian springs
B. Non-gravity spring
   i. Fissure Springs

A. Gravity spring: Gravity spring results from water flowing under hydrostatic pressure and of three Types.

(i) Depression spring:

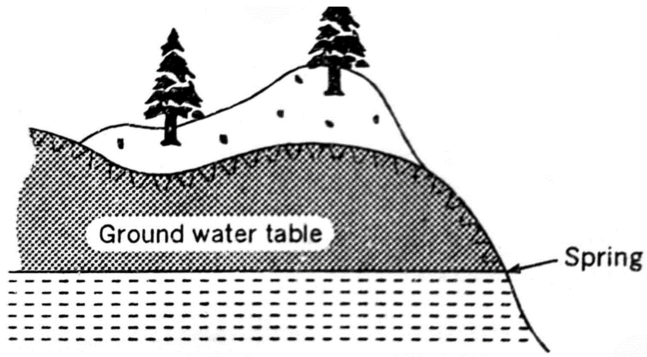


FIGURE:- DEPRESSION SPRING

These springs are formed due to the overflowing of the water table where the ground surface intersects the water table. The flow from such spring is Variable with the rise or fall of water table.

(ii) Contact Spring

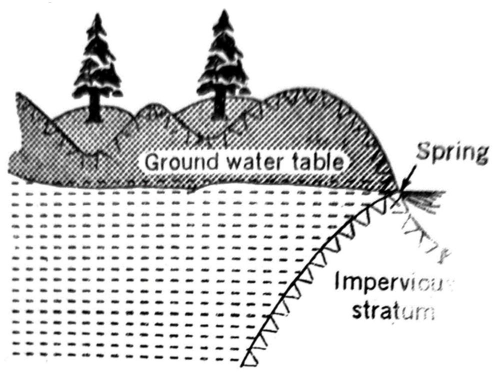


FIGURE:-CONTACT SPRING

Contact spring or surface spring is formed when an impervious stratum which is supporting the ground water reservoir becomes outcrop. The storage capacity of these types of spring is very small which ceases after a drought. This spring can be developed by constructing a cut off trench.

(iii) Artesian spring:

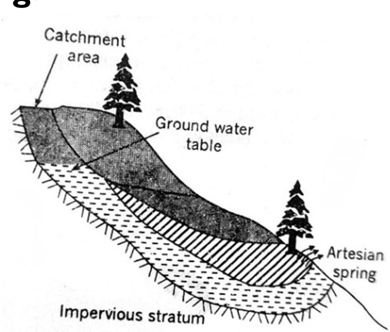


FIGURE:- ARTESIAN SPRING

These springs results from release of water under pressure from confined aquifers either at an outcrop of the aquifer or through an opening in the confining bed. The amount of water available in an artesian spring may be large if the catchment area is large. The flow may be slightly increased by removal of obstruction from the mouth of the spring,

B. Non-Gravity spring:

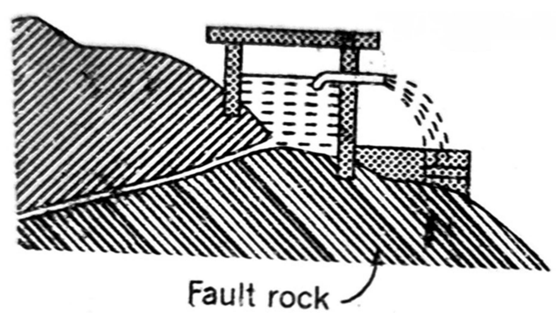


FIGURE:- NON-GRAVITY SPRING

Non-gravity spring include volcanic spring and fissure spring. The flow Water does not take place under hydrostatic pressure. These are also called hot spring and contain high minerals as well as Sulphur.

2. Wells

A well is defined as an artificial hole or pit made in the ground for the purpose of tapping water. Depending upon the method of construction, wells are classified as follows.

A. Open well or percolation well
   i. Shallow open well
   ii. Deep open well
B. Driven well
C. Tube well
   i. Strainer type tube well
   ii. Cavity type tube well
   iii. Slotted type tube well
   iv. Perforated type tube well
D. Artesian Well

A. Open well or percolation well

Open well are also known as dug or percolation well. Ground water has been utilized from ancient times by open wells. Open wells are constructed up to limited depth, so their yield is also limited. The open well is further classified into two types. They are

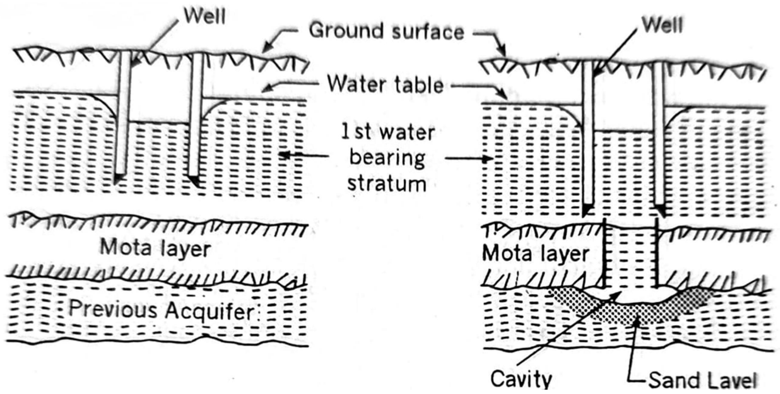


FIGURE :- SHALLOW AND DEEP OPEN WELL

i. **Shallow open well**

Shallow wells are constructed in the uppermost layer of the earth's surface and used in rural areas and small towns. It is cheap in construction. The diameter of well varies from 2 to 6m and a maximum depth of 7m. Shallow wells are lined or unlined from inside. In this well, quantity of water is very Small than deep well wells because it yield water from the top water bearing strata only. Hence, they are not suitable for public water supply schemes.

ii. **Deep open well:**

Deep open well rests on impervious strata and draws water from an aquifer below the impervious layer. The theory of deep well is based on the travel of water from the outcrop to the site of deep well. The mota layer gives the structural support to the open well resting on its surface. In this type of well, the quantity of water or yield is high because it draws water below the impervious strata.

B. Driven Well

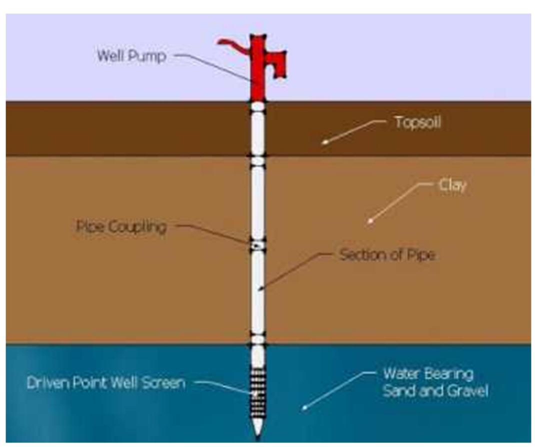


FIGURE :- DRIVEN WELL

The shallow deep well constructed by driving a casing pipe of 2.5cm to 15cm in diameter and up to 12m deep is called driven well. The casing pipe is driven first in the ground by hammering or by water jet and the pipes are inserted. The lower portion of the pipe, which is driven in the water bearing strata is perforated and is covered with fine wire gauge to prevent passage of sand and soil particles. The discharge in this well is very small & can be obtained using hand or electric pump and can be used for domestic purpose.

C. Tube well :

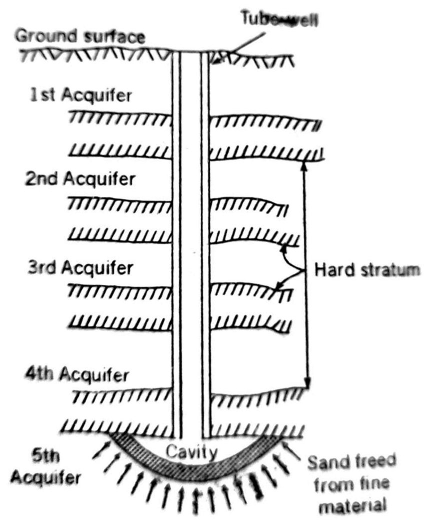


FIGURE :- TUBE WELL

Tube well is the well which is made of small diameter pipe installed after boring and inserted deep to trap water from different aquifers. As compared to open wells the diameter of tube wells are much less. The tube well is specially found in the terai regions of Nepal. Tube Wells are further classified into

i. Strainer type tube well.
ii. cavity type tube well
iii. Slotted type tube well
iv. perforated type tube well

D. Artesian Well.

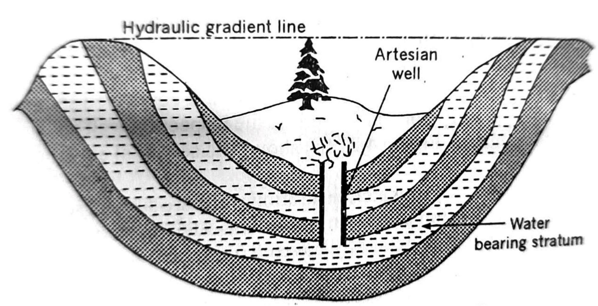


FIGURE :- ARTESIAN WELL

Artesian well is the well from where water flows automatically under pressure. Mostly they are found in the Valley portion of hills where aquifers on both side towards valley. The HGL passes much above the mouth of well, which causes flow under Pressure. In some wells, water flows continuously throughout the year and can be stored in reservoir and taken for water supply. The quality of water in artesian wells may be good but sometimes it contains minerals and can be used after certain treatment.

E. Infiltration galleries:

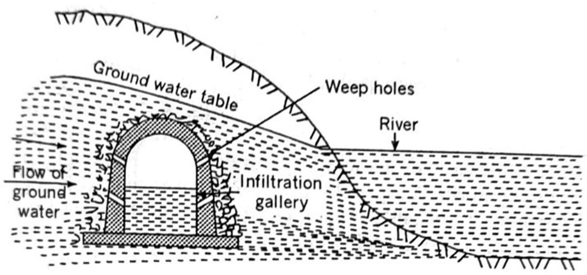


FIGURE:- INFILTRATION GALLERIES

It is a horizontal or nearly horizontal tunnel usually rectangular in cross section and having permeable boundaries so that ground water can infiltrate into it. It is generally located near a perennial recharge source such as bank of river. It can also be used to collect ground water and the water stored in tank can be used for water supply. The quantity and quality depends upon the location and area of coverage. It is constructed by the cut and covers and made up with dry brick masonry wall or porous concrete blocks with weep holes and R.C.C slab roof or an arch roof. Manholes are provided at suitable points for inspection. Series of galleries may be laid in the proper slope land collected at certain reservoir then it can be used as the water supply after certain treatment.

C. Infiltration Wells

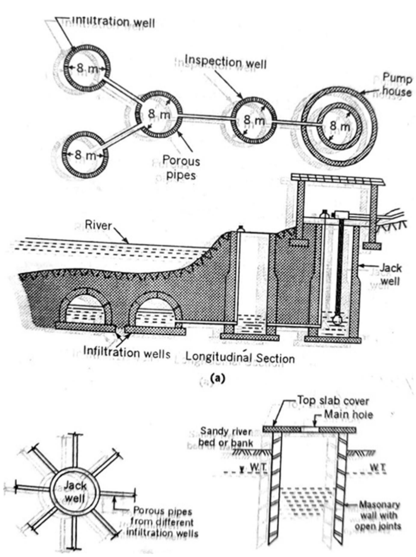


FIGURE:-INFILTRATION WELL

Infiltration wells are sunk in series in the banks of rivers to obtain large quantity of water. These wells are closed at top and open at bottom. They are constructed by brick Masonry. For inspection of well, the manholes are provided in the top cover. The infiltration wells are connected by porous pipes to collect sump called jack well and there water is pumped to purification plant for treatment.

2.4 Introduction to alternative Sources of water:

A. Rainwater Harvesting

Rainwater harvesting is the practice of collecting and storing rainwater from rooftops, land surfaces, or other catchment areas for future use. It is a simple, cost-effective, and sustainable way to supplement traditional water supplies.

Components of rainwater harvesting:

1. Catchment Area:

Surfaces like rooftops, terraces, and other structures that collect rainwater.

2. Gutters and Downspouts:

Channels that directly collect rainwater from the catchment area to the storage system.

3. Filters:

Devices that remove debris, leaves, and other contaminants from the collected rainwater before it enters the storage system.

4. Storage Tanks:

Containers such as cisterns, barrels, or underground tanks that store the filtered rainwater for later use.

5. Distribution System:

Pipes and pumps that transport the stored water to where it is needed.

Method of rain harvesting:

1. **Rooftop Rainwater Harvesting:**
   Collecting rainwater from rooftops and directing it into storage tanks.
2. **Surface Runoff Harvesting:**
   Capturing and storing rainwater that runs off land surfaces like gardens, fields, or pavements.

Benefits of rainwater harvesting:

Following are the benefits of rainwater harvesting.

1. Water Conservation.

2. Groundwater Recharge.
3. Flood Control.
4. Economic Savings.
5. Environmental Impact.

B. Conservation Pond

A conservation pond, also known as retention or detention pond is a man-made or natural water body designed to collect and store storm water runoff. These ponds help improve water quality, manage storm water, control flooding, and provide ecological benefits.

Components of conservation pond:

1. Inlet Structures:

Channels or pipes that direct storm water into the pond.

2. Pond Basin

The main area where water is stored, which may have varying depths to support different functions and habitats.

3. Outlet Structures:

Devices that control the release of water from the pond to downstream areas, typically including weirs, spillways, or pipes.

4. Vegetation:

Plants around and within the pond that help filter pollutants, stabilize the soil, and provide habitat for wildlife.

Functions:

5. Flood Control:

Temporarily stores excess storm water and releases it slowly to reduce downstream flooding.

6. Water Quality Improvement:

Filters pollutants, sediments, and nutrients from runoff through natural processes like sedimentation, adsorption, and biological uptake.

7. Groundwater Recharge:

Allows water to percolate into the ground, replenishing aquifers.

8. Habitat Creation:

Provides a habitat for aquatic and terrestrial wildlife, enhancing local biodiversity.

Benefits of Conservation Pond

1. Environmental Protection:

Reduces the impact of urban runoff on natural water bodies, protecting rivers, lakes, and streams. Enhances biodiversity by providing habitats for various species.

2. Erosion Control:

Prevents soil erosion by controlling the flow and volume of stormwater.

3. Aesthetic and Recreational Value:

Improves the landscape and offers recreational opportunities such as fishing, bird watching, and walking trails.

4. Water Supply Management:

Acts as a supplemental water source for irrigation and other non-potable uses.
Design Considerations:

5. Location:

Ideally situated in areas that receive substantial runoff and can support aquatic ecosystems.

6. Size and Depth:

Adequate to handle the expected volume of runoff and provide sufficient habitat for aquatic life.

7. Vegetation:

Incorporates native plants that enhance filtration, stabilize banks, and support local wildlife.

8. Maintenance:

Regularly inspected and maintained to ensure proper function, including removal of debris and sediment.

C. Fog collection

FIGURE: - FOG COLLECTION

Fog collection is a method of harvesting water from fog using specially designed structures to capture and condense water droplets present in the fog. This method is particularly useful in arid and semi-arid regions where other water sources are scarce.

Components of Fog Collection:

1. **Collector Frames:**

   Structures that hold the mesh or netting in place, usually made of metal or sturdy materials.

2. **Mesh/Nets:**

Fine mesh or netting that intercept fog droplets, causing them to coalesce and form larger droplets.

3. **Gutters/Trays:**
   Channels that collect the water droplets as they fall from the mesh and direct them to storage.
4. **Storage Tanks:**
   Containers where the collected water is stored for later use.

Process of Fog Collection:

1. **Capture:**
   Fog droplets are captured by the mesh or netting as fog passes through.
2. **Coalescence:**
   Small fog droplets accumulate on the mesh and combine to form larger droplets.
3. **Collection:**
   Gravity causes the larger droplets to fall into the gutters or trays.
4. **Storage:**
   Water is directed from the gutters to storage tanks.

Benefits of Fog Collection:

1. **Water Supply:**
   Provides a supplementary water source in arid and semi-arid regions. Useful in areas with high fog density and limited rainfall.
2. **Simplicity:**
   Low-tech and inexpensive to set up and maintain.
3. **Sustainability:**
   Environmentally friendly and renewable source of water.
4. **Community Impact:**
   Can improve water security and quality of life for communities with limited water resources.

Applications of fog water collection:

1. **Drinking Water:**
   After proper filtration and treatment, collected water can be used for drinking.
2. **Agriculture:**
   Provides water for irrigation, especially in foggy coastal or mountainous regions.
3. **Livestock:**
   Supplies water for livestock in areas where other water sources are scarce.
4. **Reforestation:**
   Supports reforestation and afforestation projects by providing water for young plants.

Challenges of fog Collection:

1. **Climate Dependency:**
   Effectiveness is highly dependent on local climate and fog conditions.
2. **Maintenance:**
   Regular maintenance is required to keep the mesh clean and functional.
3. **Scalability:**
   May not provide large volumes of water, limiting its use to smaller communities or specific applications.

2.5 Protection of water sources

Protection means the proper use and supervision of different pipelines and structures. Proper protection reduces maintenance and makes the water supply project sustainable. The projection works includes the protection of following

- **Source:** plantation, fencing, keeping cleanness around source making catch drains.
- **Tank and valves:** It includes the protection of storage tank, distribution tank, sedimentation tank, valves etc. by fencing, plantation, regular cleaning, proper outflow management.
- **Pipeline:** Regular Check, filling of exposed pipes immediately, plantation to Protect from probable landslide etc.
- **Tap:** It includes protection of water tap, tap stand and platform from children wastewater management etc.
- **Tools, equipment's, and plants:** proper use, storage and cleaning of tools equipment's used in regular supply and maintenance.

Barbed wire Fencing:

FIGURE:- BARBED WIRE FENCE

Barbed wire fence is one of the oldest technologies. It is barbed wire with pointed edges or pointed fixed at various intervals across the fence. The pointed edges discourage animals from trying to get through the fence. Barbed wire is inexpensive as we need only wire, fence posts and staples to erect the fence. The barbed wire is available in a variety of sizes and patterns. This type of fencing should be carefully handled during installation since it can cause injury if we get caught in the wire. For the protection of pipelines and structures this type of fencing can be also used. Properly installed and maintained fence keep unwanted and saves predators, animals out our time and money

2.6 Selection and measurement of water sources

Selection of source of water

The selection of the source of water depends upon the following factors.

a. **Location:**
   - It should be near to the consumer area of town as far as possible.
   - There may be either, surface or ground source and the selection of the source depends upon other factors. If there is no river, stream or reservoir in the area, the ultimate source is ground Source.
   - Location may be at higher elevation such that required pressure may be obtained and water can be supplied by gravity flow.

b. **Quantity of water:**
   - It should have enough water to meet the demand for the design period in wet and dry seasons also.
   - If possible, there should be enough for future extension of project.

c. **Quality of water**
   - The Water should be safe, and free from pathogenic bacteria, germs, and pollution.
   - The water quality should be such that it has less quantity of impurity which further needs less treatment.

d. **Cost**
   - It should be able to supply water of good quality and quantity at less cost.
   - The cost depends upon level of city location, ground and source, distance of Source and distribution area etc.
   - Gravity system of flow is cheaper.
   - Lesser impurities, lesser the treatment is reduced.

e. **Sustainable and safe:** It should be sustainable and safe.

f. **Reliable:** The water source should be reliable.

g. **Non conflict among water Users:** There should be no conflict among users.

Measurement of yield from water sources.

It is also called measurement of maximum discharge from the various sources. There are following methods for measuring the yield from the source.

1. Rainfall record
2. Empirical formula

1. Rain fall records:

In this method the area is measured from the map and the amount of rainfall is calculated from the available records. The maximum discharge or yield is found out.

2. Empirical formula:

The empirical formula can also be used to determine the Maximum discharge.

➢ **Dicken's formula:**

$Q = 0.01387\ C\ M^{3/4}$

Where, Q= discharge in m^3/sec.

M= Catchment area in mm^2

C= 1600 or 250 (constant).

➢ **Ryve's formula:**

$Q = 0.015C\ M^{2/3}$

Where, C=450 to 675 constant)

M = catchment area

➢ **Inglis formula:**

$Q = 319\frac{319}{\sqrt{M}}$

Where, Q= Discharge in m^3/sec.

M = catchment area.

Unit-3 Quantity of Water:

3.1 Water demand:

While designing the water supply scheme for town or city it is necessary to determine the total quantity of water required for various purposes. Demand is higher in developed countries and less in level developing countries. After calculating total demand, the source or combination of the sources is searched to achieve full demand. Total demand for Water supply is the sum of following types of demands.

1. Domestic Demand
2. Livestock Demand
3. Institution and commercial Demand
4. Public Demand
5. Industrial Demand
6. Fire Demand
7. Compensate losses Demand

1. Domestic Demand

It is the demand of water for home use, including drinking cooking, washing and. sanitation. It depends upon the habit, social Status, climatic condition, living standards etc. The domestic consumption of water in country like Nepal is 135 lpcd. But in develop countries this figure may be 350 lpcd because of Use of air coolers, air conditioners, maintenance of lawns etc.

WHO standard for domestic demand is minimum 45 lpcd and 100-160 1pcd for rural and urban areas, respectively. For design practice in Nepal rural area with public tap, it is taken as 25 to 45 lpcd (generally 45 lpcd), Semi-urban area (public & private connection without sanitation) it is taken as 65 lpcd and for urban (public and private connection with Sanitation) area it is 100 to 135 lpcd (generally 112 lpcd).

Sr. No.	Description	Amount of water in litres per head	
		Urban Community	Rural community
1	Bathing	55	26
2	Washing of Clothes	20	
3	Flushing of W.C.	30	8
4	Washing of house	10	
5	Washing of utensils	10	8
6	Cooking	5	
7	Drinking	5	3
		135 litres	45 litres

2. Livestock Demand:

The quantity of water required for domestic animals and livestock (birds) is called livestock demand. It is generally considered in rural of supply but in Nepal it is also considered in urban area. The overview of livestock demand is presented in table below.

Sr. No.	Live stock	Water requirements in litres/animal/day
1	Cows and buffalo	40 to 60
2	Horse	40-50
3	Dog	15- 20
4	Sheep or goat	15- 20
5	Chicken for 100 nos	20

3. Institution and commercial Demand

It includes the demand for office building, large house, stores, hotels, schools, hospitals, theaters club etc. For commercial and institutional demand may be up to 45 lpcd. The quantity of water demand for the public buildings other than residential is given below.

Sr. No.	Type of Building	Construction per capita per day (litres)
1	a) Factories with bathrooms	45
	b) Factories without bathrooms	30
2	Hospitals per bed	
	a) No. of beds not exceeding 100 No.	340
	b) No. of beds exceeding 100 No.	450
3	Nurses homes and medical quarters	135
4	Hostels	135
5	Offices	45
6	Restaurants (per seat)	70
7	Hotel (per bed)	180
8	Cinema concert halls and theatres	15 /seat
9	Schools	
a)	Day schools	45
b)	Boarding schools	135

4. Public Demand

It includes quantity of water required for public utility such as Road washing, Sanitation- sewer flushing, public parks and, gardens, public fountains etc.
Provision of 20- 25% of the total consumption is made designing the water works for a city. The water required for public purposes is tabulated below.

Sr. No.	Purpose	Water Requirements
1	Public parks	1.4 lit/m²/day
2	Street washing	1.0-1.5 lit/m²/d
3	Sewer cleaning	4.5 lit/head/day
4	Garden and Sports Ground	3.5 lit/ m²/d

5. **Industrial Demand**

   It is the quantity of water required for the Industrial purpose. The water required Depends on the type of industries, which are existing in the city. Normally - 20-25% of the total demand is taken for industrial demand.

6. **Fire Demand**

   During the outbreak of fire, the water is used for firefighting is called fire demand, as during the fire large amount of water is required for throwing it over the fire to extinguish it. Therefore, provision is made in the water work to supply enough water. In the cities fire hydrants are provided on the water mains at 100 to 50m apart for fire demand. The demand required for firefighting is calculated by using different empirical formulas.

   ➢ *According to Kuching Formula*

   $Q = 3182\sqrt{P}$

   Where, Q= quantity of water required in liter/min

   P= population of town or city in thousand

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

7. **Compensate losses Demand**

   It Includes losses due to defective pipe joints cracked and broken pipes, faulty valves and fittings, unauthorized connection, allowance for keeping tap open etc. while estimating the total quantity of water for a town, allowance of quantity of water is made to compensate for losses, thefts, and wastages of water.

Total Water Demand

The sum of all water demand is known as total water demand. The total water demand is given by the following expression.

EWD = DD+LD+CD+PD+ID+FD+LW

Where,

TWD = Total water demand

DD = Domestic demand

LD = Livestock Demand

CD = Commercial Demand

PD = Public/Municipal Demand

ID = Industrial Demand

FD = Fire Demand and
LW = loss and wastage

3.2 Water supply project

Water supply projects are initiatives designed to develop, manage, and distribute water resources to meet the water needs of various users, including domestic, industries, public, and firefighting. These projects aim to ensure the availability, quality, and reliability of water through the construction and maintenance of infrastructure and implementation of sustainable management practices.

Base and Design Periods

- **Base period** is the period required for survey, design and construction of water supply system. Usually, base period of two to three years is adopted.
- **Design period** is defined as the future period for which a provision is made while planning and designing the water supply programs. Usually, 15 to 20 years is adopted as design period. 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.

Base Year and 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 Year:-** Design year is defined as that year for which the water supply system is designed for. It depends on the base year and the design period and is given as:

  Design Year = Base year + Design Period

Selection Basis of Design Period

Design period must be selected in such a way that it is neither too long nor too short.

Shorter design period may lead to an uneconomical project whereas a longer design period may result in the financial burden on the present population as the components need to be of high capacities. Following are the selection basis.

1. **Availability of water at source :**
   The fluid available at the water source must be able to fulfill the needs and demands at the design year. Higher the fluid available longer can be the design period and the design period would be shorter if the fluid available is low.
2. **Development of community.**
   For the developing communities, higher will be the population growth rate due to migration from the community with poor infrastructures. So the estimation of the population may not be accurate so a short design period is selected whereas the case is just reverse for the developed community where population growth rate is low.
3. **Population Growth rate:**
   Due to migration and other natural phenomenon as birth and death the population cannot be accurately determined so the design period is taken shorter for high population growth rate and vice versa.
4. **Availability of funds**
   If the fund available for the water supply system is adequate (not limited), the system with higher capacity can be constructed for which a longer design period can be taken. Shorter design period is taken when the fund is limited.
5. **Rate of interest:**
   If the interest on the money borrowed for the construction of water supply project is low, a longer design period can be taken and vice-versa.
6. **Useful life of components:**
   Every component used in the water supply system (pipe, valves, fittings, etc.) has their useful life. The design period should not exceed the useful life of such components.

3.3 Population forecasting: necessity and methods

A. Arithmetical increase method

It is a simple method and assumes that the population is increasing at a constant rate. The rate of change of population with time is constant.

i.e. $\frac{dp}{dt}$ = c (a constant)

Integrating,

Where, P_1= Population at the time t_1, first census.

P_2= Population at the time t_2, Last available census.

Now, the population after n decade can be determined by the formula,

P_n=P + nC

Q. From the following data, forecast the population in the year 2070, 2080, 2090 fc from the Arithmetical Increase method:

Year	2020	2030	2040	2050	2060
Population (No)	25000	28000	34000	42000	47000

1. Arithmetical method

Year	Population	Increase in population
2020	25000	-
2030	28000	28000-25000 = 3000
2040	34000	34000- 28000 = 6000
2050	42000	42000- 34000 = 8000
2060	47000	47000- 42000 = 5000
	Total	22000
	Average increase (C)	22000/ 4 = 5500

Population in 2070=$P_{2070} = P_{2060} + n \times C = 47000 + 1 \times 5500 = 52500$

Population in 2080=$P_{2080} = P_{2060} + n \times C = 47000 + 2 \times 5500 = 58000$

Population in 2090=$P_{2090} = P_{2060} + n \times C = 47000 + 3 \times 5500 = 63500$

Q. The census population of a community is given below:

Year	1981	1991	2001	2011
Population	8000	12000	17000	22500

Estimate the population of the community for the years 2021, 2028 and 2031 by Arithmetical Increase method.

Solution:

Year	Population	Increase in Population
1981	8000	-
1991	12000	12000 - 8000 = 4000
2001	17000	17000 - 12000 = 5000
2011	22500	22500 - 17000 = 5500
	Total	14500
	Average increase (C)	4833

Population in 2021=$P_{2021} = P_{2011} + n \times C = 22500 + 1 \times 4833 = 27333$

Population in 2028=$P_{2028} = P_{2011} + n \times C = 22500 + 1.7 \times 4833 = 30716$

Population in 2031=$P_{2031} = P_{2011} + n \times C = 22500 + 2 \times 4833 = 32166$

B. Geometrical increase method

This method is based on the assumption that percentage increase in population from decade to decade remains constant. If the present population is Po and the average percentage growth is 'r', the population at the end of the decade will be

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

This method is suitable when city is young and rapidly increasing. This is the commonly used method in Nepal.

Q. From the following data, forecast the population in the year 2070, 2080, 2090 for a village from the Geometrical Increase method:

Year	2020	2030	2040	2050	2060
Population (No)	25000	28000	34000	42000	47000

1. Geometrical Increase method

Year	Population	Increase in population	% increase in population
2020	25000	-	-
2030	28000	28000-25000 = 3000	(3000/25000) x 100 = 12 %
2040	34000	34000- 28000 = 6000	(6000/28000) x 100 = 21.4 %
2050	42000	42000- 34000 = 8000	(8000/34000) x 100 = 23.5 %
2060	47000	47000- 42000 = 5000	(5000/42000) x 100 = 11.9 %
	Total	22000	68.8 %
		Average increase (C) = 22000/ 4 = 5500	Average % increase (r) = 68.8 %/ 4 = 17.2 %

Population in 2070= $P_{2070} = P_{2060}\left[1 + \frac{r}{100}\right]^n = 47000\left[1 + \frac{17.2}{100}\right]^1 = 55084$

Population in 2080= $P_{2080} = P_{2060}\left[1 + \frac{r}{100}\right]^n = 47000\left[1 + \frac{17.2}{100}\right]^2 = 64559$

Population in 2090=$P_{2090} = P_{2060}\left[1 + \frac{r}{100}\right]^n = 47000\left[1 + \frac{17.2}{100}\right]^3 = 75663$

Q. The census population of a community is given below:

Year	1981	1991	2001	2011
Population	8000	12000	17000	22500

Estimate the population of the community for the years 2021, 2028 and 2031 by Geometrical Increase method.

Solution:

Year	Population	Increase in Population	% increase in population
1981	8000	-	-
1991	12000	12000 - 8000 = 4000	50 %
2001	17000	17000 - 12000 = 5000	41.67 %
2011	22500	22500 - 17000 = 5500	32.35 %
	Total	14500	124.02 %
		Average increase (C) = 4833	Average % increase (r) = 41.34 %

Population in 2021= $P_{2021} = P_{2011}\left[1 + \frac{r}{100}\right]^n = 22500\left[1 + \frac{41.34}{100}\right]^1 = 31802$

Population in 2028=$P_{2028} = P_{2011}\left[1 + \frac{r}{100}\right]^n = 22500\left[1 + \frac{41.34}{100}\right]^{1.7} = 40517$

Population in 2031=$P_{2031} = P_{2011}\left[1 + \frac{r}{100}\right]^n = 22500\left[1 + \frac{41.34}{100}\right]^2 = 44948$

C. Incremental increase method

This method is improved form of arithmetic and geometrical increase method. The average increase in population is determined by the arithmetical method and to this is added the average of the net is increments increase once for each future decade. If P_o is present population, I_a is average arithmetical Increase Ia is the average incremental increase then population after 'n' decades will be

$$P_n = P_0 + n\,C + \frac{n\,(n+1)I}{2}$$

Q. From the following data, forecast the population in the year 2070, 2080, 2090 for a village from the Incremental Increase method:

Year	2020	2030	2040	2050	2060
Population (No)	25000	28000	34000	42000	47000

1. Incremental Increase method

Year	Population	Increase in population	Incremental increase in population
			(Succeeding - Preceding)
2020	25000	-	-
2030	28000	28000-25000 = 3000	-
2040	34000	34000- 28000 = 6000	6000- 3000 = 3000
2050	42000	42000- 34000 = 8000	8000 – 6000 = 2000
2060	47000	47000- 42000 = 5000	5000 – 8000 = - 3000
	Total	22000	2000
		Average increase (C) = 22000/ 4 = 5500	Average Incremental increase(I)= 2000/ 3 = 666.67

Population in 2070=$P_{2070} = P_{2060} + n\,C + \frac{n\,(n+1)I}{2} = 47000 + 1 \times 5500 + \frac{1\,(1+1)\,666.67}{2} = 53167$

Population in 2080= $P_{2080} = P_{2060} + n\,C + \frac{n\,(n+1)I}{2} = 47000 + 2 \times 5500 + \frac{2\,(2+1)\,666.67}{2} = 60001$

Population in 2090=$P_{2090} = P_{2060} + n\,C + \frac{n\,(n+1)I}{2} = 47000 + 3 \times 5500 + \frac{3\,(3+1)\,666.67}{2} = 67502$

Q. The census population of a community is given below:

Year	1981	1991	2001	2011
Population	8000	12000	17000	22500

Estimate the population of the community for the years 2021, 2028 and 2031 by Incremental Increase method.

Solution:

Year	Population	Increase in Population	Incremental increase in population
			(Succeeding- Preceding)
1981	8000	-	-
1991	12000	12000 - 8000 = 4000	-
2001	17000	17000 - 12000 = 5000	1000
2011	22500	22500 - 17000 = 5500	500
	Total	14500	1500
		Average increase (C) = 4833	Average Incremental Increase(I) = 1500/ 2 = 750

Population in 2021= $P_{2021} = P_{2011} + n\,C + \frac{n\,(n+1)I}{2} = 22500 + 1 \times 4833 + \frac{1\,(1+1)\,750}{2} = 28083$

Population in 2028=$P_{2028} = P_{2011} + n\,C + \frac{n\,(n+1)I}{2} = 22500 + 1.7 \times 4833 + \frac{1.7\,(1.7+1)\,750}{2} = 32437$

Population in 2031=$P_{2031} = P_{2011} + n\,C + \frac{n\,(n+1)I}{2} = 22500 + 2 \times 4833 + \frac{2\,(2+1)\,750}{2} = 34416$

3.4 Variation in demand of water, Average Demand, Peak Demand, Peak Factor, Factor affecting demand of water, socio-economic factor affecting demand of water

The fluctuation of water demand with respect to time is called variation of demand. The annual average daily consumption is not sufficient in design because demand varies year to year, season to season, month to month, day to day and even for hour to hour. The different variations in water demand are explained below.

a) **Seasonal variation:** The water demand varies from season to season. In summer the water demand is maximum, because people will use a more water in bathing, cooling, lawn watering and street sprinkling. This demand will be minimum in winter because less water will be used in this season for above activities.

b) **Daily variation:** Demand varies with day to day are called daily Variation. It depends on the general habit of people, climatic condition and character of city: Demand is more in the feasts and festivals.

c) **Hourly variation:** Demand also varies even hour to hour and called hourly variation. Demand is more in morning and evening, in holidays due to washing, cleaning and bathing etc. Maximum demand occurs on 6am to 10 am and 4 pm to 8pm and minimum on 12 pm to 4 pm.

d) **Monthly variation:** Demand also varies even month to month and called monthly Variation.

Demand and peak factor

Peak demand is maximum hourly demand at the maximum day of maximum season so it is obtained by

Peak demand = $PF_H \times PF_D \times PF_S \times Q_{AV}$

Where,

PF_H = Hourly peak factor.

PF_D = Daily Peak factor.

PFs = Seasonal peak factor

Qav = Average annual daily consumption.

Or, Peak Demand = (2 to 4) x 1x 1 x Q_{av} (In Nepal)

Or Peak Demand = PF x Q_{av}

Where,

PF = $PF_H \times PF_D \times PF_S$ is called peak factor; hence it is the product of hourly, daily and seasonal peak factor. It is taken as 2 to 4 in Nepal.

Factor affecting demand of water.

It has been seen that the average rate of demand of various cities considerably varies with each other. The different factors which affect rate of water demand are discussed below:-

a) **Climatic condition:** The quantity of water required in hotter and dry places is more due to use of air coolers, air conditioners, sprinkling of water in lawns, gardens etc. In cold countries the quantity of water required is less but sometimes the quantity of water required may be more due to wastage, because at such place people often keep their taps open and water continuously flows for fear of freezing of water. In taps and use of hot water for keeping their rooms warm.

b) **Size of the community:** Water demand is more with the increase of size of town because more water is required for street washing, running of sewers, maintenance of parks and gardens.

c) **Living standard of people:** The per capita demand of the town increase with the standard of living of the people. The people will start to use air conditioners, room coolers, maintenance of lawns, and use of flush latrines etc. in their standard of living.

d) **Industrial and commercial activities:** As the quantity of water required in certain industries is much more than the domestic demand, their presence in the town will automatically increase the per capita demand of the town.

e) **Pressure in distribution system:** The rate of water consumption increases with the increase in the pressure of the building.

f) **System of sanitation:** The per capita demand of the town having water carriage system will be more than the town where this system is not being used.

g) **Cost of water**: The cost of water directly affects its demand, if the water cost is more; less quantity of water will be used by the people as compared when the cost is low.

h) **Other socio-economic factors:**

- Public versus private tap stand: public tap, lower is demand.
- Habits of people: frequency and bathing habits of people in river, stream and pond also affect the demand.
- Distance to tap stand: Nearer demand is high.
- Urban versus rural: Higher demand in urban area due to sanitation system, habit, living standard.

Unit 4: Intake

4.1 Definition and Classification of Intake

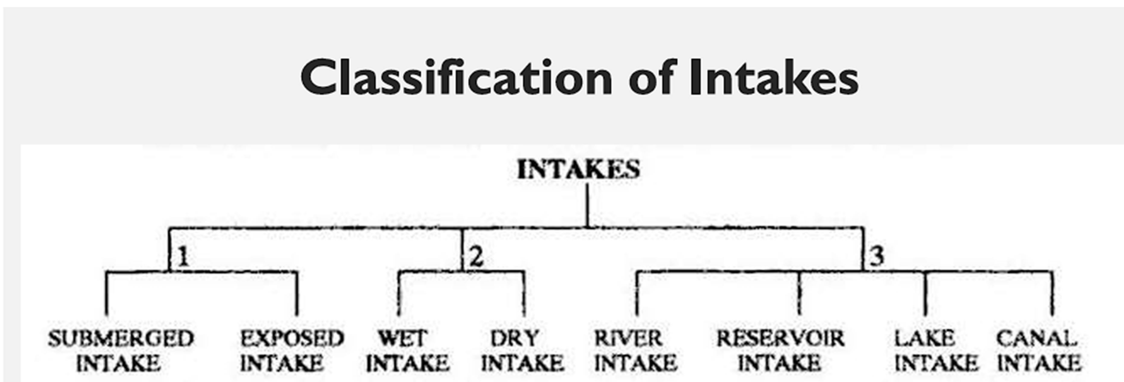
An intake is a device or structure placed in a water source to permit the withdrawal of water from source, and discharge it into an intake conduit through which it flows to the treatment plant; or discharge it into an intake well from where it is pumped to the treatment plant.

Intake consists of:

a) **Intake conduit** with a screen at its inlet end and a valve to control flow of water

b) **A structure** permitting the withdrawal of water from the source and housing and supporting the intake conduit, valve operating devices, pumps, etc. Structure is made of stone masonry, brick masonry, RCC or concrete blocks. It should be designed for all forces likely to come upon it (pressure due to water, wave action, wind, floating debris, etc.)

4.2 Classification of Intake and Characteristics



1. According to position of intake

a) Submerged Intake

- The submerged Intake structures are those which are constructed entirely under water.
- They are less expensive to construct but are difficult to maintain.
- Such intakes are commonly used to obtain water from lakes

b) Exposed Intake

- The Exposed intakes is in the form of well or tower constructed near the bank of river or in some cases even away from the bank of river.
- They are more common due to ease in operation and maintenance

2. According to presence of water in the tower

a) Wet Intake

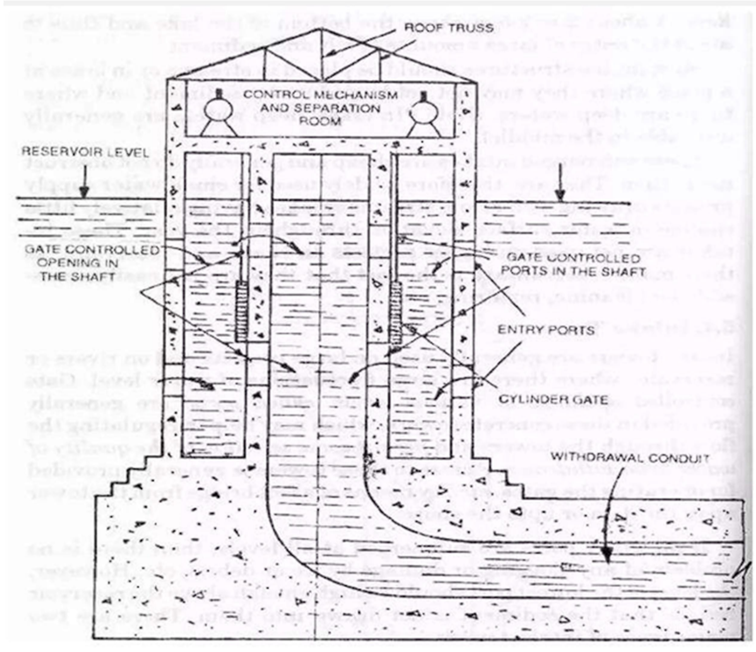


FIGURE: WET INTAKE

- The wet intake is that type of intake tower in which the water level is practically the same as the level of source of supply.
- It is sometimes known as JACK Well and it is most commonly used.
- It consists of a concrete circular shell filled with water up to the reservoir level.
- Openings are made in to the outer concrete shell as well as, in to the inside shaft.
- Gates are usually placed on the shaft, so as to control the flow of water in to the shaft and the withdrawal conduit.
- The water coming out of the withdrawal pipe may be taken to pump house for lift (if treatment plant is at high elevation) or may be directly taken to treatment plant (at lower elevation).

b) Dry Intake

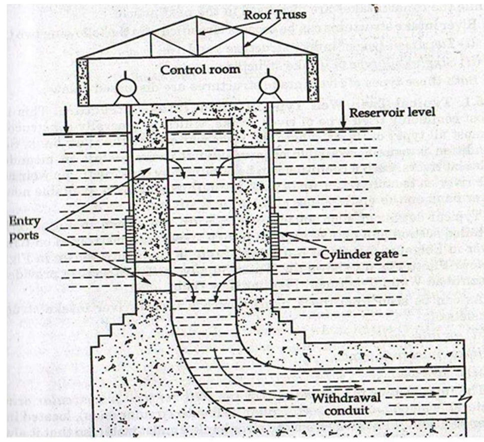


FIGURE: DRY INTAKE

- The water is directly drawn in to the withdrawal conduit through the gated entry ports.
- It has no water inside the tower if its gates are closed.
- When the entry ports are closed, a dry intake tower will be subjected to additional buoyant forces.
- Hence it must be of heavier construction than wet intake tower.
- They are useful since water can be withdrawn from any selected level of the reservoir by opening the port at that level.

3. According to the type of source

a) River Intake

- An intake tower constructed at the bank or inside of the river to withdraw water is called river intake.
- These intakes consist of circular or rectangular, masonry or RCC intake tower from where water can be withdrawn even in the dry period.
- Several inlets called penstocks for drawing water are provided at the different levels to permit the withdrawal of water when the water level drops.
- All inlet ends are provided with a screen (to prevent the entry of floating matters) with valves to control the flow of water operation from the control room.
- The penstock discharges the water into the intake tower (intake well) from where it is pumped or flow under gravity.

b) Reservoir Intake

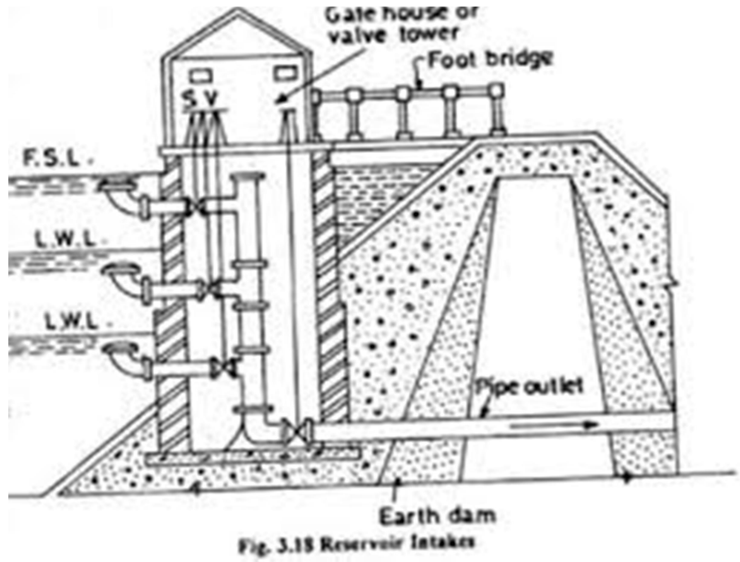


FIGURE: RESERVOIR INTAKE

Reservoir intakes, which is mostly used to draw the water from earthen dam reservoir.

- It essentially consists of an intake tower constructed on the slope of the dam at such place from where intake can draw sufficient quantity of water even in the driest period.
- Intake pipes are fixed at different levels, so as to draw water near the surface in all variations of water level.
- These all inlet pipes are connected to one vertical pipe inside the intake well.
- The type of intake to be provided depends on the type of dam constructed to create the reservoir.
- Commonly used dams are gravity dams and earthen dams.

c) Spring Intake

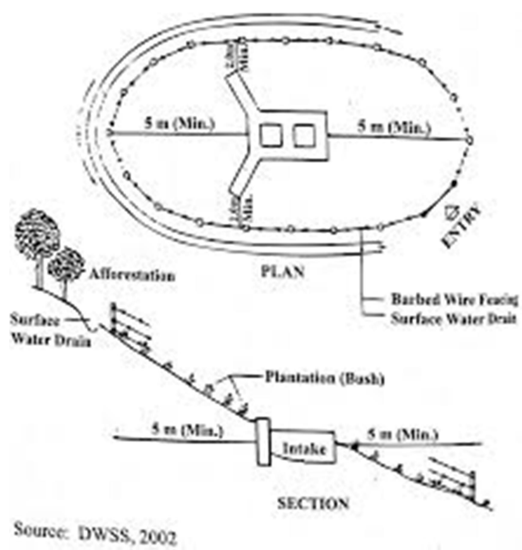


FIGURE: SPRING INTAKE

An Intake constructed at the spring source to withdraw water is called as spring intake. It is generally constructed in small rural water supply scheme in Nepal. Spring intake should be impervious and protection is provided around the source to prevent the source contamination and physical damage by runoff water.

Above figure shows the protective work done by fencing, digging bio-engineering works etc. More springs can also be joined greater discharge.

4.3 Site Selection and protection measures for intake works.

The following points should be kept in mind while selecting the site for Intake

- The best quality of water should be available at the site so that it can be easily and economically purified in less time.
- The site should be such that intake can draw sufficient quantity of water even in worst condition.
- The site of intake should be easily approachable without any obstruction.
- The site should not be located in navigation channel because such water is polluted and contains toilet and other discharge from the ship.
- The site should be stable and safe from wind currents landslides etc.
- The site of the intake should be well connected by good approach roads.
- As per possible should be near to the treatment plant so that cost of convey would be less.
- At site there should not be heavy current of water which may damage the intake structures.
- The intake site should not be located in the vicinity of the point of sewage disposal as far as possible.
- At site sufficient quantity should be available for the future expansion of the water-works.
- The site should not be located on curve. If it is required locate it on the concave or outer bank because water is available in all times.

Unit 5: Quality of water

5.1 Pure and impure Water

Pure water, often referred to as distilled or deionized water is a substance that is free from impurities, including dissolved salts, minerals, and other contaminants. It is composed solely of hydrogen and oxygen molecules, forming H_2O. Pure water is colorless, tasteless, and odorless, and it is typically used in laboratories, medical facilities, and industrial processes where high levels of purity are required. In nature, pure water is rare, as most sources contain dissolved substances, but it can be produced through processes like distillation, reverse osmosis, and deionization.

Impure Water

Impure water contains a variety of dissolved and suspended substances, including minerals, salts, organic compounds, and microorganisms. These impurities can affect the water's taste, color, and safety for consumption. Natural sources of water, such as rivers, lakes, and groundwater, often contain impurities due to the presence of soil, rocks, and human activities. Impure water can vary in its level of contamination, ranging from mildly impure, like tap water, to heavily contaminated, which may require extensive treatment to make it safe for drinking or other uses. The presence of impurities in water can have significant implications for health, industry, and the environment.

5.2 Potable and wholesome Water

Potable water

The water which is suitable for drinking having pleasant taste and useable for domestic purpose is called potable water.

Wholesome water

It is drinkable water which is neither chemically pure nor contain anything harmful mater to human health but contains useful minerals to the human health.

The following are the requirement of wholesome water.

i. It should be free from radioactive substance (micro-organism, harmful salts, disease causing bacteria and other poisonous metal.
ii. It should be colorless and sparkling.
iii. It should be tasty, odour free, soft, cool, and cheap in cost.
iv. It should not corrode pipes.
v. It should have dissolved oxygen and free from carbonic acid so that it remains fresh.

5.3 Polluted water and Contaminated water

Polluted water (प्रदुषित): This water is like contamination but is the result of contamination. This water contains substances unfit or undesirable for public health or Domestic purpose.

Contaminated water (मिश्रीत): Contamination means containing harmful matter. It is always polluted and unfit for use Water consistency of micro-organisms, chemicals, industrial or other wastes, large numbers of pathogens that cause diseases are called contaminated Water.

5.4 Impurities in water: Classification and effects

Quality of water is the degree of goodness of Characteristics (physical, chemical and biological) of water in all aspects. Absolutely pure water is never found in nature but contains number of impurities in varying amount. Water from any source may have following three types of impurities.

a) Suspended Impurities
b) Colloidal Impurities.
c) Dissolved impurities

a) Suspended impurities:

These are those impurities, which normally remain in suspension due to same specific gravity as that of water. It includes impurities like clay, algae, fungi organic and inorganic matters and minerals. These all impurities are microscopic and cause turbidity of water. The concentration of suspended matter in water is measured by its turbidity and can be removed by Sedimentation (larger one) or filtration (finer one).

b) Colloidal Impurities.

These impurities are small non-visible with naked eye and electrically charged which remains in continue motion. These materials are generally associated with organic matters containing bacteria and are the chief source of epidemics. The size of colloidal particles is between 10^{-3} mm to 10^{-6} mm. The electric charge is due to the presence of absorbed ions on to surface of the solid. Acid or neutral material as silica, glass and most organic matter are negative charge in neutral water and base Materials as Al_2O_3 and Fe_2O_3 are positives charged. Particles of similar charge repel with each other which causes movement of particle. It causes color in water and their quantity is determined by color test.

c) Dissolved impurities:

Some impurities are dissolved in water when it moves over rocks, soil etc. which are known as dissolved impurities. These dissolve impurities may contain organic compounds, organic salts and gases etc. It makes taste, hardness and alkalinity. The concentration of total dissolved solid is usually in PPM (parts per million) and obtained by weighting the residue after evaporation of the water sample from a filtered sample.

Effects of impurities

Impurity	Constituents	Effects
1. suspended Impurities	a. Bacteria	Some cause diseases
	b.Algae,Protozoa	Odour , colour, turbidity
	c. Silts, clay	Murkiness or turbidity
	d. Vegetables matters	Odour,colour,alkalinity
	e. Dead animals	Diseases, germs
2.Dissolved Impurities	**A. salts**	
	1. Calcium & Magnesium	
	a. Bicarbonate	Alkalinity, Hardness
	b.Carbonate	Alkalinity, Hardness
	c.Sulphate	Hardness
	d.Chlorides	Hardness, Corrosion
	2. Sodium	
	a. Bicarbonate	Alkalinity, Softening effect
	b. carbonate	Alkalinity, Softening effect
	c.Fluoride	Mottled enamel of teeth
	d.Chloride	Taste
	e. Sulphate	Foaming in boilers
	B. Metals & Compounds	
	1. Iron Oxide	Taste, red colour corrosiveness, hardness
	2. Manganese	Black or Brown colour
	3. Lead	Cumulative poisoning
	4.Arsenic	Toxicity, poisoning
	5.Cadmium	Toxic, illness
	6.Cyanide	Fatal
	7.Silver	Discoloration of skin, eyes
	8.Nitrates	Blue baby, infant poisoning, acidity
	9.Selenium	Highly toxic to animals, fish
	10. Boron	Affects central nervous system
	11.Barium	Toxic effect on heart, nerves.
	C.Gases	
	A. Oxygen	Corrosiveness to metal
	B. carbon dioxide	Acidity, corrosiveness
	C. H_2S	Odour, acidity, corrosiveness
3. Organic Impurities	***A. Suspended***	
	1. Vegetable	Colour,Taste,Acidity
	2. Animal(dead)	Produce harmful disease germs, alkalinity
	B.Dissolved	
	1. Vegetable	Produce Bacteria
	2. Animal(dead)	Cause pollution of water and disease germs

5.5 Hardness in water, types of hardness, alkalinity in water

Hardness: Hardness is the chemical characteristics of water which prevents the formation of sufficient lather or foam when mixed with soap. The water which does not produce lather with soap readily is called hard water. For tap water, river water sea water etc. Hardness of water is caused due to the presence of the soluble bicarbonates Sulphates and Chlorides of calcium and Magnesium when hard water is treated with soap, the Ca^{++} and Mg++ ions react with soap forms insoluble scum or curds and no lather is produced until the Ca^{++} and Mg^{++} ions and precipitated.

Effects of hardness:

The effects of hardness in water are causes

- Causes corrosion of pipelines & fittings.
- Makes food tasteless and causes bad effect to our digestive system..
- More consumption of soap while washing and bathing.
- Modifies Colour is used in dyeing work and washing clones.

Types of Hardness

Hardness is of two types. They are

a) Temporary hardness
b) Permanent hardness.

a) **Temporary hardness:** The temporary hardness of water is caused by the presence of bicarbonates of calcium and the magnesium. It is also called the carbonate hardness.
Temporary hardness of water can be removed by boiling by Clark's process.

b) **Permanent Hardness:** Permanent hardness of water is caused by the presence of Sulphates, chlorides and nitrates of calcium and magnesium. This hardness is also called as non-carbonate hardness.
The permanent hardness of water cannot be removed by simply boiling but requires special treatment (lime Soda process, zeolite process).

Alkalinity in water

- When OH- concentration of water is more than H+ concentration i.e pH more than 7.
- Caused by the presence of carbonates, bicarbonate and hydroxides of sodium, calcium & magnesium
- It is determined by titrating the sample against standard acid using methyl orange as indicator.
- Carbonate alkalinity may be present with bicarbonate alkalinity or hydroxide alkalinity.
- Bicarbonate alkalinity and hydroxide alkalinity do not exist together in water.
- Total alkalinity is the sum of carbonate and bicarbonate alkalinity or the sum of carbonate Alkalinity and hydroxide alkalinity.

5.6 Living organism in water

Contaminated water may contain various micro-organisms and hence should be treated before we otherwise this water may spread diseases. There are various types of living organism in water. Some of them are algae bacteria, virus, helminthes etc.

1. **Algae:**

FIGURE: ALGAE IN WATER

An algae is an unicellular simple photosynthetic aquatic plant which is self-nourishing by deriving energy from simple Inorganic substances with the help of sunlight. It has no root system and is microscopic in fresh water but several hundred meters in length in salty water. The different effect of algae is

- Causes turbidity, Colour and objectionable odour unpleasant taste.
- The growth of algae can be controlled by adding copper Sulphates.

2. **Bacteria:**

Bacteria are the single celled minute microorganisms possessing no defined nucleolus and having no Chlorophyll for making its own food. They are normally present in contaminated water and reproduction occurs by binary fission. The size of bacteria is of 1-4 microns and can't be seen with naked eyes. Vibrio, Cocci, Bacilli etc. are the types of bacteria. These bacteria may be beneficial for human health or may not. Pathogenic diseases are caused due to bacteria.

3. **Virus:**

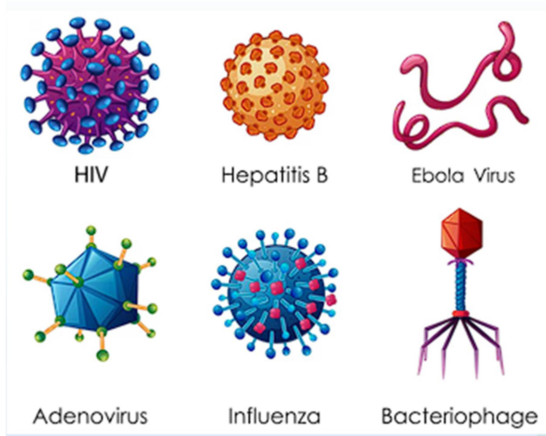


FIGURE: VIRUS

It is Unicellular animal type living organism and infectious for plant and animal cell. It grows in animal organ & dies if left in air. The presence of virus in water may create different diseases like paralysis, hepatitis, throat diseases. Water can be prevented from virus by adding high amount of chlorine. For example Rhino virus transfer common cold disease.

4. **Helminthes(Worms):**

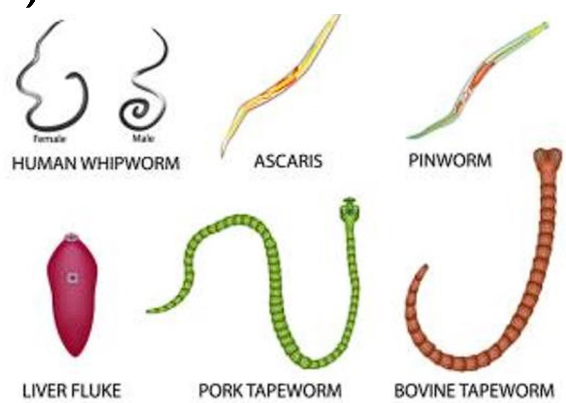


FIGURE: WORMS

Helminthes are well as Macroscopic and can Microscopic enter directly in directly to the human body through skin or drinking of water. They may be parasitic as well as free living. Hook worm, tape worn etc. are parasite. They are classified as

- Nematodes or round worms
- Rotifers
- Flat worms (platy helminthes)

5.7 Water Related diseases

1. **Water Borne Diseases:**

If water carrying pathogens entered into the body with drinking water, they cause diseases which are called Water Borne diseases. About 80% of communicable diseases are transmitted by water. Cholera, Dysentery, Diarrheoa etc. are the examples of water borne diseases.

2. **Water Washed Disease:**
The disease caused due to lack of personal hygiene is called water washed disease. Skin sepsis, trachoma, fungal infection is the examples of water washed diseases. For prevention the quantity of water should be increased.

3. **Water Based Diseases:**
The diseases or infection transmitted through aquatic animal and pathogens which spend their life cycle in water is called water based diseases. Prilhasi, schistosomiasis Guinea worm, Lingo flukes etc. are the examples of water based diseases.

4. **Water related Vectors:**
Insects that live in surrounding of water can transfer disease carrying pathogens to humans called water related vectors. For example Malaria, Sleeping sickness, Filariasis yellow fever, hooks worms.

Category	Comments
Water-borne diseases	Caused by the ingestion of water contaminated by human or animal faeces or urine containing pathogenic bacteria or viruses; includes cholera, typhoid, amoebic and bacillary dysentery and other diarrhoeal diseases.
Water-washed diseases	Caused by poor personal hygiene; includes scabies, trachoma and flea-, lice- and tick-borne diseases in addition to the majority of waterborne diseases, which are also water-washed.
Water-based diseases	Caused by parasites found in intermediate organisms living in water; includes dracunculiasis, schistosomiasis and some other helminths.
Water-related diseases	Transmitted by insect vectors which breed in water; includes dengue, filariasis, malaria, onchocerciasis, trypanosomiasis and yellow fever.

Transmission Routes

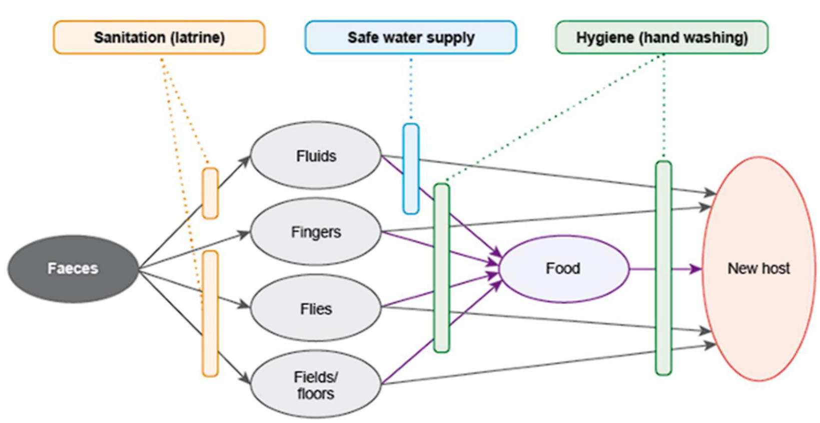


FIGURE: TRANSMISSION ROUTES

The faeces (on the left of the diagram) come from an infected person. The new host (on the right of the diagram) could be any man, woman or child who is not currently infected with the disease. Infections can be transmitted from faeces to the new host as follows:

- Infection from fluids usually involves drinking or cooking with water contaminated with faecal organisms.
- In the fingers pathway, a person ingests the organisms (usually during eating) if they have come into contact with faeces and have not washed their hands properly afterwards. This contact can occur from defecation, from cleaning a child's bottom, from touching dirty surfaces or eating food prepared in an unhygienic manner.
- Flies and cockroaches often thrive on excreta. If they land on food they can transfer faecal matter that can be subsequently ingested by a person.
- Field (or soil) infection can occur by the ingestion of unwashed raw vegetables and fruit grown in soil contaminated with faeces. Contaminated soil may be transported by feet or shoes for long distances. Infections can also be transmitted through dirty floors, perhaps if food is dropped on the floor and then picked up and eaten.
- Effective sanitation, clean water and good hygiene behavior provide barriers to this transmission and this can be the primary preventive measures

Preventive Measures:

- Wash hand before eating; use soap for washing.
- Protect Food, Water from fly and other disease carriers.
- Use pure drinking water.
- Keep the surrounding clear and free of diseases.
- Do not share the clothes used by infected person.
- Awareness programs about personal cleanliness, environment sanitation, and sanitary disposal of faeces should be launched.
- Wash vegetables and fruits properly before using them.

5.8 Water quality standard for drinking purposes

(A) National Drinking Water Quality Standard

S.N.	Category	Parameters	Units	Concentration Limits	Remark
1	Physical	Turbidity	NTU	5 (10)	
2		pH		6.5-8.5*	
3		Color	TCU	5 (15)	
4		Taste and Odor		Non-objectionable	
5		TDS	mg/L	1000	
6		Electrical conductivity (EC)	µs/cm	1500	
7	Chemical	Iron	mg/L	0.3 (3)	
8		Manganese	mg/L	0.2	
9		Arsenic	mg/L	0.05	
10		Cadmium	mg/L	0.003	
11		Chromium	mg/L	0.05	
12		Cyanide	mg/L	0.07	
13		Fluoride	mg/L	0.5 -1.5*	
14		Lead	mg/L	0.01	
15		Ammonia	mg/L	1.5	
16		Chloride	mg/L	250	
17		Sulphate	mg/L	250	
18		Nitrate	mg/L	50	
19		Copper	mg/L	1	
20		Total Hardness	mg/L as $CaCo_3$	500	
21		Calcium	mg/l	200	
22		Zinc	mg/L	3	
23		Mercury	mg/L	0.001	
24		Aluminum	mg/L	0.2	
25		Residual Chlorine	mg/L	0.1-0.2*	in systems using chlorination
26	Microbiological	E. Coli	MPN/100 ml	0	
27		Total Coliform	MPN/100 ml	0 in 95% samples	

* These values show lower and upper limits

( ) Values in parenthesis refers the acceptable values only when alternative is not available.

5.9 Water Sampling and Storing

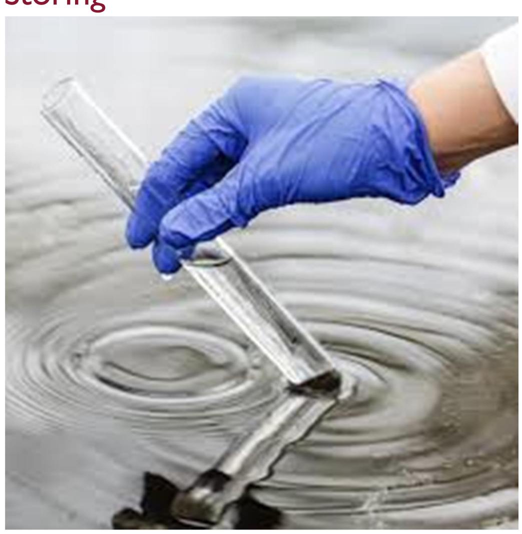


FIGURE: WATER SAMPLING

It is a process of collecting representative water samples from surface water bodies to ensure that acceptable field methods and Quality Assurance/ Quality Control procedures are followed when performing water quality assessments to ensure integrity and reliability of results.

Precaution while collecting the sample of water

- Should be handled with great care.
- Should be collected 40-50 cm below the surface.
- Pumped sufficiently before collecting the sample from ground source.
- Should be collected in clean and sterilized bottles having stoppers.
- Should be rinsed 2 or 3 times with the acids, distilled water and with water being collected.
- Proper location, depth and frequency of sampling are important.

Water Storing

1. **Containers:** Use clean, inert containers made from materials like glass, polyethylene, or stainless steel. The choice of material depends on the type of analysis being conducted. For instance, glass containers are typically used for organic compound analysis, while plastic is preferred for inorganic ions.
   A tag is tied on the bottle indicating the following:
   i. No. of samples.
   ii. Date of sampling.
   iii. Source of water.
   iv. Place of sampling, time of sampling.
   v. Temperature, atmospheric pressure.
   vi. Name and designation of person collecting samples

2. **Preservation:** Some water samples may need preservation to prevent changes in composition between the time of collection and analysis. This can involve refrigeration, adding preservatives (like acidifying with HCl or adding a biocide), or filtering the sample to remove particulate matter.

3. **Storage Conditions:** Store samples in cool, dark conditions to minimize the effects of light and temperature on the sample. The storage duration before analysis should be minimized to prevent degradation.

Water Sampling

Types of Sampling:

1. **Grab Sampling:** A single sample taken at a specific location and time. It provides a snapshot of the water quality at that moment.

2. **Composite Sampling:** A combination of samples taken over time or across different locations. It gives an average value for the water quality over a period or area.

Sampling Techniques:

1. **Surface Sampling:** Involves collecting water from the surface of the water body. Use a clean container, avoid disturbing the sediment, and rinse the container with the sample water before collection.
2. **Depth Sampling:** For deeper water, use a device like a Van Dorn bottle or a Niskin bottle, which allows sampling at specific depths.
3. **Flow-Proportional Sampling:** Often used in streams and rivers, where the sample collection rate is adjusted according to the water flow rate, ensuring a representative sample.

5.10 Physical Analysis

A. Temperature

- Measured by ordinary thermometer.
- Most desirable temperature of water for water is 4.4 °C 10°C, greater than 25 °C is undesirable and temperature of water above 35°C are unfit for drinking purposes .
- Temperature has an effect on properties - density, viscosity, vapors pressure, surface tension of water as well as chemical, biochemical and biological activity

B. Colour

- Ability to absorb the light.
- Colour is generally due to organic matters either in dissolved condition or in colloidal suspension, metallic ions, humus, industrial waste etc.
- The Colour produced by one mg of platinum cobalt in a liter of distilled water has been fixed as the unit of Colour (1 mg/lit of color in platinum cobalt scale)
- The Colour in water is not harmful but aesthetically objectionable.
- Measured using Tintometer.
- For public w/s the Colour of drinking water should not be greater than 5 mg/l in platinum cobalt scale, greater than 5 mg/l is tolerable but greater than 25 mg/l is rejected.
- It can also be measured in hazen unit °H.
- Colour can be removed by sedimentation, filtration, aeration and use of chemicals

C. Turbidity

- Turbidity is degree of clarity of water and resistance to the passage of light through it.

- Caused by suspended matters (clay, silt, finely divided organic and inorganic matters etc.), plankton, vegetable fibers, microorganisms etc.
- It makes water muddy, cloudy and aesthetically unattractive.
- It makes treatment process difficult.
- It is measured in terms of silica scale in mg/l or ppm.
- Turbidity produced by 1 mg of silica in 1 liter of distilled water represents 1mg/l turbidity in silica scale.
- For drinking turbidity within 5 ppm is acceptable, up to 10 ppm is tolerable but greater than 25ppm is rejected
- It can be removed by sedimentation, sedimentation with coagulation, filtration etc.
- Various instruments used to measure turbidity of water are as follows.
  - **i.** Turbidity rod or tape (In Field)
  - **ii.** Jackson's turbidimeter (In Lab)
  - **iii.** Baylis turbidimeter (In lab)

i. Turbidity rod or Tape

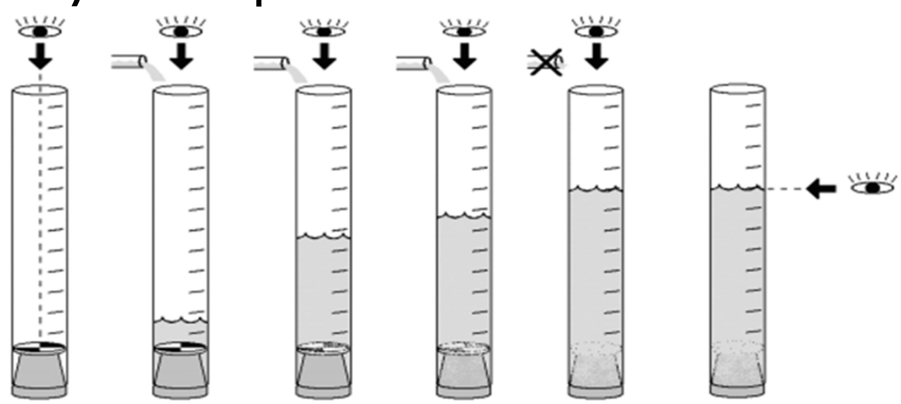


FIGURE: TURBIDITY TEST BY TURBIDITY ROD

In field, turbidity is measured using turbidity rod. It is graduated aluminum rod of about 203 mm long and platinum needle is fixed at the lower.

For test, a vertical stick is inserted in the nickel ring to support and keep the rod in position. The graduated aluminum rod lowered in water at the depth till the needle jut disappears from the eye view eye due to the turbidity of water. The turbidity of water can be read on the graduated scale near the water surface. This method gives rough value only.

ii. Jackson's turbidimeter

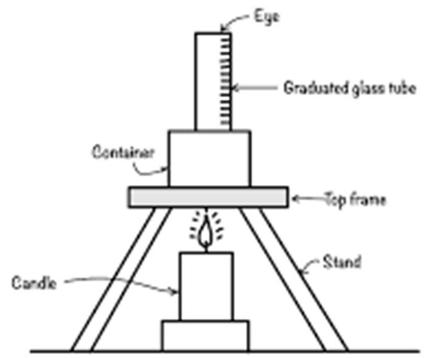


FIGURE: TURBIDITY TEST BY JACKSON'S TURBIDIMETER

In the lab the turbidity of water is measured with the help of Jackson Turbidimeter instrument

It consists of a graduated glass tube placed in a metal cylinder container, which is supported in standard stand and a standard candle is placed. To measure the turbidity, candle is lighted, some quantity of water is placed into the glass tube and image is observes from the top of glass tube. The depth of water increased by adding sample to the tube till the image of candle ceases to be seen. As the tube is -graduated give direct readings, the reading at the water level in the glass tube will be the turbidity of water.

D. Taste and Odour

Taste

- May be present in water due to the presence of dissolved gases, salts, organic matters, chemicals, minerals, suspended particles, aquatic life etc..
- Taste and odor is measured in terms of threshold number.
- Taste is measured by flavor threshold test.
- Water sample to be tested is diluted with water free from taste to the extent that mixture becomes taste free.
- Flavor threshold no. is given as:

  $FTN=\frac{A+B}{A}$

  A = volume of water sample in ml

  B = volume of taste free water (diluents') added in ml

Odor

- Odor is measured by threshold odour test.
- Water sample to be tested is diluted with water free from taste to the extent that mixture becomes taste free.
- Threshold odor no. is given as:

  $TON=\frac{A+B}{A}$

  FTN and TON should be preferably 1 but should not exceed 3.

Undesirable taste and odor can be removed by aeration and chemical treatment of water

5.11 Chemical Analysis

A. Total Solids

- Total solids (TS) are the sum of the total dissolved solids (TDS) and total suspended solids (TSS).
- Total solid is measured by evaporating the filter water (obtained from suspended solid test) and weighing the residual.
- TS, TSS and TDS are expressed in mg/l.
- TSS are normally present in small amount in water as compared to TDS.
- For drinking water, TDS should not be greater than 500mg/l, greater than 500 mg/l is tolerated but greater than 1500 mg/l is rejected.

$$\text{TSS, mg/L} = \frac{\text{Weight of Suspended Solids (g)}}{\text{sample volume, mL}}$$

B. pH value

The water found in nature, may be acidic or basic depending on the nature of dissolved salts and minerals. The acidity and alkalinity is measured in terms of pH value because pH value indicates the concentration of hydrogen ion in water. The water having pH-range 6.5 to 8 is suitable for drinking. The pH value of water can be determined by.

i. Colorimetric method
ii. Electrometric method

i. Colorimetric Method

In this method some indicator (such as methyl orange) is added to the water sample till the Colour Changes from original to final Colour of given indicator. This Colour produced is then compared to the Colour tubes, glass disc and charts supplied by the manufacturers and PH is determined.

ii. **Electrometric method**

This is the in instruments which measures the PH and displays in the digital display. The Instrument is first calibrated using two standard solution of known pH and then it is ready to use for PH measurement.

C. Chlorides content test:

The Chloride content in water is due to the mix of sewage water or use of saline water from sea. Excess of chloride - is dangerous and unfit for use. The chloride can be determined by titrating the water with silver nitrate and potassium chromate. In titration process reddish colours will be formed if chlorides are present.

Unit-6 Treatment of Water

6.1 Objectives of Water Treatment

The raw water which is found in various natural sources cannot be directly used by the public for the various purposes since it may contain various types of impurities like Floating matters (like leaves, dead animals), suspended impurities (silt, clay, sand) fine suspended matter, micro-organism and colloidal matters, dissolved gases, pathogenic bacteria. These are the chief source for spreading different types of diseases, germs. So, treatment of water is necessary before using it for our daily purpose and other Industrial use. The amount and type of treatment process will depend on the quality of raw water and the standards of quality to be required after treatment.

Objectives of water treatment:

The main objective of water treatment process is to remove the impurities of raw water and bring the quality of water to the required Standards.

The objective may be summarized as

a. To remove the dissolved gases, objectionable color, odour turbidity and hardness.
b. To kill all the pathogenic germs, which are harmful to the human health.
c. To make water fit for domestic use as cooking, and various industrial purpose.
d. To eliminate corrosive affecting pipe.
e. To reduce the impurities to a certain level that doesn't cause harm to human health.

Treatment system.

The treatment system directly depends on the Impurities present in water. For removing various types of impurities, the following treatment process is used.

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

6.2 Screening

The process followed by passing water through screens to remove large suspended matters like sticks, branches of tree, leaves, dead bodies, pebbles etc. and other small suspended matters is called screening. There are two types of screens.

1. Coarse Screen
2. Fine Screen

1. Coarse screen:

Coarse screens are generally placed in front of the fine at the inlet to remove large suspended floating matters generally from the surface source. These screens are generally called bar screen and consist of bar grills of 25mm diameter. Mostly bar screens are kept Inclined so that they can be cleaned easily with a rake and to increase flow area of opening. The opening are of 50 mm to 150 mm.

FIGURE:- COARSE SCREEN

2. Fine screen:

Fine screens are used to remove smaller suspended Impurities at the surface or ground water Intakes. Sometimes it is also used after a bar screen. It is generally used alone in the case of ground water intakes such as in spring intake. In case of surface intake, fine Screens are usually arranged with rotary drum perforated with holes of about 6mm diameter. Fine screen and normally get clogged are to be cleaned frequently. so, nowadays for surface intake fine screens are avoided and fine particles are separated in sedimentation.

FIGURE:- FINE SCREEN

6.3 Plain Sedimentation

Plain sedimentation is the process of removing suspended impurities like silt, sand, clay etc. present in water by keeping it in a tank or basin so that suspended matter may settle down in the bottom due to force of gravity. It is done after screening and before sedimentation with coagulation and is located near the filter units. The main purpose of plain sedimentation is to remove large amount of suspended particles present in raw water.

It has different advantages which are listed below.

- It lightens the load on the subsequent process.
- The operation of subsequent purification process can be controlled in a better way, because plain sedimentation delivers less variable quality of water.
- The cost of cleaning the chemical coagulation basin is reduced.
- No chemical is lost with sludge discharged from the plain setting basin.
- Less quantity of chemicals is required in subsequent treatment processes.

Type of sedimentation Tank

Sedimentation tanks are generally made of RCC and may be rectangular and circular in shape.

a. Rectangular tanks:

These are rectangular in plan and consist of large number of baffle walls. The function of baffle walls is to reduce the velocity of incoming water to increase the effective length of the travel of the particle and prevent the short circuiting. The tanks are provided with channel type Inlet and outlet expanding on the full width. Sludge pipe is provided at the floor through which sludge is taken out under hydrostatic force by operating the gate-valve.

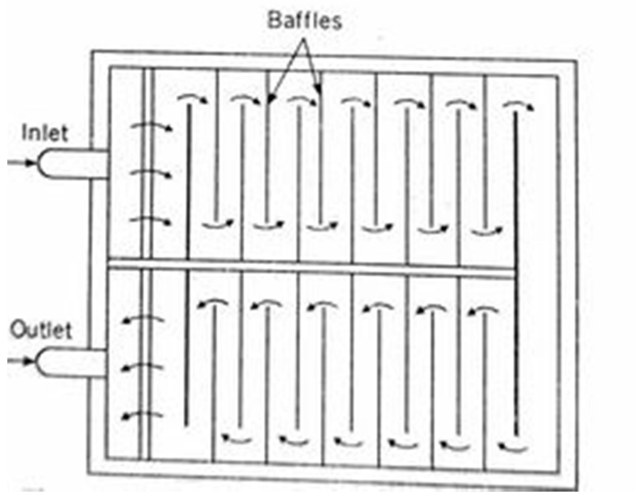


FIGURE:-RECTANGULAR SEDIMENTATION TANKS WITH BAFFLE WALL

b. Circular tank:

Circular tanks are generally used in sedimentation with coagulation. There are two types of sedimentation tanks classified based on flow of water inside it. They are radial flow circular tank and circumferential flow circular tank.

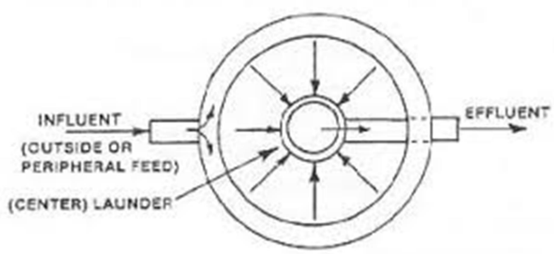
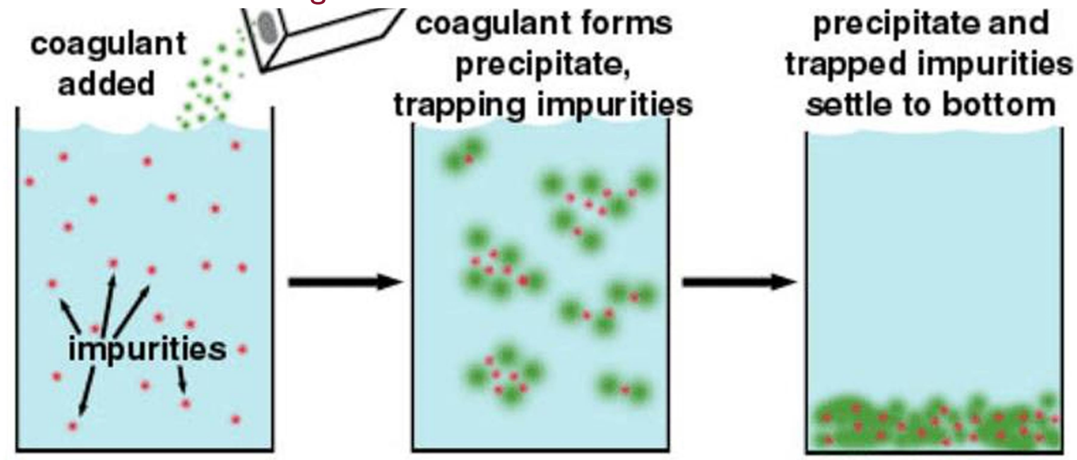


FIGURE:- CIRCULAR SEDIMENTATION TANK

In the case of radial flow circular tank waters inters in the tank trough central inlet pipe placed inside the deflector box. This deflector box deflects the water downwards and then it goes bottom side of the deflector box. The water flows racially from the deflector box towards the circumference of the tank where outlet is provided on the full periphery. All the suspended particles settle downwards on the sloppy floor and clear water goes through the outlet.

6.4 Sedimentation with coagulation



Sometimes very fine suspended particles cannot be removed by plain sedimentation. The settling down and removal of such fine suspended particles and Colloidal matter can be achieved by chemically assisted sedimentation called as sedimentation with coagulation. In this process certain chemicals are added to water due to which insoluble gelatinous preceptor is formed. This precipitate has the property of removing fine and colloidal particles quickly and completely. The chemical removes color, odor, and taste. After Precipitation, the water is sent to sedimentation basins where sedimentation of fine and colloidal particles, takes place through the precipitate.

The process of adding coagulants to raw water and mixing it thoroughly is known as **coagulation**.

The chemical added during the process of coagulation are called **coagulant**.

The different types of coagulants used during the process are

i. Aluminum Sulphate or alum.
ii. Iron Salts
iii. Chlorinated coppers
iv. Sodium aluminate

i. Aluminum Sulphate or alum (फिटकिरी)

This is the chemical coagulant which is widely used in water treatment plants. It reacts in water in the presence of alkalinity and if natural alkalinity is not present sufficient lime is added.
The following reaction takes place with various types of alkalinities.

Reaction:-

i) $Al_2(S0_4)_3.18H_2O + 3ca\ (HCO_3)_2 \rightarrow 2\ Al\ (OH)_3 + 3CaS0_4 + 18H_2O + 6CO_2$

(Alum) (Floc) ↓ Increase hardness ↓ Increases corrosiveness

ii) $Al_2(S0_4)_3.18H_2O + 2ca\ (OH)_2 \rightarrow 2Al\ (OH)_3 + 3CaS04 + 28H_2O$.

iii) $Al_2(S0_4)_3.\ 18H_2O + 3Na_2Co_3 \rightarrow 2Al\ (OH)_3 + 3Na_2S04 + 18H_2O + 3Co_2$.

Dose → 7 to 20 mg/l. (14 usual does)

Does depend upon turbidity, colour, taste, PH value, temp^r etc.

The insoluble and Colloidal aluminum hydroxide $Al(OH)_3$ forms the floc which removes the fine suspended & colloidal impurities. It is suitable for water having pH value between 6.5 and 8.5. The alum required for coagulation mainly depends on the turbidity and Colour of water. The dose of alum varies from 5mg/l for relatively clear water to about 25mg/ l for very turbid water.

Advantages:

- It forms excellent floc which is better than that form by any other coagulant.
- The floc formed is stable & not broken easily.
- It is relatively cheap and removes Odour taste and Colour.
- It does not require skilled supervision & produces clear and Crystal free water.

ii. Iron Salts

The various irons salts used as coagulants are ferrous sulphate, ferric Sulphate and ferric Chloride.

- **Ferrous sulphate ($FeSo_4.7H_2O$)**

  It is commonly used in coagulation and is cheaper than alum. It gives good result for water having pH Valve above 8.5. It is used along with lime.

  $FeSo_4.7H_2O + Ca(OH)_2 \rightarrow Fe(OH)_2 + CaSo_4 + 7H_2O$

  Here, $Fe(OH)_2$ is unstable and absorbs dissolved oxygen and forms the stable floc. $4\ Fe\ (OH)_2 + 2H_2O + O2 \rightarrow 4Fe_2\ (OH)_3\downarrow$.

- Ferric Sulphates ($Fe_2(SO_4)_3$)

  It is also used as a coagulant in conjunction with lime and the reaction is

  $Fe_2(SO_4)_3 + 3Ca(OH)_2 \rightarrow 2Fe(OH)3\downarrow + 3CaSo_4$

  The effective pH range with ferric sulphate is 4 to 7.

h. Ferric Chloride ($FeCl_3$)

It is used as a coagulant in conjunction with lime or without lime. The effective range of pH for coagulant with ferric Chloride is 3.5 to 6.5.

$FeCl_3 + 3H2O \rightarrow Fe(OH)_3 + 3H^+ + cl^-$ (when used without lime)
$2FeCl_3 + 3Ca(OH)_2 \rightarrow 2Fe(OH)_3\downarrow + CaCl_2$ (when use with lime)

Advantages:

- Produce, fast forming, denser, quick set and less breakable floc than alum.
- Can be used over a wide range of pH value.

iii. Chlorinated coppers

It is the Combination of ferric sulphate and ferric chloride.

$$6FeS04.\ 7H_2O + 3Cl_2 \rightarrow 2Fe_2\ (S04)_3 + 2FeCl_3 + 4\ 2H_2O$$
$$2Fe.Cl_3 + 3Ca\ (HCO_3)_2 \rightarrow 2Fe\ (OH)_3 + 3CaCl_2 + 6CO_2\ .$$
$$2FeCl_3 + 3Ca\ (OH)_2 \rightarrow 2Fe(OH)_3 + 3Cacl_2\ .$$
$$Fe_2\ (S04)_3 + 3\ Ca\ (HCO_3)_2 \rightarrow 2Fe\ (OH)_3 + 3CaS04 + 6CO_2\ .$$

iv. Sodium aluminate

Reacts with salts of calcium and magnesium.

$$Na_2Al_2O_4 + Ca\ (HCO_3)_2 \rightarrow Ca\ Al_2O_4 + Na_2CO_3 + CO_2 + H_2O.$$
$$Na_2Al_2O_4 + CaCl_2 \rightarrow CaAl_2O_4 + 2NaCl.$$
$$Na_2Al_2O_4 + CaS0_4 \rightarrow CaAl_2O_4 + Na_2S0_4.$$

- Removes both temp. and permanent hardness and is effective for a pH range of 6 to 8.5 .

***Process of sedimentation with coagulation**

The different operations involved in sedimentation with coagulation are

a) Feeding the coagulant
b) Mixing of coagulant
c) Flocculation
d) Sedimentation.

a) Feeding the coagulant:

The coagulant may feed to raw water either in powder form or in solution form. The feeding is done with using dry feeding or wet feeding devices. The choice between wet and wet feeding depends on

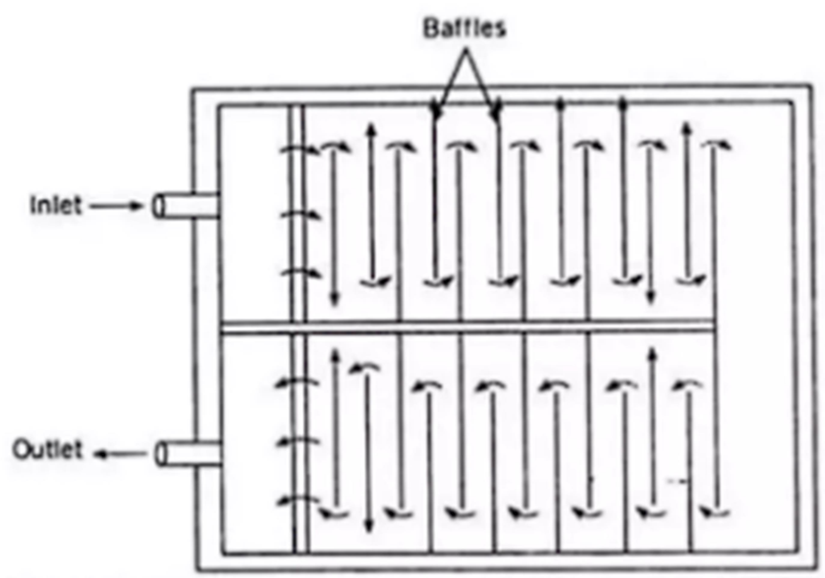
- Type of coagulant, and the economy in total cost of plant.
- Dosage of coagulants: High dose dry feed & Vice versa.
- Size of the treatment: large size wet feeder is used and vice versa.

b) Mixing of coagulants:

After adding coagulants in water, then next operation is to mix thoroughly in water so that they fully disperse into the entire mass of water. This mixing is done by mixing devices. Various Mixing devices are as follows.

- Mixing basin with baffle walls.
- Mixing basin with mechanical means.
- Mixing Channel.
- Hydraulic Jump method.
- Compressed air method.
- Centrifugal pumping method.

Mixing basin with baffle walls



These are rectangular basin or tanks which are provided with baffle walls. The disturbance is created by the presence of baffle walls in the path of following water causes vigorous agitation of water which resolves in through mixing of water with coagulant.

c) Flocculation:

The process of formation of floc is called flocculation. From the mixing basin water is taken to the flocculator for flocculation. In flocculator slow stirring of water is done to buildup of the floc particle. The flocculator provides the number of gentle contacts between the flocculating particles which are necessary for the formation of floc.

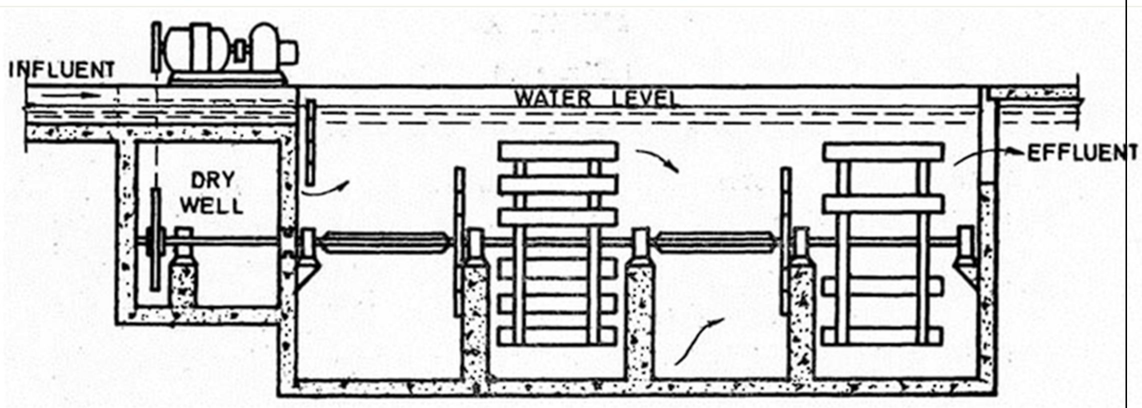


FIGURE: MECHANICAL FLOCCULATOR

d) sedimentation/Clarifiers

The water from the flocculator is taken to the sedimentation tank or clarifier. In this open tank the floc which has been formed above is allowed to settle and is separated from the water. It consists of floc chamber and sedimentation tank as shown in figure.

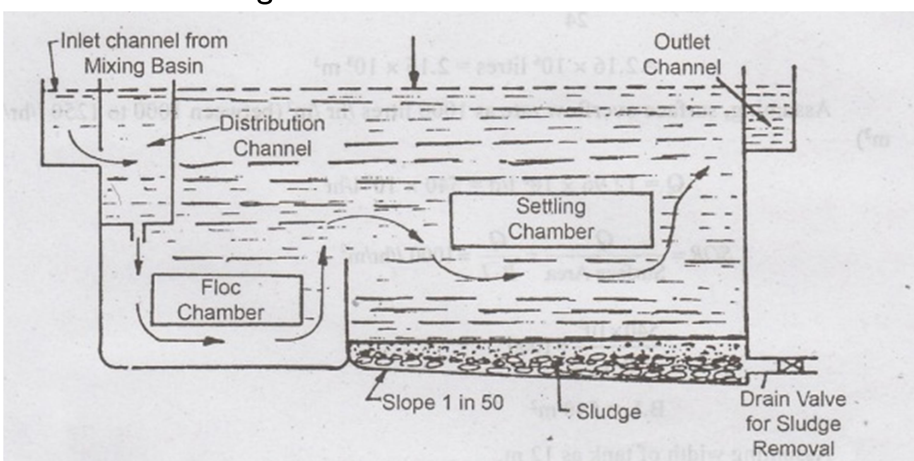


Fig. 2.14 Coagulation – Sedimentation Tank

The detention period for floc chamber is about 15 to 40 minutes and that for sedimentation tank is about 3 to 4 hours.

Dorr Clariflocculator

The all four process (i.e. coagulant feeling, flash mixing, flocculation and clarification) may be done in a single unit called Dorr Clariflocculator.

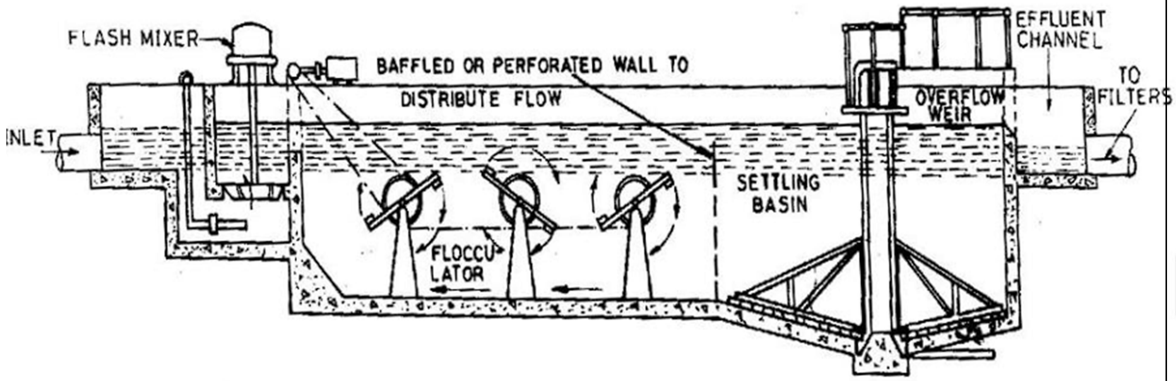


FIGURE: DORR CLARIFLOCCULATOR

The coagulant is fed into raw water through the feeding device and the mixture is thoroughly mixed in the flash Mixture then it flows to the flocculator. Here the slow stirring of water permits the formation of floc particles. The flocculated water is then passed into the Clarifier where the floc along with the suspended and colloidal matter present in water settle down and are thus removed. The water from the clarifier than flows to the filter.

Jar Test

FIGURE: JAR TEST

The optimum dose of coagulants is determined by Jar test. At First all the sample of water is taken in every jar. Then coagulant is added in jar in varying amount. The quantity of coagulant added in each jar is noted. With the help of electric motor all the paddles are rotated at a speed of 30-40 R.P.M for about 10 min. After this the speed is reduced & paddles are rotated for about 20-30 min. The rotation of paddle is stopped and the floc formed in each jar is noted and is allow settling. The dose of coagulant which gives the best floc is the optimum dose of coagulants.

6.5 Filtration

The process of removing dissolved minerals, microscopic organism, Colour, taste, odour, and very fine colloidal impurities by passing water through the bed of sand or other granular materials is called filtration.

Theory of filtration

When water is passed through the bed of filter media, the following action takes place. They are

i. Mechanical Straining
ii. Sedimentation and adsorption.
iii. Biological Metabolism
iv. Electrolytic Action

i. Mechanical Straining:
Sand consists of small pores therefore suspended particles which are large in size cannot pass through sand bed and are trapped then removed which is called mechanical straining. Due to smaller in size of colloidal matters or bacteria they may not be strained.

ii. **Sedimentation and adsorption:**
The void between the sand bed acts as small settling basin. Very small particles of suspended matter, colloidal particles and some bacteria settle in these settling basins. Due to the physical attraction been the suspended particle and sand grain and presence of gelatinous coating formed due to these matters and bacteria adheres them and are removed.

iii. **Biological Metabolism:**
Suspended impurities contains some portion of organic Impurities such as algae, plankton etc. which are caught by voids between sand grain. These matters are used by bacteria for survival and convert them into harmless compounds from biological metabolism. These harmless compounds formed are deposited at the surface of sand which is known as dirty skin. Bacteria not only break into organic impurities into harmless compound but also destroy each other and make a balance life in the filter.

iv. **Electrolytic action:**
When two substances of opposite charges come into contact, the Charge is neutralized and in doing so, new Chemical substances are formed. Sand Particles in filter media also have changes of some polarity. This attracts the Suspended, Colloidal, and dissolved matter of opposing polarity in neutralizing and changes the chemical Characteristics of Water. After long use the electric charge of filter sand is exhausted, which is renewed by washing the filter bed.

Types of filters

A tank or device with filter Media uses for the filtration is called filter. Based on the filtration rate and driving force to overcome friction by water flowing, they classified as follows.

i. Slow sand filter (SSF)
ii. Rapid-Sand filter (RSE)
iii. Pressure filter (PF)

i. Slow Sand Filter

Slow sand filter is the earliest type of gravity filter whose rate of filtration is slow (≤1/20th of that RSF or PF). It requires greater quantity of sand and larger surface area. Bed clearing of slow sand filter is done by surface scraping which involves a lot of labors and cost hence it is suitable for small town.

Construction

The Slow sand filter is watertight shallow tanks about 2.5 to 4 m deep and having surface area 100m^2 to 2000 m^2 in plan. This tank consists of 60-90 cm bed of sand supported on 30-60 cm thick gravel bed. A section of slow sand filter is shown in figure below.

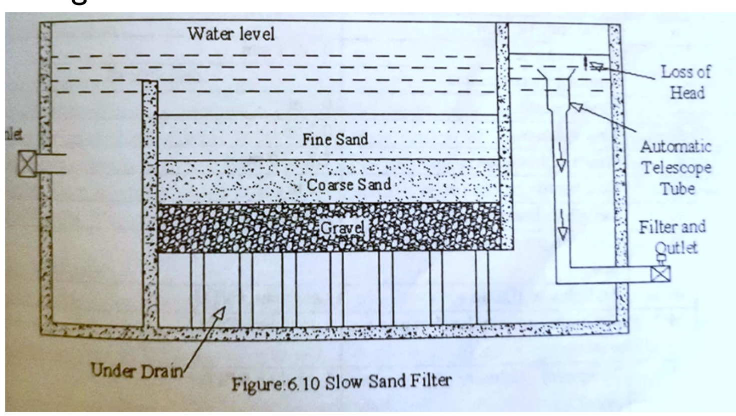


FIGURE: - SECTION OF SLOW SAND FILTER

Components of Slow Sand Filter

i. Inlet
ii. Enclosure tank
iii. Filter media
iv. Base material
v. Under drainage system
vi. Appurtenance
vii. Outlet

i. Inlet

The inlet of a slow sand filter consists of chamber fitted with Sluice value or one equilibrium float valve. Mostly the inlet pipe is carried vertically in the body of the filter with the mouth of the inlet pipe flush with the water level.

ii. Enclosure Tank

Open and watertight rectangular tank made up of masonry or concrete.

- Depth : 2.5 m to 4m
- Surface area: 100 to 2000 m^2
- Filtration rate: 100 to 200 lph/m^2
- Length to width ratio: 2
- Cross slope in floor of tank: 1 in 100 to 1 in 200 towards the central drain.

iii. **Filter Media**
It consists of 90 to 110 cm thick Sand layer with effective size of sand 0.25 to 0.3mm. Finer the sand there will be better turbidity and bacterial removal but lowers the filtration rate.

iv. **Base Materials**
The sand layer is supported on base material of 30-60mm thick gravel bed. Four layer of gravel bed each about 15 cm thickness with size 3-6, 6-20, 20-40 and 40-65 mm are provided from top.

v. **Under drainage system:** This system supports filter media and the base material then collect water to deliver it in clear water reservoir.

vi. **Outlet:** Water after passing through the filter bed is collected in the outlet chamber where a regulating arrangement is provided to obtain a regular discharge from the filter.

vii. **Appurtenances:** In addition to the arrangement described above, some other appurtenances are also used in the filtration. Some of them are vertical air pipe, depth controlling devices, head loss measuring device, rate maintaining devices.

Operation:

The water from the sedimentation tanks enters the slow sand filter through inlet then passes through filter media. The water is uniformly distributed over the sand bed without causing any disturbances. The filtration is continued until the difference between the water lever on the filter and in the outlet, chamber is slightly less than the depth of water above the sand. The purified water is collected by under drains and comes out from outlet clean water reservoir.

Maintenance
During filtration, the filtration media gets clogged due to Impurities which stay in the pores. Due to this the resistance of to the passage of water and loss of head also continuously increases. So, about 2-3 cm sand from the top of bed is

scrapped and replaced with clear sand. The scrapped sand is washed with water, dried, and stored for the future, use. SSF is cleaned after 1-3 months depending upon impurities.

Result of slow sand filtration

Slow sand filter are highly efficient in the removal of bacterial load from water. It is expected that they may remove about 98 to 99% of bacterial load. It also removes tastes and Colour from the water.

ii. Rapid Sand Filter

Rapid sand filters are the most commonly used gravity filters in large water supply. System. In these filters the water is passed after Sedimentation with coagulation.

Construction:

Rapid gravity filter consists of an open watertight rectangular tank constructed with masonry or concrete. The depth of tank varies from 2.5 to 3.5 m

A section through a rapid sand filter is shown in the figure.

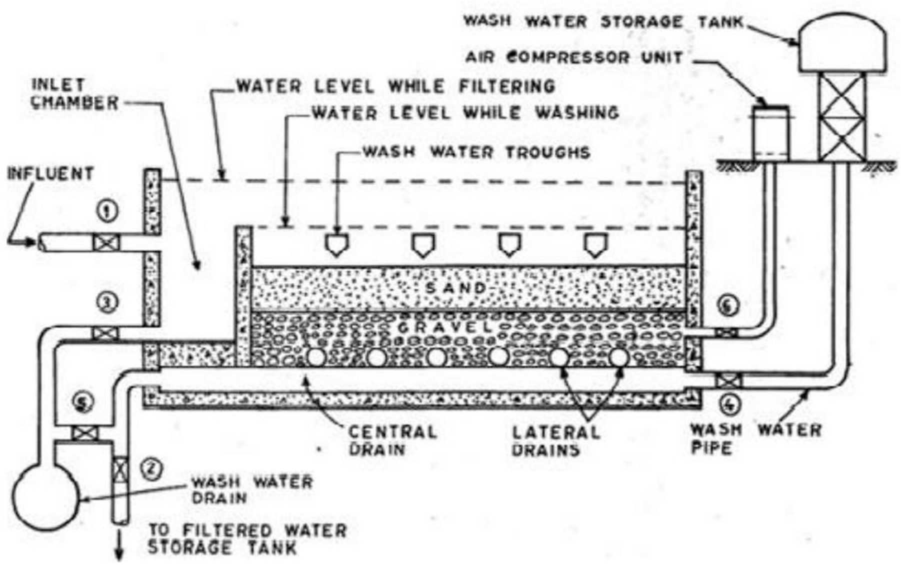


FIGURE:-SECTION OF RAPID SAND FILTER

Components of Rapid Sand Filter

i. Enclosure tank
ii. Filter media
iii. Base material
iv. Under drainage system
v. Appurtenance
vi. Outlet

a) Enclosure Tank

It is open and watertight rectangular tank made of masonry or concrete. The depth is 2.5 to 3.5m; surface area is 10-50 m^2. Various numbers of filters units in series may be provided.

b) Filter media

The filter media consists of coarse sand layers of effective size varying from 0.35 mm to 0.55 mm. the finer variety is kept near top and coarser variety near the bottom.

c) Base materials

The base material Consists of gravel in thickness of 60-90 cm. usually first Six layers each of 10-15cm are used. The sand layer is supported by base materials and should be of uniform grading for proper and efficient function of the filter.

d) **Under drainage system**

The under drainage system is provided to collect the filtered water to provide uniform distribution for back wash.

e) **Appurtenances**

Various types of accessory such as head loss indicator, wash water trough, air compressor, rate control device etc. are also used in rapid sand filter.

Operation:

The water from the coagulation sedimentations tank enters the filter unit through uniformly distributed on inlet and is uniformly distributed on the whole sand water after passing through the sand bed is collected through the under drainage system in the filtered water well. The outlet chamber in this filter is equipped with filter rate controller. In the beginning, the loss of head is very small. But as the bed gets clogged the loss in head increases and the controller adjusts it to a limit.

Maintenance

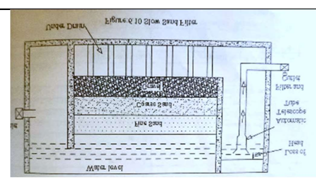
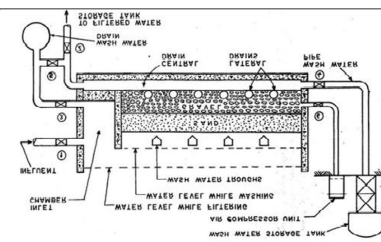
As sand as the bed get clogged, the loss of head increases due to which the rate of filtration is low and thus filter bed requires it's washing. It is done by the back flow of water through the sand bed. Nowadays, the washing of filter bed is done only at the surface by applying clear water at a rate of 270 l /m²/min under a pressure of 0.7 to 1.1 kg/cm² through nozzles.

Results of Rapid Sand Filter

Rapid sand filter removes suspended matter, color, odour and bacteria from water. It is less efficient in iron and manganese removal. This filter cannot remove bacteria completely; therefore filtrate water must be disinfected.

*Comparison between slow sand filter and Rapid Gravity Filter (Rapid Sand Filter)

Item	Slow Sand Filter (SSF)	Rapid Sand Filter (RSF)
1. Area requirements	Requires very large area (50 to 1000 m^2).	Requires Small Area (10 to 50 m^2.

2. Filtration Rate	100 to 200 lit/hr/m^2	3000 to 6000 lit/hr/m^2
3. Quantity of sand	Requires considerable quantity of sand.	Requires less quantity of sand.
4. Quality of Sand	Finer filter media of 0.2 to 0.4 mm effective size.	Slightly coarser filter media of 0.4 to 0.6 effective sizes.
5. Quality of Raw water	It may not be treated with chemical but should not have turbidity more than 50 PPM.	Treatment with chemical is essential.
6. Distribution	Uniform	Smaller in top and coarse in bottom.
7. Period of cleaning	1 to 3 months	1 to 3 days
8. Method of Cleaning	Scrapping 2-3 cm from the surface and replacing it with new sand.	By back washing with water under pressure.
9. Function of under drains	Only collects filtrate water.	Collect water and distribute of backwashed water.
10. Skill Supervision	Not required.	Most Essential.
11. Loss of head	15 cm to 75 cm.	2 m to 4 m.
12. Cost of maintenance	Small.	More.
13. Efficiency	Efficient in removal of bacteria and suspended matter.	Cannot remove all bacteria, disinfection is necessary. Removes Colour, taste and odour.
14. Figure		

iii. Pressure Filter

It is a rapid sand filter consists of a steel cylindrical tank in which water under pressure. The operation of pressure filter is similar that of rapid sand filter except that the coagulated water is directly applied to the filter without mixing and flocculation. The filters are used on small supplies where is received under pressure. Mostly, these are used for industrial plants. The pressure filter may be vertical or horizontal. The size of vertical filters varies generally from 0.3m to 2.75m in diameter and height may be 2 to 2.5m.The cleaning of filter bed is done by back washing like rapid gravity filter.

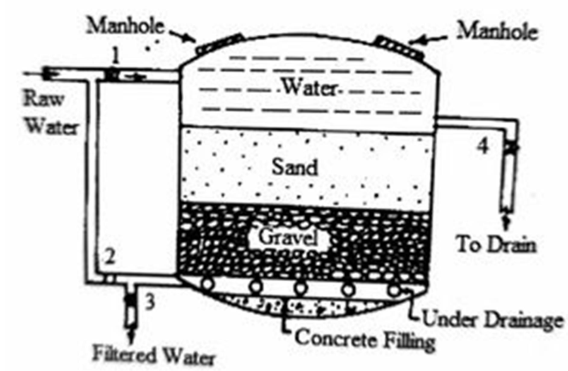


FIGURE: - PRESSURE FILTER

6.6 Disinfection

The process of killing the pathogens from the water and making it safe to the user is called **disinfection**. The filters are unable to remove all the disease bacteria. They can only remove few types of bacteria. So, it is necessary to kill all the disease-causing bacteria by using chemicals or substances, the chemicals substances which are used for killing bacteria are known as disinfectants. Among different disinfectant chlorine has been found as the most ideal disinfectant and is widely used at all the water works.

Requirements for a good disinfectant.

- The disinfectants should be able to destroy all harmful bacteria from the water and make it perfectly safe for use.
- They should do their task within the required time at normal temperature.
- They should be economically and easily available.
- It should be safe to handle, and method of application should be simple.
- After their treatment, the water should not become toxic or impact Colour and odour.
- The nature of disinfectants should be such that their concentration or strength in treated water can be quickly determined.

Methods of disinfection

The disinfection of water can be done by the following methods.

- Chlorination.
- Boiling
- Ultra-violet ray treatment
- Ozone treatment.
- Electro catadyne method
- Sodis method
- Potassium permanganate treatment.

a) Disinfection by boiling

The water can be disinfected by boiling for 15 to 20 min. By boiling all the disease-causing bacteria are killed and water becomes safe for use. This process can only, kill the existing germs but does not provide any protection against future possible contamination.

b) Disinfection by ultra-violet ray

Ultra-violet rays are highly disinfectants and kill the disease bacteria. This process is very costly and requires skill manpower and costly equipment. When these rays pass through turbidity removed water, they penetrate in water and kill the bacteria.

c) Disinfection with ozone

Ozone is an excellent disinfectant. It is used in gaseous form, which is faintly blue in color and of pungent odour. Ozone is produced by passing a high tension electric current through a stream of air in closed chamber.

$$3O_2 \xrightarrow[\text{Electric voltage}]{\text{Passing through high}} 2O_3$$

The ozone is highly unstable so it breaks down in the ordinary oxygen and liberates nascent oxygen.

$$O_3 \longrightarrow O_2 + O \text{ (nascent oxygen)}$$

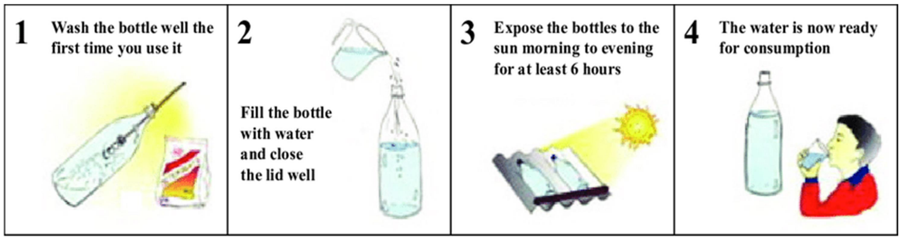
The nascent oxygen is very powerful oxidizing agent and it kills all the bacteria as well as oxidizes the organic matter present in water.

d) Electro catadyne method

The electro catadyne method for water disinfection utilizes electric current to generate disinfecting agents within the water.

During this process, an electric current is passed through water using electrodes, often made of titanium or mixed metal oxides, leading to the electrolysis of water. This results in the production of reactive species such as hydroxyl radicals, ozone, and hydrogen peroxide, which possess strong oxidizing properties capable of effectively killing or inactivating a wide range of microorganisms, including bacteria, viruses, and protozoa. The method may also produce some byproducts like chlorine or chloramines if chloride ions are present in the water. This approach is advantageous as it doesn't require the addition of external chemicals and is highly effective against various pathogens.

e) Sodis method



The SODIS (Solar Water Disinfection) method is a simple and low-cost technique for disinfecting water using solar energy. In this method, clear PET(polyethylene terephthalate) plastic bottles are filled with contaminated water and then placed in direct sunlight for at least six hours, or up to two days if the weather is cloudy. The ultraviolet (UV-A) rays from the sun, combined with the increased temperature inside the bottles, effectively kill or inactivate harmful pathogens such as bacteria, viruses, and parasites. SODIS is particularly suitable for small-scale water purification in areas with limited access to clean drinking water, as it does not require any chemicals or complex equipment. This method is widely used in developing countries due to its simplicity, affordability, and effectiveness in reducing waterborne diseases.

f) **Potassium permanganate treatment.**

This is most common disinfectant used in village for disinfection of dug well water, pond water or private sources of water. In addition to killing of bacteria, it also reduces the organic matters by oxidizing them.

6.7 Chlorination

Chlorine and its compound used in proper quantity as disinfectant in water are called Chlorination. Chlorine is most ideal disinfectant, throughout the world and is widely used at all the water works.

When Chlorine is dissolved in water it hydrolysis immediately as

$$Cl_2 + H_2O \leftrightarrow HOCl^- + H^+ + Cl^-$$

After some time, the hypochlorous acid further Ionizes as

$$HOCl^- \leftrightarrow H^+ + OCl^-$$

The Hypochlorous acid (HOCl) and hypochlorite ion (OCL^-) penetrate cell walls and reacts with the enzyme system in the cell of microorganism which result the death of the micro-organism.

Chlorine dose/demand

It is defined as the difference between the amount of Chlorine added to water and the amount of Chlorine remaining at the end of a specified contact period.

The quantity of chlorine required to be added to water to leave 0.2 mg/l or ppm of freely available residual chlorine after 10 min of contact process is called optimum dose of Chlorine.

The Chlorine demand for sample of water depends on

- Nature and concentration of chlorine consuming substances present in water.
- Time of contact.
- PH-valve of water.
- Temperature of water
- Variable conditions in the process of Chlorination.
- And so many other factors.

The Chlorine dose for given water can be determined by two methods.

In the first method tests are made and the residual Chlorine is determined to for Various Chlorine doses. The results are then plotted on a graph paper and a smooth curve is drawn. From the curve, the dose corresponding to the desired residual is determined directly. Second method is mathematical method in which the required dose is extrapolated or Interpolated from the observed values

Forms of Chlorination

Depending upon the stage of treatment at which Chlorine is applied to water and also upon the expected results of application of Chlorine; chlorination may be of following forms.

a) Plain chlorination
b) Pre-chlorination
c) Post Chlorination
d) Double Chlorination
e) Break point Chlorination
f) Super Chlorination.
g) De-chlorination.

a) Plain Chlorination

The application of Chlorine to plain or raw water is called plain Chlorination. The water of lakes and springs are pure and can be used after plain Chlorination. The dose of plain Chlorination is 0.5 to 1 ppm.

b) Pre-chlorination

When Chlorine is added to raw water before any treatment it is known as pre chlorination. Thus chlorine is added in small dose before raw water enters sedimentation tanks. It has following advantages.

- Reduces quantity of coagulants required.
- Reduces bacterial load in the filter.
- Eliminates taste and Odour.
- Controls the algae and planktons in the filter.

c) Post chlorination

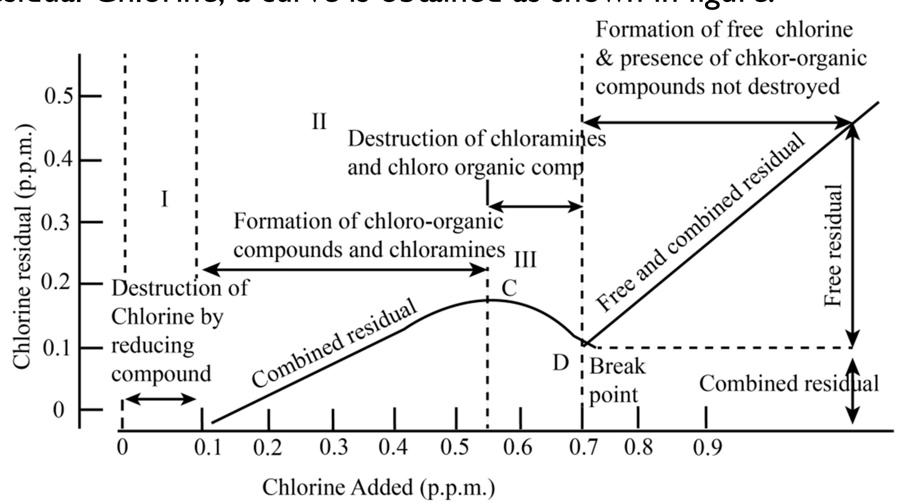
The application of Chlorine after all treatment is called post chlorination. It is applied after filtration and before entering into the distribution pipe. The contact period should be 30 min, before use of water.

d) Double Chlorination

When raw water containing large number of bacteria, Chlorine is applied two or more points in purification process, it called double or multiple Chlorination. It consists of pre-chlorination just before the raw water enters the sedimentation tank and post chlorination at water leaves the filter and before entering the distribution system.

e) Break point Chlorination

The application Chlorine to the water with Chlorine dose equal to slightly higher than that at which break point occurs is known as break point Chlorination. When chlorine is added to water, it reacts with organic and inorganic matters and forms common compounds. If chlorine demand is less in water, any Chlorine added to such water will appear as residual Chlorine. Now, if the chlorine dose is increased, the combined available residual Chlorine also increased. Then the Chlorine dose is so increased the compound get oxidized and the substance which are newly formed does not react with orthotolodine to show any residual. If the addition of Chlorine is continued & a graph is plotted between Chlorine dose & residual Chlorine, a curve is obtained as shown in figure.



On studying the curve, it will be noticed that, Residual Chlorine in the beginning increases with the applied chlorine dose but after point is it suddenly drop up to point D. The point at which residuals Chlorine again starts increasing are known as Break Point Chlorination. After reaching this point if chlorine is added, it remains as free residual Curve becomes a straight line.

f) Super Chlorination

The application of chlorine beyond the break point Chlorination is called super chlorination. It is done during epidemics in certain locality due to water borne diseases. Generally 2 to 3 ppm beyond the break point is applied for super chlorination.

g) Dechlorination

It is defined as the partial or complete reduction of residual Chlorine in water by chemical or physical treatment. In this method, some chemicals are added for the purpose of reducing the chlorine residual to a desired value.

The Different Methods of dechlorination,

- Sulphur dioxide (SO_2): It is mostly used for larger plants.

  $$SO_2 + Cl_2 + 2H_2O \longrightarrow H_2SO_4 + 2HCL$$

  The acids so formed are neutralized by the natural alkalinity present in the water.

- Sodium Bi-sulphate ($NaHSO_3$): It is used for smaller treatment plants. It is cheaper and more suitable than sodium sulphate.

  $$NaHSO_3 + Cl_2 + 2H_2O \longrightarrow NaHSO_4 + 2HCL$$

Advantages of Break point Chlorination

- ➢ It completely oxidizes the ammonia and other Impurities of water.
- ➢ The Colour of water due to organic matters is also removed.
- ➢ It completely destroys all the disease bacteria.
- ➢ It removes taste and odour from the water.
- ➢ It prevents growth of weeds in water.

Test of Chlorine

The determination of chlorine (residual) after the desired contact period is necessary. For this we can use Orthotolidine and the test is known as Orthotolidine test.

This is most easy and common test for determining the residual chlorine. In this test 100 ml of Chlorinated water sample is collected in test tube. 1 ml of Orthotolidine. Solution is added in the test tube. The Colour formed is noted and the value of the residual chlorine is directly determined by comparing the Colour so obtained with the standard Colour of known chlorine residuals.

6.8 Softening

Water Softening is the process of removing hardness-causing minerals, primarily calcium (Ca^{2+}) and magnesium (Mg^{2+}), from water. The hardness in water can cause various problems such as scale buildup in pipes, reduced soap effectiveness, and damage to appliances.

A. Temporary hardness is caused by the presence of dissolved bicarbonate minerals, primarily calcium bicarbonate ($Ca(HCO_3)_2$) and magnesium bicarbonate ($Mg(HCO_3)_2$). This type of hardness is called "temporary" because it can be removed by boiling or adding certain chemicals that precipitate the bicarbonates.

Removal Methods for Temporary Hardness

1. **Boiling**
   Boiling water is a simple and effective method to remove temporary hardness. When water is boiled, the bicarbonate ions decompose into carbonate ions, carbon dioxide, and water. The carbonate ions then react with calcium and magnesium ions to form insoluble carbonate salts, which precipitate out of the water.
2. **Addition of Lime (Lime Softening)**
   Adding lime (calcium hydroxide, $Ca(OH)_2$) to water can also remove temporary hardness. The lime reacts with the bicarbonates to form insoluble carbonates, which then precipitate out.

$$\mathrm{Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 \downarrow + 2H_2O}$$

$$\mathrm{Mg(HCO_3)_2 + Ca(OH)_2 \rightarrow CaCO_3 \downarrow + MgCO_3 \downarrow + 2H_2O}$$

B. Permanent hardness is caused by the presence of dissolved minerals that cannot be removed by boiling. These minerals primarily include calcium and magnesium sulfates, chlorides, and nitrates (e.g., $CaSO_4$, $MgSO_4$, $CaCl_2$, $MgCl_2$).

Removal Methods for Permanent Hardness

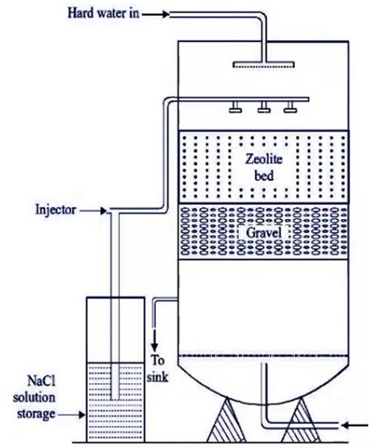
1. **Ion Exchange Method (Zeolite Process)**

Zeolite Process of Water Treatment

After sometime, the zeolite will be exhausted. At this stage the hard water supply is stopped and the sodium zeolite will be retained by passing NaCl solution

$$CaZ + 2NaCl \rightarrow Na_2Z + CaCl_2$$

$$MgZ + 2NaCl \rightarrow Na_2Z + MgCl_2$$



This is the most common and effective method for removing permanent hardness.
Process:

- Hard water passes through a resin bed containing sodium (Na^+) or potassium (K^+) ions.
- Calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in the water are exchanged with sodium or potassium ions in the resin.
- The softened water, now containing sodium or potassium ions, exits the softener.

2. Lime-Soda Softening:

Adding lime (calcium hydroxide, $Ca(OH)_2$) and soda ash (sodium carbonate, Na_2CO_3) to precipitate calcium and magnesium as their insoluble carbonates.

Reactions:

$$Ca^{2+} + Na_2CO_3 \rightarrow CaCO_3 \downarrow + 2Na^+$$

$$Mg^{2+} + 2NaOH \rightarrow Mg(OH)_2 \downarrow + 2Na^+$$

Advantages:

- Effective for large-scale water treatment.
- Reduces both temporary and permanent hardness.

Disadvantages:

- Requires careful handling and dosing of chemicals.
- Produces sludge that needs to be disposed of.

6.9 Miscellaneous treatment

1. Aeration Methods

The Colour, odour and taste in the water comes due to the presence of dissolved gases such as hydrogen, Sulphide organic water industrial wastes containing

Phenol, excessive Chlorine etc. Aeration method can be used for removing the Colour, odour and tastes.

Aeration is the process of bringing water in intimate contact with air. While a doing so, the water absorbs oxygen from the air. The carbon dioxide gas is also removed up to 70% and up to certain extent bacteria are also killed. Iron, Manganese and gas are also removed up to certain extent from the water.

The different Method of aeration which are commonly used are

a. By air diffusion.
b. By trickling beds.
c. By using spray-nozzles.
d. By using Cascades.

a. By air diffusion

FIGURE: AIR DIFFUSION AERATION

In this method perforated pipes are fixed in the bottom of the setting tanks. The compressed air is blown through the pipes which comes out in the form of bubble and Stir the whole water at grated speed during the upward movement of the air thoroughly mixed with the water and does its aeration.

b. By trickling beds

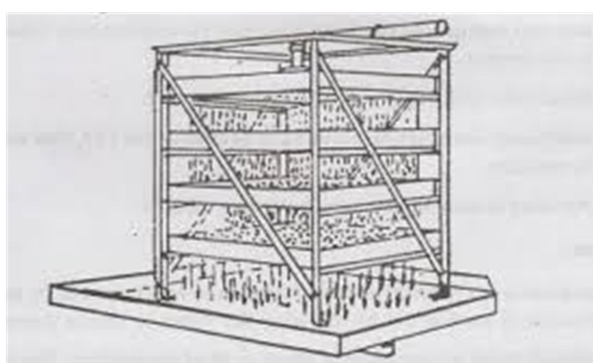


FIGURE: TRICKLING BED AERATION

In this method the water is allowed to flow on the trickling beds of coke which are supported on the perforated bottoms of the tray. During the downward movement the water gets mixed up with the air and the aeration takes place.

c. By wing spray nozzles

FIGURE: WING SPRAY NOZZLES AERATION

In this method the water is thrown up in the air into fine sprays to a height of 2-2.5 m under water pressure of 0.7 to 1.15 kg/cm². When small particles of water come in contact of greater surface area of the air, they absorb it and the water is aerated.

d. By using cascades.

FIGURE: CASCADE AERATOR

In this method, the water is allowed to fall from 1-3 m height in series of concrete step or over a weir in thin film. During the falling, the water gets thoroughly mixed with the atmosphere air and gets aerated.

2. Removing iron and manganese

Removing iron and manganese from water is essential to prevent staining, unpleasant tastes, and potential health issues. Here are some common methods for removing these metals:

- Oxidation and Filtration: Effective for high concentrations; requires proper dosing and filtration.

- Ion Exchange: Effective for low to moderate concentrations; requires regular resin maintenance.
- Aeration: Simple and chemical-free; requires subsequent filtration.
- Biological Filtration: Environmentally friendly; requires careful management of bacteria.

3. Domestic water purification

Domestic water purification processes are essential to ensure that water is safe for drinking and other household uses. These processes typically involve multiple stages to remove contaminants, including physical, chemical, and biological impurities. Here are the common stages and methods used in domestic water purification:

Stages of Domestic Water Purification

1. Pre-Filtration
2. Sedimentation
3. Filtration
4. Disinfection
5. Additional Treatments

Unit-7 Reservoirs and Distribution System

7.1Water Storage (Reservoir)

Reservoir is a device or tank which is used to store water. The reservoir may be public Storage or private storage and they may be constructed under at or above the ground. Water may be conveyed to the reservoir by gravity, pumping or dual system.

The different objectives of reservoir are

- To provide a reserve against failure of main or in intermittent systems of supply.
- To meet peak demand by reserving water in other timings.
- To reduce the pressures on the various appliances and installations.
- To economize the size of main pipe.
- To maintain uniform pressure in the distribution Systems.
- To meet the emergency demands such as firefighting.
- To use lighter pipes in the distribution system.

According to use, reservoir May be classified as

a) Clear water reservoir
b) Service reservoir / Distribution reservoir

a) Clear water reservoir

It is used to store the filer water until it is pumped or conveyed into the service reservoirs for distribution. The reservoirs are generally built under ground or half below ground level and half above ground level depending on site conditions and constructed with masonry and RCC. The minimum capacity of the reservoir should be 14-16 hours average daily flow and it should be divided into two or more compartments to enable repairing and cleaning.

b) Service reservoir/ Distribution reservoir

It is used to store the filtered water from clear water reservoir and constructed before distribution system. It is constructed with Masonry and RCC. The service reservoir should be designed for balancing storage and pre storage and fire storage.

7.2 Distribution System

For efficient distribution, it is required that the water should reach to every consumer with required rate of flow. Therefore, some pressure in pipeline is necessary, which should force the water to reach at every place. Depending upon the methods of distribution, the distribution system is classified as the follows:

1. Gravity system.

2. Pumping system.
3. Dual system or combined gravity and pumping system

1. Gravity system.

When some ground sufficiently high above the city area is available, this can be best utilized for distribution system in maintaining pressure in water mains. This method is also much suitable when the source of supply such as lake, river or impounding reservoir is at sufficiently higher than city. The water flows in the mains due to gravitational forces. As no pumping is required therefore it is the most reliable system for the distribution of water as shown in figure below.

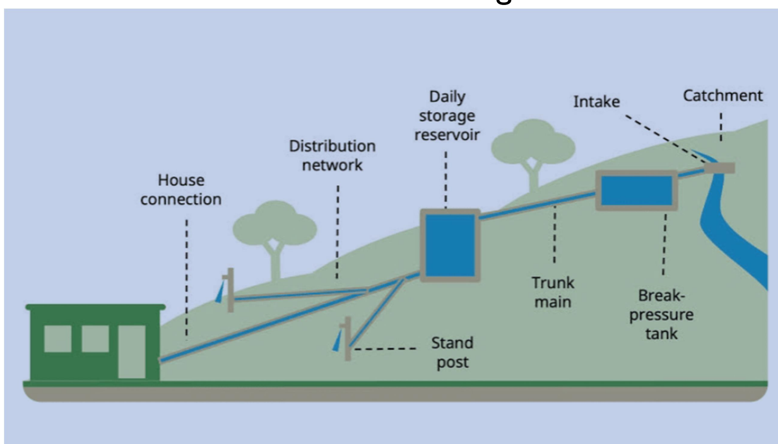


FIGURE:-GRAVITY SYSTEM

2. Pumping system:

Constant pressure can be maintained in the system by direct pumping into mains. Rate of flow cannot be varied easily according to demand unless number of pumps is operated in addition to stand by ones. Supply can be affected during power failure and breakdown of pumps. Hence diesel pumps also in addition to electrical pumps as stand by to be maintained. During fires, the water can be pumped in required quantity by the stand by units.

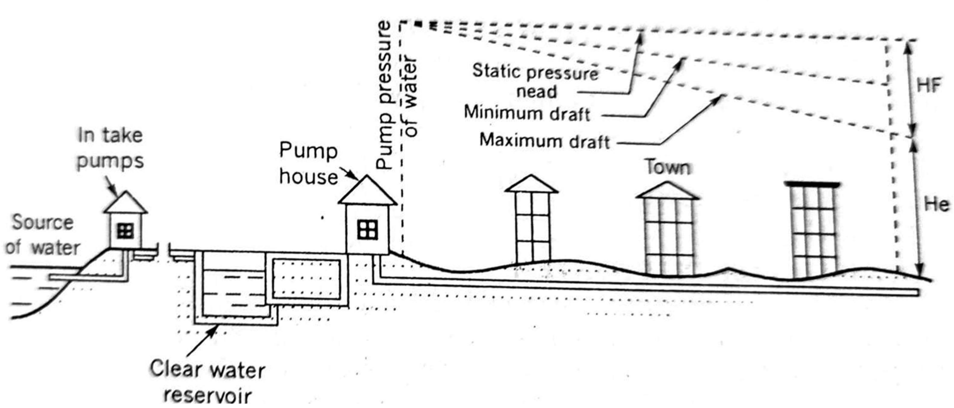


FIGURE:- PUMPING SYSTEM

3. Dual system or combined gravity and pumping system

This is also known as dual system. The pump is connected to the mains as well as elevated reservoir. In the beginning when demand is small the water is stored in the elevated reservoir, but when demand increases the rate of pumping, the flow in the distribution system comes from the both the pumping station as well as elevated reservoir. As in this system water comes from two sources one from reservoir and second from pumping station, it is called dual system. This system is more reliable and economical, because it requires uniform rate of pumping but meets low as well as maximum demand. The water stored in the elevated reservoir meets the requirements of demand during breakdown of pumps and for firefighting.

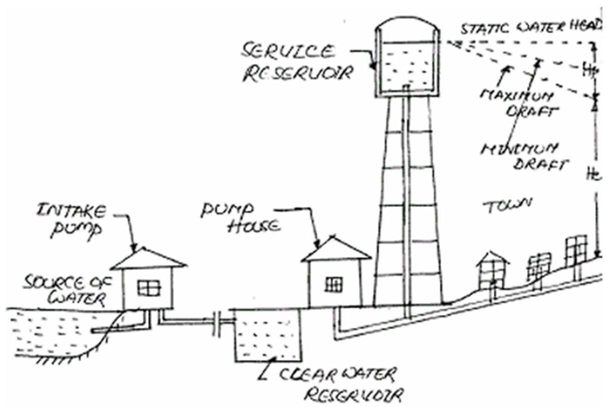


FIGURE:- DUAL SYSTEM

7.3 Introduction of Ferro cement Tank

Ferro cement tanks are used in many regions as water storage tanks and are very much useful in rural water supply. These tanks are fairly cheap, simple to make and easy to repair.

FIGURE:- FERRO CEMENT TANK

No need to use a lot of cement because of the wire reinforcement. Ferro cement tank are constructed by plastering both outer and inner side of chicken wire attached to a pipe frame. After 7-8 days when outer plaster becomes hard pipe frame is taken out. The inner part is then cleaned with water and again like outside it is plastered with 1:2 Mortars. It should be cured for at least one week. The thickness of wall becomes about 5 cm after plastering. Since the wall is very thin, it can be easily damaged due to human activities and animals. So, it should be compounded with brick, Stone or fenced. Ferro cement tank has provision of a closed chamber with inlet, outlet, and overflow and washout valve. The roof of the tank is covered to keep out dirt and insects.

Advantages Ferro cement tanks are

- ✓ Ferro cement, tanks are fairly cheap, simple to construct and easy to repair.
- ✓ It can be also used for storing food grains, rain water.
- ✓ The cover of the tank is attached with the wall which prevents the entry of dirt, smoke, and insects.

Disadvantages Ferro cement tanks are

- ✓ Skilled technician are required for the construction of the tank.
- ✓ The quality of sand, cement and water should be good.
- ✓ Larger capacity Ferro cement tanks cannot be constructed. For example if we want to construct a tank having a 40,000 liter capacity, then we should construct two Ferro cement tanks of 20000 liter capacity each.

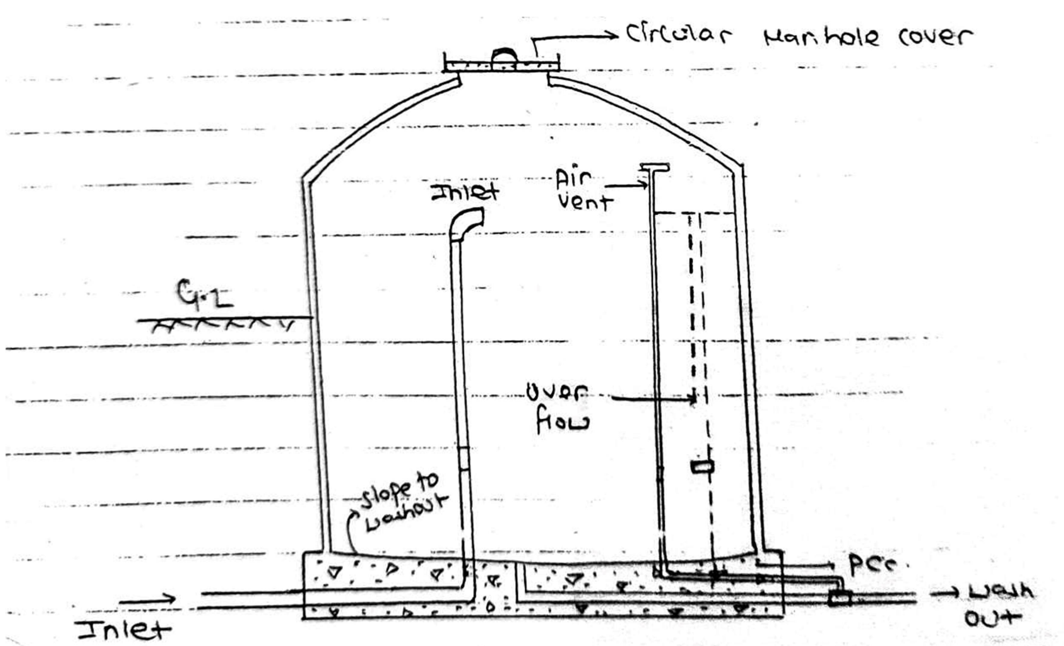


FIGURE-DIAGRAM OF TYPICAL FERRO CEMENT TANK

7.4 Layout of distribution system

The water stored is distributed through a system consisting of network of pipeline with appurtenances which is called the distribution system. Water through distribution system is taken to individual house, industries, institution and public places. Generally in practice, there are four different systems of distribution which are used, depending upon their layout and direction of supply.

a) Dead End or Tree system
b) Grid Iron system
c) Circular on Ring system.
d) Radial system.

a) Dead End or Tree-System

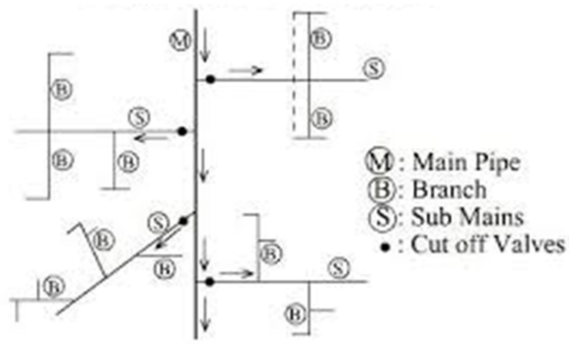


FIGURE- DEAD END OR TREE SYSTEM

In this system, one main starts from service reservoir along the main road and sub-mains connected to the main in both the direction along other roads which meet the main road. The sub mains are further divided into several branches from which service connections are given to the consumers. So the network of pipelines covers the entire area as like as a branch of a tree and no cross connection is done but various dead are available. This system is mostly adopted in towns or cities developed in haphazard (Irregular) way.

Advantages

- Easy in calculation of pressure at any point and hence design of pipes, valve and network is easy.
- Less number of cut off valves are required.
- Pipe lying is very simple.
- Cheap in initial cost.

Disadvantages

- Sediment deposition may occur and no fresh water is available because of dead ends and hence quality of water is degraded.
- If system fails by breaking of pipes or closed for repair, no supply of water is possible for the locality beyond that point.
- The water available for firefighting is low because supply can neither be increased nor be diverted.

b) Grid Iron system (Reticular system)

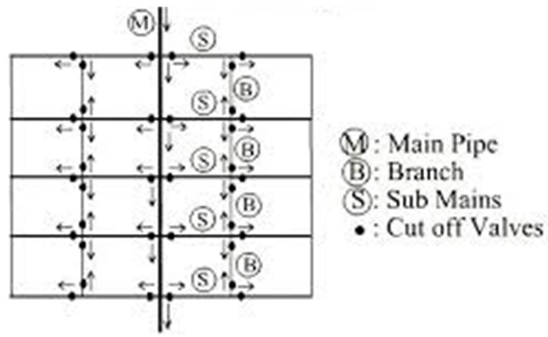


FIGURE: GRID IRON SYSTEM

This system of distribution is suitable for cities planned in the rectangular pattern or grid iron pattern. In this system main pipe line is laid along the main road. Sub mains are taken in both the directions then branch lines inter connects all sub-mains so that water can circulate through entire distribution system.

Advantages

- Circulation of water is available hence no stagnation or sediment deposit and no chance of pollution.
- Repair or damage in any section affects only in very small area.
- Firefighting water can be easily available by diverting the water from other sections to affected areas by closing the valves of nearby localities.
- Due to interconnection, water is delivered to every point of the system with minimum head loss.

Disadvantages:

- More number of cut off valves and longer length of pipes are required.
- Design of pipes and calculation of pressure is laborious, complicated & difficult.
- Cost is high.
- If one section is to be repaired more numbers of valves are required to close.

c) Circular or Ring System

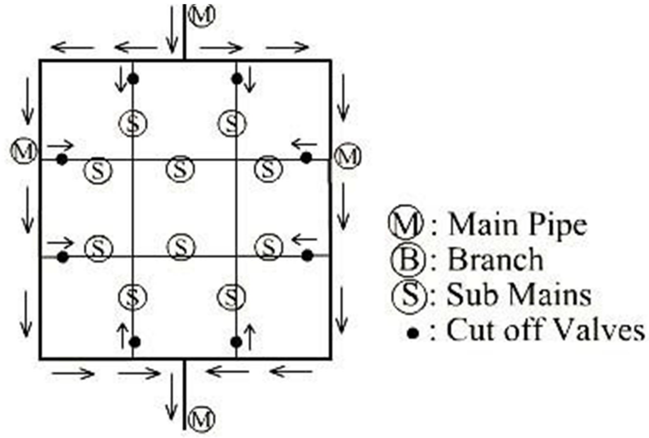


FIGURE: CIRCULAR OR RING SYSTEM

This system can be adopted only in well planned localities of cities. Here entire distribution area is divided into small circular or rectangular blocks and water mains are located around all the four side of rectangle or round the circle. The branches are laid along the inner roads.

Advantages

- The design of this system is easier.
- Large quantity of water is available for firefighting.

Disadvantages

- Requires more valves and pipe length.

(The advantages and disadvantages are same as that of grid-Iron system.)

d) Radial system

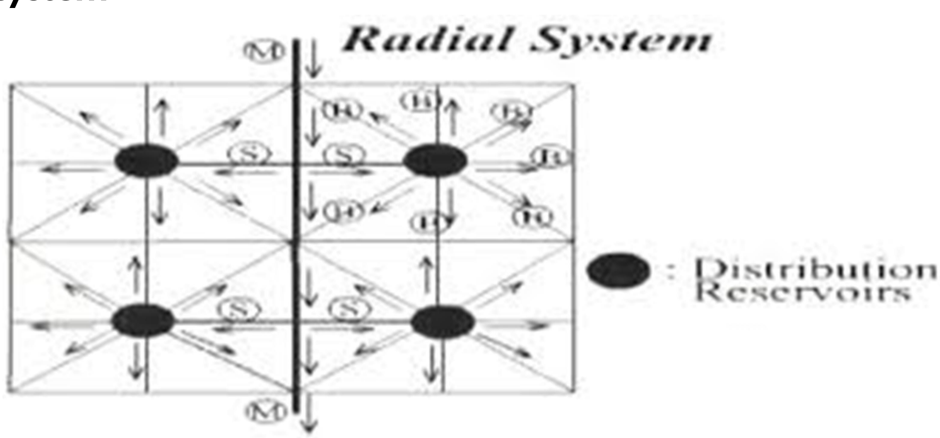


FIGURE: RADIAL DISTRIBUTION SYSTEM

In this system the entire distribution area is divided into small circular or rectangular zone and each center of a zone is provided with distribution reservoir and water is flowed radically towards periphery from branches. In this system there is high pressure distribution and gives quick and efficient water distribution and hence more efficient in firefighting. This system is suitable for cities having radial road networks.

7.5 System of supply

Water supply systems can be broadly categorized into continuous and intermittent systems.

1. Continuous Water Supply System

A continuous water supply system provides a steady and uninterrupted flow of water to consumers throughout the day and night. It is designed to meet the constant demand for water by ensuring that there is always a supply available at any given time.

Advantages:

- Provides reliable access to water for households, industries, and businesses at all times.
- Reduces the risk of waterborne diseases by ensuring that users have consistent access to clean water, promoting better sanitation and hygiene practices.
- Improves overall customer satisfaction and supports economic activities by ensuring a steady supply.

Disadvantages:

- Requires investment in infrastructure, including storage tanks, pumping stations, and distribution networks, to maintain continuous service.
- Continuous operation of pumps and other system components can lead to high energy consumption and operational costs.
- Requires ongoing maintenance and management to prevent system failures and ensure reliable operation.
- Chance of waste of water is high.

2. Intermittent Water Supply System

An intermittent water supply system provides water to consumers only during specific periods or hours, rather than continuously. This type of system is often used in areas where resources are limited or where infrastructure constraints prevent the establishment of a continuous supply.

Advantages:

- Generally requires less infrastructure investment compared to continuous systems, making it more feasible in resource-constrained settings.
- Lower operational costs due to the reduced need for continuous pumping and treatment.
- Can be adapted to varying levels of demand and resource availability.

Disadvantages:

- Consumers may experience difficulties in accessing water during non-supply periods, leading to potential health and hygiene issues.
- Dependence on water storage can lead to problems if tanks run dry or if there is insufficient storage capacity.
- Pipelines are likely to rust faster due to alternate wetting and drying. This increases the maintenance cost.
- There is also pollution of water by ingress of polluted water through leaks during non-flow periods.
- More wastage of water due to the tendency of the people to store more water than required quantity and to waste the excess to collect fresh water each time.

Unit-8: Gravity Water Supply System

8.1 Concept of gravity water supply

A gravity water system utilizes the natural force of gravity to transport water from a higher elevation to a lower one, eliminating the need for pumps. Typically, water is sourced from a spring, well, or reservoir located at an elevated position. From there, it flows into a collection tank. The elevation difference creates pressure that propels the water through a network of distribution pipes. These pipes lead to storage tanks and tap stands, where the water can be accessed for various uses, such as drinking, washing, and irrigation.

Gravity water systems are particularly advantageous in rural or remote areas due to their low operational costs and simplicity, as they require no energy for pumping and have fewer mechanical parts. However, they depend on an adequate elevation difference to function effectively and have limited reach. Water availability might also fluctuate with seasonal changes, especially if the system relies on surface water sources. Despite these limitations, gravity water systems are a reliable and cost-effective solution for providing water in areas without extensive infrastructure.

8.2 Schematic diagram of typical gravity water supply system

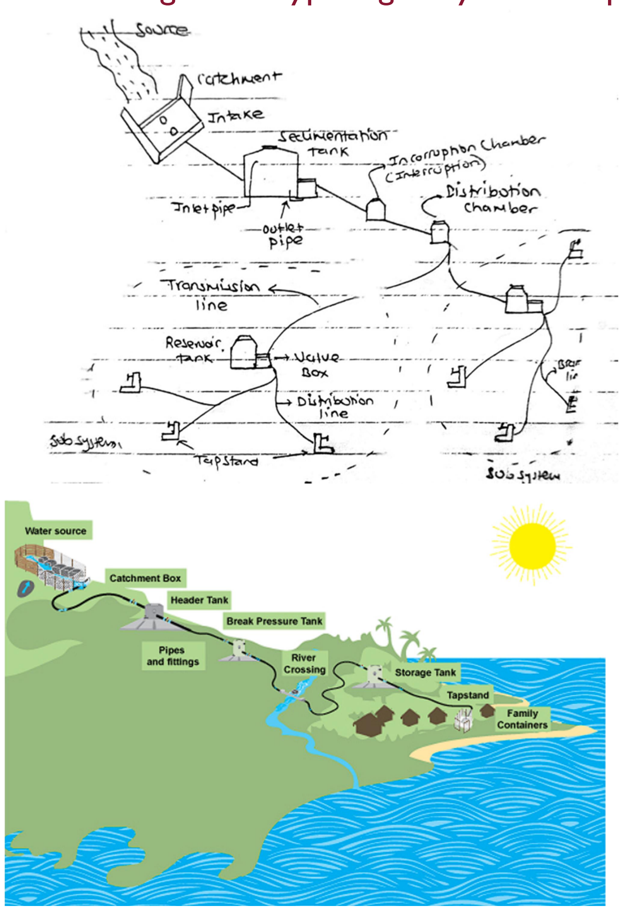


FIGURE:-SCHEMATIC DIAGRAM OF GRAVITY FLOW WATER SUPPLY SYSTEM

General components of Gravity Flow water supply System.

1. **Intake:**

   Intake is the structure constructed to collect water from source. This may be either masonry or RCC. The water collected from intake is send to either collection chamber if water is collected from multiple sources or directly to transmission pipeline. The intake consists of inlet, outlet pipe, overflow pipe and washout.

2. **Collection Chamber(CC):**

   Collection chamber is constructed when water from two or more than two sources are to be collected. Collection chamber may be either attached with intake or made separately. Collection chamber includes inlet, outlet, overflow, and washout. Valve chamber is constructed to protect the fittings.

3. **Wash Out (WO):**

   Wash out valve is kept at the lowest point when the pipeline is going U profile. This is kept at valley and just after collection chamber. This is used to washout the sediments from the pipeline i.e., to remove suspended particles.

4. **Sedimentation Tank (ST):**

   Sedimentation tank is provided when the water contains high silt or sediments is high. ST helps water to remain stagnant and allows the sediments to settle down due to gravity. The fine suspended solid is removed from this chamber. It includes inlet, outlet, overflow, and valve chamber.

5. **Interruption Chamber (IC)/ Break Pressure Tank (BPT):**

   Interruption chamber and break pressure tank is provided when the head of water is more than sixty meters. Interruption chamber is provided in transmission line and break pressure tank is provided in distribution line. Both of this are used to reduce the pressure and prevents pipe from bursting. It consists of valve chamber, valves, outlet, inlet, overflow, and washout

6. **Air Valve (AV):**

   Air valve is provided to remove the air from the pipeline. If the air isn't removed from the pipe this air blocks the water flow. This is provided in summit and air is removed automatically.

7. **Distribution Chamber (DC):**

   If the water is to be distributed to reservoir tank located in different community, then distribution chamber is to be constructed. The construction of DC is same as that of collection chamber. It also contains inlet, outlet, and washout. Air vent is provided in outlet pipe.

8. Pipeline:

The pipeline is provided to flow water. In this purpose either HDPE or GI pipe is used. HDPE pipe is buried whereas GI pipe is not buried. Anchor block is provided to support GI pipe. The pipeline from intake to RVT is called transmission pipeline and from RVT to tap is called distribution pipeline.

9. Pipe Crossing:

Pipe crossings are provided when the pipeline is to be crossed from stream or George. Pipe crossing is either suspended crossing or non-suspended crossings.

10. Reservoir Tank (RVT):

Reservoir tanks are constructed to storage water therefore this is also known as storage tank. Reservoir is to be constructed near the community where water is to distribute. This RVT is either of Ferro cement, stone masonry or RCC tank depending upon the water to be collected. In Nepal rural water supply Ferro cement reservoir is highly used. RVT consists of valve chamber. Inlet, outlet, washout, air vent is provided reservoir.

11. Tap stand:

The last point of gravity water supply system is tap. The tap stand can either be household or community tap stand. Community tap stand is provided at center of 5-6 household. The maximum distance between the house and community tap is one hundred meters.

8.3 Hydraulic Grade Line

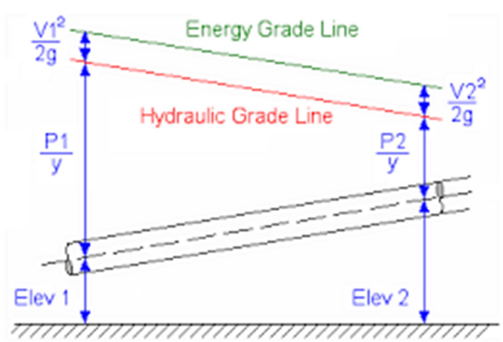


FIGURE: HYDRAULIC GRADE LINE

The hydraulic grade line (HGL) is a graphical representation of the energy or pressure available to the fluid at various points along a pipeline or open channel. It indicates the height to which water would rise in a piezometer tube connected to the pipeline at any given point. The HGL is crucial for understanding the behavior of fluid flow within a system and ensuring proper design and operation.

8.4 Break Pressure Tank (BPT)

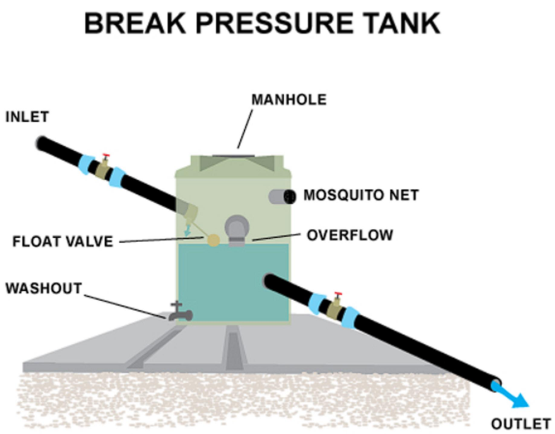


FIGURE:-BREAK PRESSURE TANK

The flow of water inside the pipe is due to the pressure. If pressure is low water can't flow but it is high then the diameter and standard of pipe material should be maintained due to which the cost of project is high. In order to minimize this cost and to make the project more effective, a tank is constructed in the distribution line to break the static pressure and save the pipe from bursting. This tank allows the flow to discharge in the open atmosphere so reduces the hydrostatic pressure to zero and establish the new static level. It may be rectangular, circular or square in plan and made of masonry of RCC or Ferro cement. BPT has provisions of closed chamber with inlet, outlet, over flow and a float valve to stop the wastage of water. However, experience has shown that these types of system have a high failure rate due to the high operation and maintenance requirements of the float valve. For the construction of BPT, the site should be selected after making discussion with expert engineers. If it is constructed in our own way then problem like irregular circulation of water, bursting of pipes can be seen.

Interruption Chamber (IC)

Interruption chamber is placed along the transmission main to break the pressure. Whenever, the operating pressure is likely to exceed the pipe's pressure rating by exposing the flow to atmosphere condition, an IC reduces the operating pressure to zero.

The only difference between IC and BPT is that BPT is placed along the distribution line and it has a float valve to conserve water at the reservoir tank (RT) when all or some of the tap stands are closed.

8.5 Public Tap Stand Post

FIGURE:- PUBLIC STAND POST

Public stand post is the last component of the water supply schemes and is the point from where people collect water at designed rate to meet their household demands normally in rural areas. These stand posts usually provide the community with a better at a more quality of water at or more convenient location than the existing traditional source. The burden of fetching water will be greatly reduced. However, the quality of water used in the house hold will largely depend on the sanitary practices of the individual user.

The public stand post must be properly designed and kept at aesthetically pleasant, clean and inviting palace. Waste water should be properly disposed. Tap stand in Nepalese practice must be chosen by the users themselves and located at the place of no dispute. One tap stand must be constructed for every 8 to 10 households. It should be located in such way that the fetching distance should not be greater than 200m horizontal and should be greater than 500 m verticals. All tap stands must be constructed as per government guidelines using local materials.

8.6 Residual Head Requirement

Residual head:

Residual head, also known as residual pressure, is the remaining pressure in a water supply system after accounting for losses due to friction, elevation changes, and other factors as water travels from the source to the point of use. Ensuring adequate residual head is crucial for effective water distribution, especially in regions with complex topography like Nepal.

- For a system with private connection minimum pressure 15m
- For a system without private connection minimum pressure 5m
- At public stand post, desirable pressure = 15 m
- At public stand post absolute minimum pressure =5m
- At public stand post maximum pressure= 55

Static Head (H_s)
The vertical distance between the free surface of the water source and the discharge point (or any point of interest within the system).

8.7 Pipeline Design

Designing a pipeline involves multiple factors and calculations to ensure efficient and reliable operation. Key considerations include pressure losses due to friction, changes in elevation, and the need for sufficient residual head at the point of use.

1. Flow Rate Calculation
Flow rate (Q) is typically determined based on the demand of the water supply system. It is usually expressed in liters per second (L/s) or cubic meters per second (m^3/s).

2. Continuity Equation
The continuity equation is used to relate the flow rate, pipe diameter, and velocity:

$$Q = A \cdot v$$

Where,
Q = Flow rate (m^3/s)
A = Cross-sectional area of the pipe (m^2)
v = Flow velocity (m/s)

For a circular pipe:

$A = \frac{\pi D2}{4}$

Where,
D is the diameter of the pipe.

3. Darcy-Weisbach Equation for Head Loss
The Darcy-Weisbach equation is used to calculate the head loss due to friction in the pipe:

$$h_f = f \cdot \frac{L}{D} \cdot \frac{v^2}{2g}$$

Where:
h_f= Head loss due to friction (m)
f= Darcy-Weisbach friction factor (dimensionless)
L= Length of the pipe (m)
D= Diameter of the pipe (m)
v = Flow velocity (m/s)
g = Acceleration due to gravity (9.81 m/s^2)

4. Bernoulli's Equation

Bernoulli's equation relates the energy states between two points along the pipeline:

$$\frac{v_1^2}{2g} + \frac{p_1}{\gamma} + z_1 = \frac{v_2^2}{2g} + \frac{p_2}{\gamma} + z_2 + h_f$$

Where,
v_1, v_2 = Velocities at points 1 and 2 (m/s)
p_1, p_2 = Pressures at points 1 and 2 (Pa)
γ = Specific weight of the fluid (N/m³)
z_1, z_2= Elevations at points 1 and 2 (m)
h_f= Head loss due to friction (m)

5. Hazen-Williams Equation for Water Flow

For water distribution systems, the Hazen-Williams equation is often used for its simplicity:

For water distribution systems, the Hazen-Williams equation is often used for its simplicity:

$v = k \cdot C \cdot R^{0.63} \cdot S^{0.54}$

$Q = A \cdot v$

where:

- v = Flow velocity (m/s)
- k = Conversion factor (0.849 for SI units)
- C = Hazen-Williams roughness coefficient (dimensionless)
- R = Hydraulic radius ($\frac{D}{4}$) for a circular pipe (m)
- S = Slope of the energy grade line (m/m)
- Q = Flow rate (m^3/s)
- A = Cross-sectional area (m^2)

Unit-9: Conveyance of water

After collecting water from intake, it is conveyed to treatment plant or reservoir or distribution through conduits. Conveyance from intake to treatment plant and treatment plant to reservoir is called transmission and reservoir to consumer tap is called distribution.

Conduit: It is the device used to carry water. In ancient times, water is conveyed through open Channel or wooden log channels. Slowly the use of masonry chamber of rectangular and circular are introduced and then this open channel was closed from top. Normally conduits can be classified into:

i. Gravity Conduit
ii. Pressure Conduit

i. **Gravity conduit**: These are the conduits in which water flows under the action of gravity and there is a free water surface exposed to the atmosphere. Examples canals, tunnels, aqueducts etc.

ii. **Pressure conduit**: These are the conduit where water can flow under pressure. Mostly it is seen that water level in the source is at lower elevation than the treatment plant, in such cases water can be conveyed by means of closed pipes under pressure. Example, pressure tunnel, pressure aqueducts etc.

Pipes: Pipes are the circular conduit in which water flows under pressure. These are made of various materials such as wrought iron, Steel, cement, timber, plastic, asbestos, cement concrete, Galvanized iron. The selection of pipe material depends upon its carrying capacity, its durability and life, type of water to be conveyed, it's possible corrosive effect, availability of fund maintenance and repair cost etc.

Requirement of a good pipe:

- It should be able to withstand external & internal stresses as well as temperature stress.
- It should be light, non-corrosive & cheap.
- It should be smooth for minimum friction and durable.
- It should have facility of easy joints.
- It should be available in all sizes, transport and erection should be easy.
- It should not react with water to alter its quality.
- Cost of pipes should be less.
- The damaged units should be replaced easily.

9.1 Types of Pipes

According to the nature of material used pipes are classified as

i. Cast Iron (CI) pipes

ii. Galvanized Iron (GI) pipes
iii. Steel pipes
iv. Plastic pipes

i. Cast iron (CI) pipe:

FIGURE:- CAST IRON PIPES

Cast-iron pipes are mostly used in water supply Schemes. They are highly resistant to corrosion; therefore have long-life an about 100 years. These pipes are easy to join and can withstand high pressure. They are durable, strong, and moderate in cast. But they are Brittle and very heavy so difficult to transport and may be expensive. These pipes are suitable for distribution system.

ii. Galvanized iron (GI) pipes.

FIGURE:- GALVANIZED IRON PIPES

It is made of wrought iron or mild steel which are Galvanized by providing protective coating of zinc on inner and outer surface of pipe. It can be found in 12-25 mm diameter and 7meter in length.

- It is cheap, light, easy in handling transport, easy in joining with screwed socket Joints.
- These pipes are resistance to corrosion when exposed to atmosphere.
- It may get corroded by acidic and alkaline water.
- Suitable for main lines where pressure is high and when pipe is exposed in open atmosphere.

- Used in rocky alignment and crossing in Nepal.

iii. Steel pipes

FIGURE:- STEEL PIPES

Steel pipes are manufactured by rolling the flat plates of steel to proper diameter and welding to the edges. The life of these pipes is 25 to 50 years, which is much short as compared with cast iron pipes.

- These pipes are light weight, strong and in withstand high pressure then cast-iron pipes.
- They are cheap, easy to construct and can be easily transported than cast iron pipes.
- These pipes cannot withstand external loads. These pipes are much affected by corrosion and are costly to maintain.
- Steel pipes are not used for distribution but occasionally used for main lines, where pressure is high, and diameter is more.

iv. Plastic Pipes

Plastic pipes are very common now days and heavily used because it is corrosion resistant, light in weight and economical. It is not used for transporting hot water. The various types of plastic pipes are.

i. Low density polyethylene (LDPE) pipes
ii. High density polyethylene (HDPE) pipes
iii. Polyvinyl chloride (PVC) pipes.
iv. PPR (Polypropylene Random Copolymer) pipes

i. Low density Polyethylene (LDPE) Pipes:

These pipes are flexible and found up to 63mm outer diameter. This pipe requires support closer due flexibility. Used in long runs and is not suitable for installation of internal water supply.

ii. High density polyethylene (HDPE) Pipes:

FIGURE:- HDPE PIPES

These pipes are tougher as compared to low density polyethylene. These pipes are made up to 1600 mm diameter, but outer diameter of 25 to 90 mm is used in rural water supply in Nepal. HDPE is a thermos plastic made from petroleum. HDPE Pipes with large diameter is used for conveyance of water in rural water supply in Nepal. It is cheaper in cost, durable (life 50 years), smooth, resists corrosion, light and easily jointed and bent. Small diameter of HDPE pipes are not used due to difficulties in site jointing and taking out of various connections. It is also not suitable for hot water supply.

iii. PVC (Polyvinyl Chloride) pipes

FIGURE: - PVC PIPES

They are widely used in various applications due to their durability, cost-effectiveness, and versatility. They are made from a type of plastic that is resistant to corrosion, chemical damage, and weathering, making them suitable for both indoor and outdoor use. PVC pipes have a smooth interior surface that reduces friction and increases flow efficiency, which is beneficial for plumbing systems. These pipes are lightweight, easy to handle, and can be cut, shaped, and joined using solvent cement, making installation straightforward and efficient.

iv. PPR (Polypropylene Random Copolymer) pipes

FIGURE: - PPR PIPES

These are made from a type of plastic known for its high resistance to heat and chemical stability. They are highly durable, withstanding impact and mechanical stress, and have a lifespan often exceeding 50 years with proper use. PPR pipes can handle temperatures up to 95°C, making them suitable for hot water systems. They resist corrosion and chemical leaching, ensuring water purity, and are UV resistant, which makes them suitable for outdoor installations. Additionally, they offer good thermal and acoustic insulation properties.

9.2 Laying procedure of water supply pipelines.

Pipes are generally laid below the ground level, but sometimes when they pass in open areas, they may be laid over the ground. The various operation involved in laying of pipes are discussed below.

a. **Preparation of detailed map**

   First, detailed map showing all roads, Streets, lane. etc. is prepared on this map the proposed pipeline with as sizes and length will be marked. In addition to this position of valves and other pipe specials, stand posts etc. will also be made so that at the time of lying there should be no difficulty in these connections.

b. **Locating proposed alignment of pipeline on the ground**

   After the general planning the center line of the pipeline will be transferred on the ground from the detailed plan. The center line will be marked by means of stakes driven at 30 m Interval on straight lines, on curves the stakes will be driven at 7 m to 15 m spacing.

c. **Location of pipes with respect to ground surface during laying**

   Pipes may be laid above ground from source to treatment plant and distribution main and pipes are laid below the ground surface. Pipes if laid on ground surface, they must be laid on well compacted surface to avoid future settlement. If underground laying is done trench is excavated.

d. **Excavation of trench:**

When the center line of pipe has been marked on the ground surface, the excavation for the trench will be started. The width of trench will be 30 cm to 45 cm more than the external diameter of the pipe. The excavation of the trench is done in such a way that only pipe should be supported, and its joint portion should remain over hanging. The pipeline should be laid more than 90 cm below the ground so that pipe may not break due to impact of the heavy traffic moving over the road or ground. If the excavation is to be done in soft soils, Timbering of trench is required to prevent it from fall or collapse.

e. **Lowering the lowered pipes:**

The pipe shall be into the trench by means of suitable pulley blocks, ropes etc. In no case the pipe shall be rolled and dropped into the trench. The pipes should be gently laid so that protective coating and end of pipe are not damaged.

f. **Joining pipes:**

After lowering the pipes, they are joined using proper joints. The spigot of one pipe is carefully centered into the socket of the next pipe and pushed to the full distance that it can go. It should be kept in mind that the valves are placed at the proper place or not.

g. **Testing of pipes:**

After laying and joining, pipes are tested for water leakage and pressure along a section of 500 m length. For this one end of pipe is closed and from another end Water is pumped with double of working pressure and is kept for 24 hours. It is satisfactory if the leakage is greater than permissible limits.

h. **Back filling and disinfection before first use:**

When the pipeline is tested and if the tested section is accepted then back Filling of the trench is done. The soil which was excavated is filled back in the trenches all around the pipes and should be well rammed or tamped. Care should be taken to avoid back filling with large store which may damage the pipelines. In case of sloppy ground, back filling of soil shall be done at least 10 cm above the ground level.

Before first we the pipelines should be disinfected using 50 Ppm of Chlorine by maintaining it with full water for 12 hours. The pipe is then emptied and flushed with fresh treated water. Thus, pipes are ready for carrying potable water to the consumers.

9.3 Pipe Joints

For easy handling, transportation and placing in position pipes are manufactured in small length of 2-6m. So pipes, should be Joined together after placing in the position for continuation. A device is required to join the pipe which is called pipe joint.

Hence, proper joint should be used as per condition, material of pipe, internal water pressure and condition of support.

Various types of joints commonly used in water supply pipe lines are

i. Spigot and socket joint
ii. Flanged joint
iii. Expansion joint
iv. collar joint
v. Screwed and socket joint

i. Spigot and socket Joint:

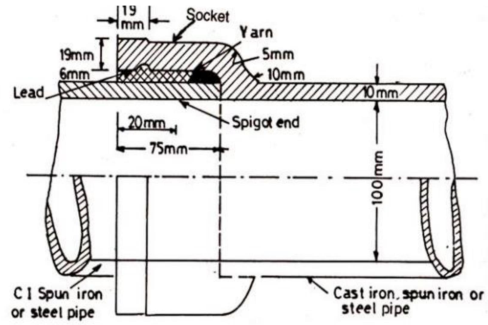


FIGURE:- SPIGOT AND SOCKET JOINT

It is also known as bell and spigot joint. This type of joint is mostly used for cast iron pipes. For the construction of this Joint the spigot of one pipe is slipped in socket or bell end of the other pipe until contact is made of the base of the bell. After this yarn of hemp is wrapped around the spigot end of the pipe and is rightly filled in the Joint by means of yarning iron up to 5cm depth. The hemp is tightly packed to maintain regular annular space for preventing jointing material from falling inside the pipe.

ii. Flanged joint

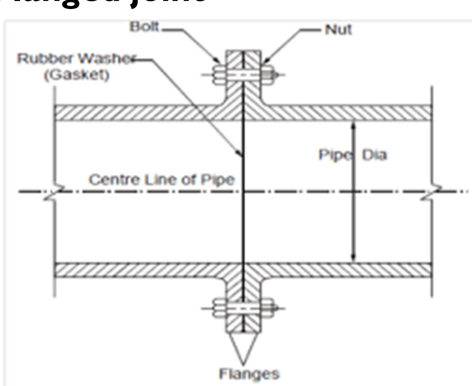


FIGURE: FLANGED JOINT

This joint is mostly used for temporary pipelines of CI, GI, and steel pipes because it is easy to dismantle and reassemble.

In this joint, both pipes have flange at both ends. The flanges are brought together, and one hard washer made from rubber is placed between flanges then bolted for water tightened.

These joints are not used at vibration and deflection places. It is suitable for pumping station filter plant, laboratories, and boiler house.

iii. Expansion Joint

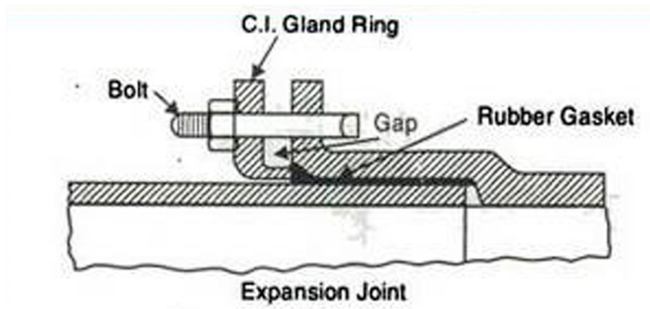


FIGURE:- EXPANSION JOINT

This joint is used at such place where pipes or expand contract due to change in atmospheric temperatures and thus checks the setting of thermal stress in the pipe. In this joint socket end is flanged with CI follower ring which can be freely slide on the spigot end and an is tightly pressed between annular space of socket and spigot by means of bolt. When pipe expands socket end moves forward in the space provided and moves backward it contracts. Elastic rubber gasket keeps joint watertight.

iv. Collar joint:

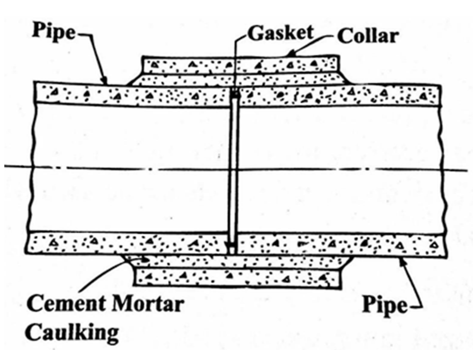


FIGURE:- COLLAR JOINT

Collar joint is most commonly used for joining Concrete and asbestos-cement pipe for joining the pipe with this joint, two ends of pipes is brought in one level and rubber gasket placed between steel rings or jute rope soaked in cement is kept on groove and collar is placed so that some lap on both pipes is remained. Then 1:1 cement mortar is filled between the space of collar and pipe.

v. **Screwed and Socket joint:**

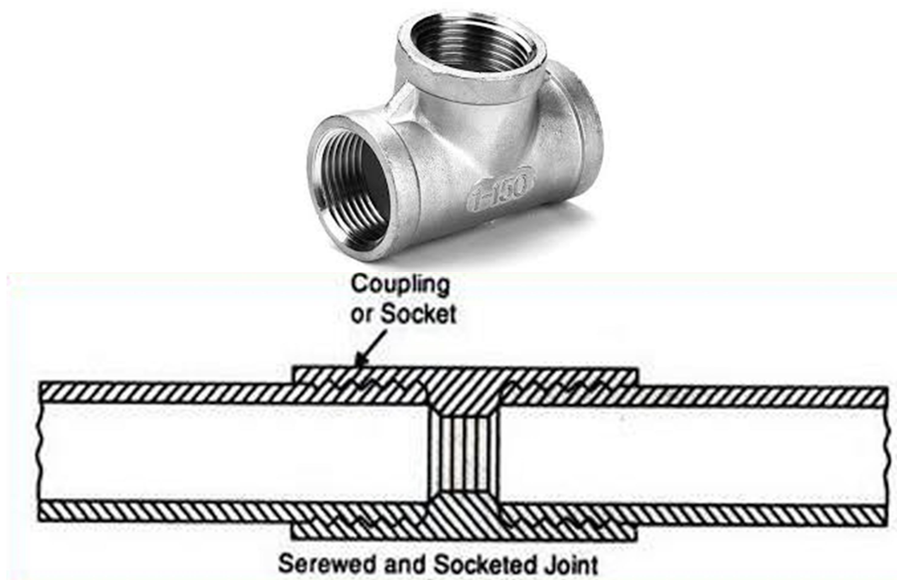


FIGURE:- SCREWED AND SOCKET

This joint is used for connecting small diameter CI and GI pipes for internal plumbing. Both pipe ends have thread and socket is screwed to connect them. In general connections on pipe in house plumbing for water supply is done with this type of joint.

9.4 Testing of pipes Joints (Leakage Test)

After laying and joining, pipes are tested for water leakage and pressure along a section of 500 m length. For this one end of pipe is closed and from another end Water is pumped with double of working pressure and is kept for 24 hours. It is satisfactory if the leakage is greater than permissible limits given by the following formula,

$$Q = \frac{ND\sqrt{P}}{3.3}$$

Where,

Q= allowable leakage in Cm^3/hr.

N= number of joints in the tested Street.

D= Diameter of pipe in mm.

P= Average test pressure during test in Kg/Cm^3.

10.1 Valves

Water appurtenance

Water appurtenance refers to auxiliary structures or accessories associated with a primary water system that enhance its functionality and efficiency. These include components such as valves, meters, hydrants, and backflow preventers. Each element plays a critical role in ensuring the smooth operation and safety of the water supply system.

For example, valves regulate water flow and pressure, meters measure usage for billing purposes, hydrants provide access for firefighting, and backflow preventers protect the water supply from contamination. Together, these appurtenances contribute to the reliability, safety, and maintenance of water infrastructure, ensuring that water is delivered effectively and efficiently to end users.

Valves

Valves are the devices which are used in water supply system to control the flow of water, to regulate pressure, to release air, to prevent back flow and for other purpose. There are different types of valves available for different purposes, they are

a) Sluice valve or gate or cut off valve
b) Reflux or check valve or non-return valve
c) Globe valve
d) Air or air relief valves
e) Scour or drain or blow off valve

a) Sluice valve or gate or cut off valve

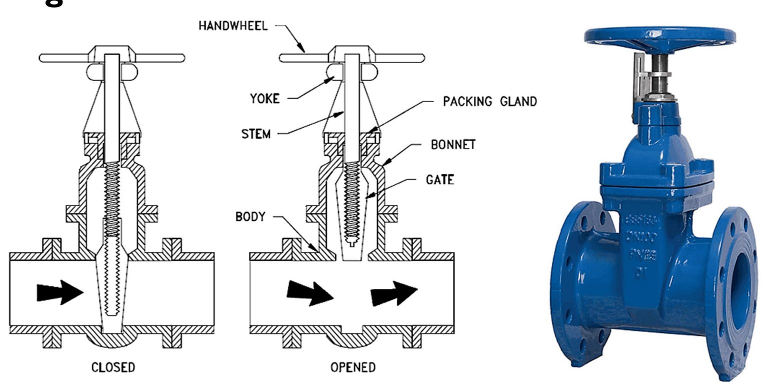
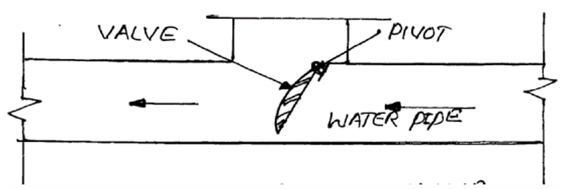


FIGURE:- SLUICE VALVE

Sluice valves are also known as gate valve or cut off valve and commonly used in water works practice. These valves are used to regulate the flow in the pipe and provided at every junction and at the interval of 3 to 5 km.

Sluice valve consists of a small Chamber in which a circular wedge at the center is placed and this is further connected to the handle, which can be rotated forward and downward movement of wedge to regulate and control the flow. It is cheaper, offer less resistance to flow less head loss than other.

b) Reflux or check valve or non-return valve



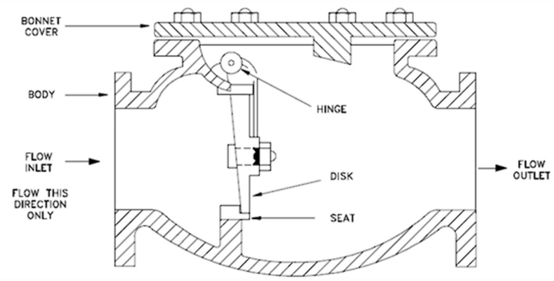


FIGURE:- REFLUX VALVE

Reflux valves are used when flow is to be maintained only in one direction in the pipe. These valves are also known as Check valve. Reflux valve consists of a disc pivoted at the one end in such, a way that it opens when flow is forward and closes if water tends to flow in reverse direction. These Valves are generally very Small, simple and inexpensive. The bodies of most of the Check Valves are made of plastic or metal. These valves work automatically and must not control by person or by any external control. Generally reflux valves are used in the suction line of the pumping system to prevent the backflow when pump is at the rest.

c) Globe valve

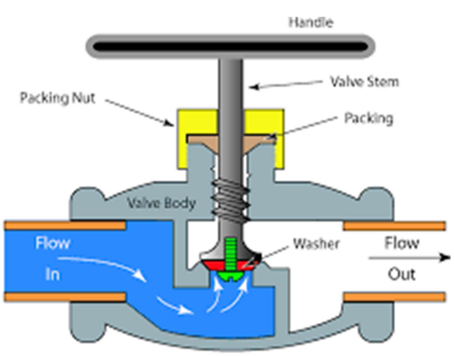


FIGURE:- GLOBE VALVE

Globe valves are used for regulating the flow through pipes as in sluice valve but the head loss is higher than in sluice valve. In this type of valve, flow rate control is determined not by the size of the opening in the value seat, but rather by the lift of the valve plug. One feature of globe valve is that even if used in the partially open position there is less risk of damage to the valve set or valve plug by the fluid than with other types of Valve. The pressure drop across the valve is greater than that of other type of Valve because the passage way is S-shaped the valve operation time is also longer since the valve Stem Must be turned several times. Among different types of globe valve needle type globe valves are suitable for flow rate control.

d) Air or air relief valves

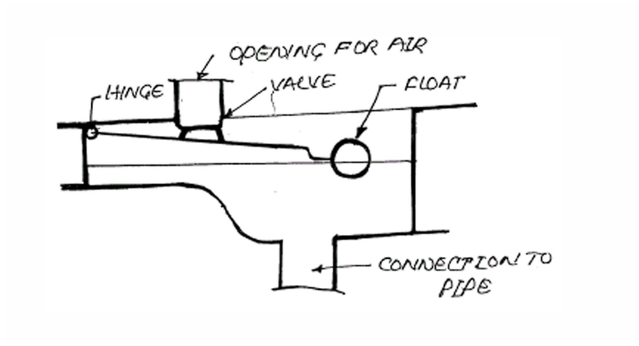


FIGURE:- AIR RELIEF VALVE

When water enters in pipe lines, it also carries air with it which tends to accumulate at high points of the pipe. When the quantity of air Increases, it causes serious blockage to the Flow of water. Therefore it is most essential to remove the accumulated air from the pipe line. Hence, a type of valve called air valve or air relief valve is placed to release this accumulated air.

It consists of a cast iron chamber bolted on the pipe cover the opening in the crown. A float mass and a lever in it are so adjusted that when the Chamber is filled with water under pressure from the pipe below, the float remains rose up and opening is closed If there is no water but accumulated air in the chamber, the float sinks then the opening is opened and all the air is released.

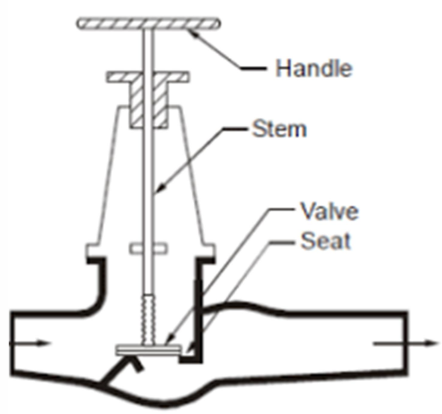
e) Scour or drain or blow off valve

Water may be carry sand and silt which may be deposited in the To emptying or draining the pipe for removing sand or silt deposited in the pipe and for Inspection, repair etc. an valve is placed at the dead ends and at depressions which is called as scour value or drain valve. When this valve is opened the water rushes out thus removing all silt, clay from the Water line. These are ordinary valves operated by hand

10.2 Fittings

Fittings are those devices which are used in water supply system to connect pipes as well as in the outlet indoor or outdoor to convey and get water. Example of fitting are stop cock, water tap, water meter, pipe fittings (bends, tees, Wye, socket, unions, caps, cross, reducer), wash basin, shower, sink etc.

a) Stop cock



Stop cock is used to regulate flow of the fluid through a pipe. These can be easily closed and opened by rotating the handle. It is provided in the building just inside or outside to stop supply of water whenever required during repairs, or breakage in plumbing fittings. All the stops cock should be checked before use. Different varieties of stop cock are available in the market.

b) Water tap

Water tap are generally provides inside the building and in streets for taking water. Water tap can be easily closed and opened by rotating the handle. The water tap should be made of rust proof metal alloys to prevent it from rusting. The water tap should be tested before use to ensure whether there is leakage or not. Verities of water tap are available in the market.

c) Water meter

FIGURE: WATER METER

Water meter is the device which is used to determine the quantity of water flowing through pipes. Various types of water meter are available in the market. Types of meter includes rotary, reciprocating, oscillating disc meter. It is necessary to measure the quantities of water supplies to private house, industries, public building etc.

Requirement of good meter

- ✓ It should not offer any resistance to the flow of water.
- ✓ It should be easily maintained and repaired. It should be economical.
- ✓ It should have screen on its inlet side to exclude the silt, sand, clay etc.
- ✓ It should measure discharge up to 2% accuracy.

d) Pipe fittings

Besides valves, taps various type of pipe fitting such as bends, tees, wye, socket, unions, caps, cross, reducer are used during laying of distribution pipes.

i. **Bends**

It is a pipe fitting commonly used to change the direction of a pipeline a certain number of degrees. 1/4 bend, 1/8 bend, 1/16 bend and 1/32 bend are available. 1 bend corresponds to change in direction of 360° theoretically. Hence, 1/4 bend, 1/8 bend, 1/16 bend and 1/32 bend correspond to 90° bend, 45° bend, 22.5° bend and 11.25° bend respectively. Bend is also known as **elbow**. When two ends differ in size, this fitting is called **reducing elbow**. The ends may be machined for butt wielding, threaded (usually female), or socketed, etc. Elbows are available in short radius and long radius variants.

ii. **Tee**

A tee is the most common pipe fitting. It is a pipe fitting which is "T" shape having one inlet and two outlets. A tee is used for a pipe fitting connecting pipes of different diameters or for changing the direction of pipe runs. They are categorized as equal tee and unequal tee .It is available with all female thread sockets, all solvent weld sockets, or with opposed solvent weld sockets and a side outlet with female threads.

iii. **Cross**

Cross fittings connect four pipe sections together. They are also called 4-way fittings. If a branch line passes completely through a tee, the fitting becomes a cross. A cross has one inlet and three outlets, or vice versa. They often have solvent welded socket ends or female threaded ends.

iv. Wye

Wye is a fitting with three openings to create branch lines. This fitting has a shaped of 'Y'. A wye has one inlet and two outlets, or vice versa. They often have solvent welded socket ends or female threaded ends.

v. Socket

Socket is a female end or the hub of a fitting that fits over pipe. Sockets may be of two types which are plain socket and reducing socket. The plain socket is used to connect two pipes of same diameters. The reducing socket is used to connect pipe of different diameter.

vi. Union

A union is used to connect two pipes of same diameter which allows quick and convenient disconnection of pipes for maintenance or fixture replacement. A union provides a simple transition, allowing easy connection or disconnection at any future time. A standard union pipe is made in three parts consisting of a nut, a female end, and a male end.

vii. Reducer

A reducer is a fitting that joins two pipes of different diameters to reduce the diameter of a pipe run. A reducer allows for a change in pipe size to meet flow requirements of the system, or to adapt to existing piping of a different size. When a reducer is reversed in direction, it allows increasing the diameter of a pip run and is known as increaser.

viii. **Plug**

A plug closes off or seals the end of a pipe. Generally plug has male threaded and fits inside the fitting it is mated to. It is similar to cap but cap has female thread.

ix. **Nipple**

A nipple is defined as being a short stub of fittings which has external male pipe thread at the end, for connecting two other fittings. The length of the nipple is usually specified by the overall length with thread. Nipples are available in different lengths.

e) Wash Basins

A wash basin, also known as a sink, is a fixture commonly found in bathrooms and kitchens, designed for washing hands, face, or dishes. It typically consists of a bowl-shaped basin with a faucet that provides water and a drain to remove wastewater. Wash basins come in various materials, including ceramic, stainless steel, and glass, and can be mounted on countertops or walls. They are essential for maintaining hygiene and are often complemented with accessories like soap dispensers and mirrors.

f) Shower

A shower is a device used for bathing that sprays water over a person's body, typically from an overhead nozzle or handheld attachment. Showers are preferred for their convenience and efficiency, as they use less water than a traditional bath and allow for quick rinsing. They can be adjusted for temperature and water pressure, providing a refreshing and hygienic way to clean the body. Showers are commonly found in bathrooms and are used daily as part of personal hygiene routines.

g) Sink

A sink is a basin used for washing hands, dishes, and other items, typically found in kitchens, bathrooms, and utility areas. It is equipped with a faucet for running water, and usually has a drain to carry away wastewater. Sinks may also include additional features such as a built-in soap dispenser, spray nozzle, or garbage disposal. They are essential fixtures in homes and buildings, providing a convenient spot for cleaning and other water-related tasks.

10.3 Operation and maintenance

Proper operation and maintenance (O&M) of water supply systems are crucial for ensuring the reliability, efficiency, and safety of water distribution.

Methods of Operation and Maintenance

❖ Regular Maintenance

1. Inspection and Monitoring:

- ✓ Daily Checks: Routine checks on critical components such as pumps, valves, and control panels.
- ✓ Water Quality Testing: Regular testing for contaminants and ensuring compliance with health standards.
- ✓ Meter Readings: Monitoring flow meters to detect anomalies in water usage.

2. Cleaning:

- ✓ Pipe Flushing: Periodic flushing of pipelines to remove sediment and biofilm buildup.
- ✓ Tank Cleaning: Regular cleaning of storage tanks to prevent algae growth and contamination.

3. Lubrication:

- ✓ Pump and Motor Lubrication: Ensuring that moving parts are well-lubricated to reduce wear and tear.

4. Minor Repairs:

- ✓ Leak Detection and Repair: Regularly checking for and repairing leaks in pipes, joints, and fittings.

- ✓ Valve Maintenance: Ensuring that all valves are functioning properly and are not corroded or jammed.

5. **System Upgrades**
   - ✓ Software Updates: Keeping control and monitoring software up-to-date.
   - ✓ Component Replacement: Replacing worn-out parts before they fail.
6. **Documentation**:
   - ✓ Maintenance Logs: Keeping detailed records of maintenance activities, repairs, and inspections.
   - ✓ Inventory Management: Managing spare parts and materials inventory to ensure availability when needed.

❖ **Emergency Maintenance**

1. **Emergency Response Plan:**
   - ✓ **Preparation:** Developing and regularly updating an emergency response plan that includes contact information for key personnel, suppliers, and emergency services.
   - ✓ Training: Regular training of staff on emergency procedures and drills to ensure preparedness.
2. **Rapid Leak Detection and Repair:**
   - ✓ Leak Detection Technology: Utilizing advanced technologies such as acoustic sensors and pressure monitoring to quickly identify leaks.
   - ✓ Emergency Repair Kits: Keeping emergency repair kits with essential tools and materials for quick fixes.
3. **Pump and Motor Failures:**
   - ✓ Backup Systems: Installing backup pumps and generators to ensure continuous operation during failures.
   - ✓ Emergency Service Contracts: Having contracts with service providers for rapid repair or replacement of critical components.
4. **Power Failures:**
   - ✓ Backup Power: Ensuring that backup generators are operational and have sufficient fuel.
   - ✓ Manual Operation: Training staff to operate critical components manually if automated systems fail.
5. **System Overloads:**
   - ✓ Flow Control: Implementing measures to manage and control water flow during high-demand periods to prevent system overloads.
   - ✓ Pressure Relief Valves: Installing pressure relief valves to protect the system from excessive pressure.

Unit 11: Water supply in Emergency Situation

11.1 Introduction

SPHERE Guidelines: Humanitarian Standards in Water Supply, Sanitation, and Hygiene Promotion (WASH)

The SPHERE Handbook is a set of guidelines developed to improve the quality and accountability of humanitarian response in emergencies. It includes standards, indicators, and guidance for providing essential services to people affected by disasters or conflicts. The WASH (Water, Sanitation, and Hygiene) chapter of the SPHERE Guidelines focuses on ensuring access to safe water, adequate sanitation, and hygiene promotion.

Key Aspects of the SPHERE Guidelines in WASH:

1. **Water Supply**

Objective: To ensure people have access to sufficient and safe water to maintain health and dignity.

Key Standards:

❖ **Water Quantity:**
- ✓ Minimum of 15 liters per person per day in emergencies.
- ✓ 7.5 liters per person per day should be allocated for drinking and cooking.

❖ **Water Quality:**
- ✓ Free from harmful pathogens and chemicals.
- ✓ Chlorine residual of 0.2-0.5 mg/l at the point of delivery.
- ✓ Turbidity below 5 NTU (Nephelometric Turbidity Units).

❖ **Accessibility:**
- ✓ Water points should be within 500 meters of households.
- ✓ Queuing (Stand in line) time at water sources should not exceed 30 minutes.

11.2 Quantity of water required in emergencies

In emergency situations, the SPHERE Guidelines recommend a minimum water supply of 15 liters per person per day. This quantity is intended to cover basic needs, including drinking, cooking, and personal hygiene.

Here's how the 15 liters are typically allocated:

a) **Drinking and Cooking**: Approximately 7.5 liters per person per day should be reserved for drinking and cooking.
b) **Personal Hygiene:** The remaining 7.5 liters are allocated for personal hygiene, such as washing hands, bathing, and other sanitation needs.

This minimum standard is designed to ensure that even in emergency conditions; people have access to enough water to maintain their health and dignity.

Additional water may be needed for specific situations, such as medical facilities, food preparation centers, or when dealing with vulnerable populations like children, the elderly, or people with specific health needs.

11.3 Cleaning and disinfecting water sources, tanker, pot/ utensils

During emergencies, the risk of water contamination increases significantly due to disruptions in regular water supply systems and potential exposure to pollutants. Ensuring that water sources, storage containers, and utensils are properly cleaned and disinfected becomes crucial to prevent waterborne diseases. Here's how to effectively clean and disinfect water sources, tankers, and pots/utensils during emergencies:

1. **Cleaning and Disinfecting Water Sources During Emergencies**
   a) **Ground Sources:**
      - **Initial Response**: Immediately remove any visible debris or pollutants that may have entered the water source due to the emergency, such as floodwaters or debris from natural disasters.
      - **Emergency Chlorination:** If contamination is suspected, perform shock chlorination by adding chlorine (like calcium hypochlorite) directly to the well or borehole. Aim for a high chlorine concentration (50 mg/L) to ensure thorough disinfection.
      - **Emergency Flushing:** After chlorination, pump out the highly chlorinated water until the chlorine smell is faint or absent, ensuring the water is safe for consumption.

   b) **Surface Water Sources:**
      - **Temporary Protection:** Use makeshift barriers (e.g., sandbags, plastic sheeting) to protect surface water from further contamination during the emergency.
      - **Quick Filtration:** Employ rapid filtration methods like portable sedimentation or basic sand filters to reduce turbidity and visible contaminants before chlorination.
      - **Emergency Chlorination:** Chlorinate the filtered water, ensuring adequate mixing and contact time before use.
2. **Cleaning and Disinfecting Water Tankers During Emergencies**
   a) **Emergency Preparation:**
      - **Rapid Inspection:** Before using a tanker to distribute water, quickly inspect for any obvious contamination or damage.
      - **Emergency Cleaning:** If the tanker has been exposed to contaminants, clean it with a high-strength detergent or soap solution, scrubbing the interior surfaces as thoroughly as possible given the time constraints.

- **Disinfection:** Prepare a stronger chlorine solution (100-200 mg/L) and fill the tanker with it, ensuring all interior surfaces are exposed to the disinfectant for at least 30 minutes.
- **Quick Rinsing:** After disinfection, rinse the tanker with clean water. If time does not permit, ensure the remaining chlorine concentration is safe for drinking (less than 5 mg/L).

3. **Cleaning and Disinfecting Pots/Utensils During Emergencies**

   a) Rapid Cleaning:

   - **Washing:** If water is scarce, use as little as possible for scrubbing pots and utensils with a soap or detergent solution. Focus on removing visible dirt and food residues.
   - **Rinsing**: Rinse with the cleanest available water to minimize soap residues.

   b) Emergency Disinfection:

   - **Boiling:** If fuel and time allow, boil the utensils for at least 5 minutes to kill any pathogens.
   - **Chlorine Solution:** If boiling is not feasible, submerge utensils in a chlorine solution (200 mg/L) for at least 30 minutes. This can be made by adding approximately 1 tablespoon of bleach per liter of water.
   - **Rinsing:** After disinfection, if safe water is available, rinse the utensils. If not, allow them to air dry without rinsing to minimize recontamination.

   c) Emergency Storage:

   - **Safe Storage:** Store the cleaned and disinfected utensils in a covered, clean area away from potential contaminants to ensure they remain safe for use.

11.4 Rehabilitation of small-scaled piped water distribution system, water treatment works after an emergency.

Rehabilitating small-scale water distribution systems and water treatment works after an emergency is crucial to restoring safe and reliable water supply to affected communities. Emergencies, such as natural disasters, conflicts, or technical failures, can severely damage these systems, making quick and effective rehabilitation essential to prevent public health crises. Below is a guide on how to approach this process:

Rehabilitation of Water Distribution Systems

a) Pipeline Repair and Replacement:

- ✓ **Leak Detection and Repair:** Use leak detection methods (e.g., acoustic devices, pressure testing) to identify and repair damaged sections of the pipeline. This helps reduce water loss and prevent contamination.

- ✓ **Pipe Replacement:** Replace severely damaged or broken pipes with new ones. Use materials that are durable and appropriate for the local environment and water quality conditions.
- ✓ **Temporary Bypasses:** In cases where permanent repairs may take time, install temporary bypasses to restore water supply quickly.

b) Pump and Valve Repair:

- ✓ **Pump Maintenance:** Repair or replace damaged pumps to ensure the system can maintain adequate water pressure and flow. This includes checking for electrical faults, mechanical wear, and clogging.
- ✓ **Valve Functionality:** Inspect and repair or replace damaged valves to ensure proper control of water flow within the system.

c) Storage Tank Rehabilitation:

- ✓ **Tank Cleaning:** Thoroughly clean and disinfect storage tanks that may have been contaminated during the emergency. This includes removing sludge, debris, and biofilms from the tank walls and floors.
- ✓ **Structural Repairs:** Repair any structural damage to storage tanks, such as cracks or leaks, to prevent further contamination and water loss.

Rehabilitation of Water Treatment Works

a) Restoring Treatment Processes:

- ✓ **Filtration Systems:** Clean or replace filtration media that may have been compromised. Ensure that all filters (e.g., sand, carbon) are functioning effectively to remove physical and chemical contaminants.
- ✓ **Chemical Treatment:** Restore or replenish chemical dosing systems for disinfection (e.g., chlorine, UV systems) and coagulation/flocculation processes. Adjust dosing based on water quality testing results.
- ✓ **Sedimentation Basins:** Clean sedimentation basins to remove any accumulated silt or debris that could interfere with water clarification.

b) Temporary Water Treatment Solutions:

- ✓ **Mobile Treatment Units:** Deploy mobile water treatment units to provide safe water while permanent treatment facilities are being rehabilitated. These units can include portable filtration, chlorination, and UV systems.
- ✓ **Point-of-Use Treatment:** Distribute point-of-use water treatment methods (e.g., chlorine tablets, ceramic filters) to households until the centralized system is fully restored.

11.5 Emergency treatment of drinking water at the point of use

In emergencies, treating drinking water at the point of use is essential to prevent waterborne diseases. Boiling, chlorination, filtration, solar disinfection, chemical disinfection tablets, and UV light purifiers are all effective methods, depending on the resources available and the specific contaminants present. Each method has its strengths and limitations, so sometimes a combination of methods may be necessary to ensure water safety. Proper treatment of drinking water at the household level helps protect health and prevent the spread of disease during emergency situations.