5. Public Health Engineering

5.1 Water Supply.

5.1.1 Introduction

Potable water – Water that is clear and free from micro-organisms & chemicals ie. safe for drinking by humans & other animals is called potable water.

Wholesome Water – Water that is practically clear, colorless, odourless, palatable, sparkling & reasonably free from objectionabl chemical salts in solution & from microscopic organisms i suspension is called wholesome water.

Contaminated water – the water that contains the micro-organisms such as bacteria, worms, viruses etc. is called contaminated water. (non-potable and should not be used for drinking)

Typical components of water supply schemes.

The water supply system consists of collection, transmission, treatment, storage, and distribution works. There are many components of water supply system to perform these works. Each components has its ow specific function. The typical components of water supply schemes are

1. Intake

→ structure or device constructed at the water source for the purp of drawing water from the source and conveys it to the othe components of the water supply system.

→ Comprises of the screen at open end to screen out large and floati materials, conduit to convey the water from the source, valve to regulate the flow & housing in the form of chamber or tower.

2. Pump.

↳ machine commonly placed at the intake site to lift the water from the source.

↳ Pumping of water is required when the consumer area is at higher elevation than the source.

↳ Pumping of water should be avoided as far as possible becaus it increases the operation & maintenance cost of water supply sy

3. Transmission Main

→ Conduit or pipe laid to convey the water from the source to the service reservoir.

→ designed for the flow equivalent to the maximum daily demand.

→ Sometimes the pipes are laid from the source directly to the consumer areas without the provision of service reservoir. In such a case, there is no transmission main in the water supply system.

4. Collection chamber

→ provided at or near by the intake site to collect the water from one or more sources.

→ breaks the incoming water pressure into the atmospheric pressure forming a new static water level which will prevent the backflow of water from one source to another & from the source to the aquifer.

5. Distribution chamber

↳ provided at a junction in the pipeline when water has to be conveyed into more than one direction at atmospheric pressure.

6. Interruption chamber.

↳ chamber or tank located in the transmission main to break the excessive internal water pressure build in the pipeline.

↳ Converts the high pressure into atmospheric pressure forming the new static water level.

↳ provision of interruption chamber at strategic location will avoid the necessity of high pressure rating pipes & optimizes the system cost.

7. Water treatment Works

↳ provided in water supply system to remove the impurities present and make the water safe & potable for drinking purpose.

↳ Various types of water treatment processes such as screening, Sedimentation with or without coagulation, filtration, disinfection, aeration, softening, etc.

↳ The water treatment process to be adopted depends on the type of impurities present in raw water.

8. Reservoir

- used to store water.
- depending on the purpose of use, it can be clear water ~~se~~ reservoir or service reservoir.
- Clear water reservoir is provided at the water treatment site to store the treated water.
- Service reservoir equalizes the hourly demand fluctuations & stores the water for the break down reserve & fire fighting purpose.

9. Distribution System

- network of pipeline to convey the water from the service reservoir to the consumer premises.
- designed for the maximum or peak flow.
- the pipelines in the distribution system are classified as main, sub-mains, branches & laterals.

10. Break Pressure Chamber (BPC)

- chamber or tank located in the distribution system to break the excessive internal water pressure build in the ~~pipep~~ pipeline.
- provided with a float valve inside.

11. Public Stand Post (PSP)

- Structure in the pipeline from where water is distributed to the consumer.
- used in the water supply system where private household connection is not feasible / affordable.
- PSP consists of faucet, valve & stand post with necessary facilities of water collection, washing & bathing.
- good drainage should be provided so that there is no stagnation of waste water.

12. Valves

- accessories provided in the pipeline for specific purpose.

Sluice / gate valve = regulate the flow

Globe Valve = control the flow in pipeline

Check / non return valve = allows the flow only in one direction

Pressure release / safety valve = releases the excessive water pressure developed

Air release / air valve = releases the excessive air pressure build in pipeline

Drain valve = washes out sediments deposited in the pipeline

13. Valve chamber

↳ Chamber in which one or more valves are located.

↳ operate the valve

14. fittings

↳ used in the water supply system for its proper functioning & utilization

Bends & elbows – used to change the direction of the flow.

Reducer & increaser – used to change the pipe sizes.

Tees – used to divert the flow into two direction at right angle to each other.

Crosses. – three directions

Plugs & caps – stop the flow at pipe end.

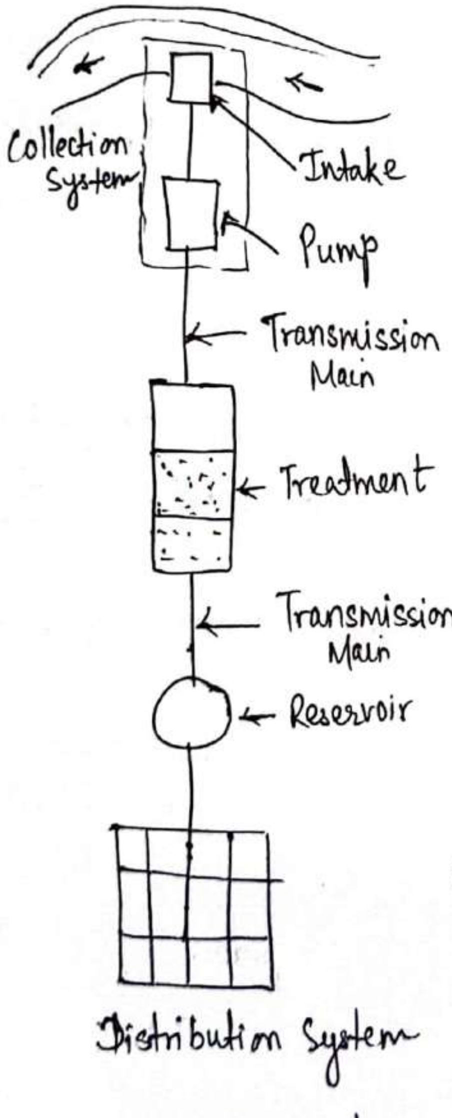


fig: Urban water supply system

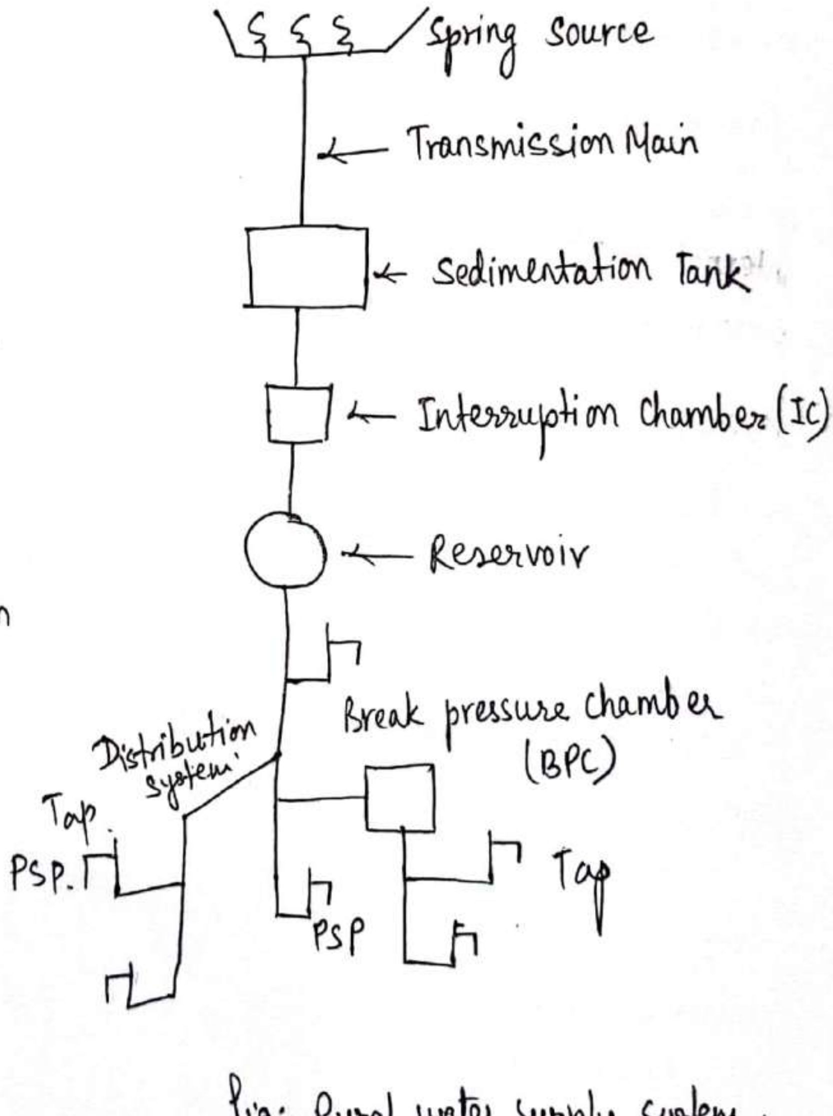
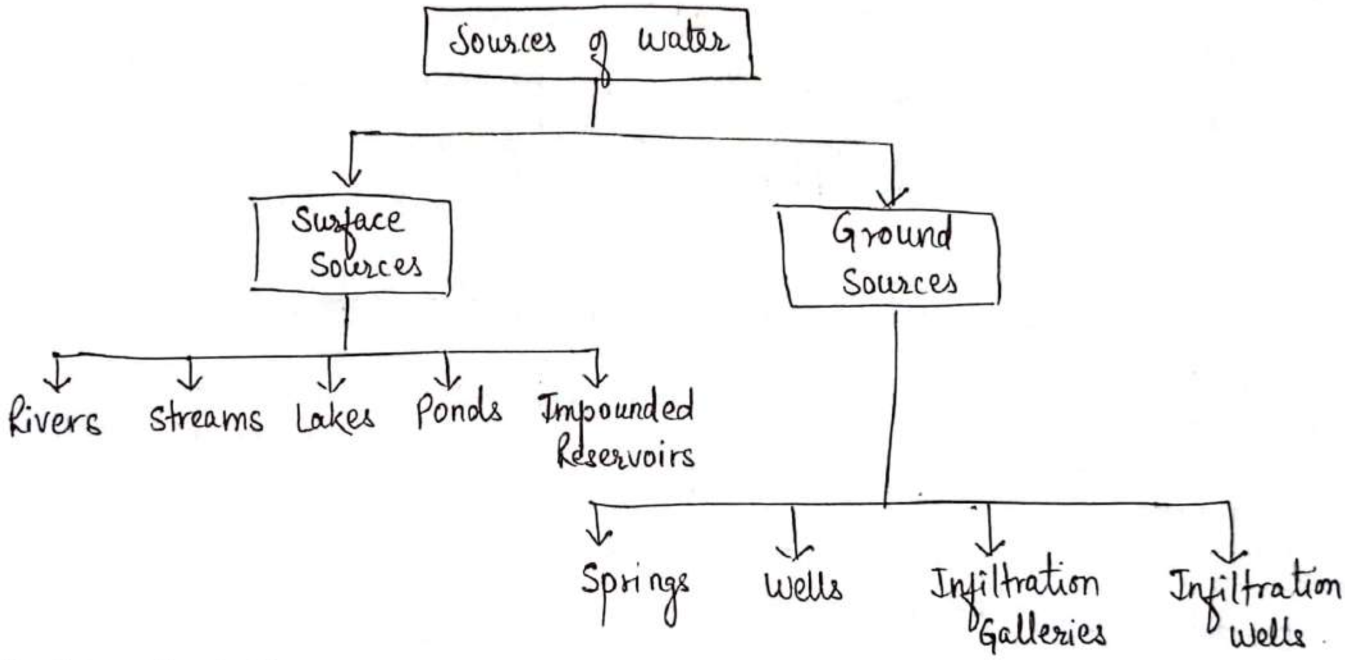


fig: Rural water supply system. (Gravity flow)

5.1.2. Sources of Water

- The primary source of water supply is precipitation which is the water falling from the atmosphere to the surface of the earth in the form of rain, snow, hail etc.
- The various sources of water available for the water supply may be broadly classified into the following two categories as
  - (a) Surface sources of water
  - (b) Sub-surface or underground or ground sources of water



1. Surface Sources

- These are those sources of water which are available at the ground surface.
- The various sources of water included in this category are rivers, streams, lakes, ponds & impounded reservoirs.
- The quantity & quality of surface water depends on a combination of climatic & geological factors.

(a) Rivers

- Natural channel which carries surface runoff received by it from its catchment or drainage basin.
- also carries the ground water flow added to it & the runoff resulting from the melted snow.
- most important sources of water supply; quantity of water available is large.
- Either perennial or non-perennial. (Necessary storage arrangements)
- The river water is fairly pure close to the point of origin in mountains but as the river approaches plains, the quality of water deteriorates.
- disposal of untreated or even treated sewage into the rives is liable

to contaminate the river water.

↳ As such, the rivers water must be properly analyzed & treated before Supplying to the public.

(b) Streams

↳ natural drainage channel found in the mountainous regions.

↳ may be either perennial or non-perennial

↳ quantity of water available in streams is much less in compared to rivers due to its small catchment area.

↳ Source of water supply in hilly / mountainous region of Nepal.

↳ generally used without any treatment.

↳ However, the stream water must be properly analyzed & treated if necessary before supplying to the public.

(c) Lakes

↳ large natural depression or hollow formed in the earth's surface which gets filled with water.

↳ quantity of water available from a lake depends upon its size, catchment area, annual rainfall, porosity of the ground & geological formations.

↳ quality of water available from a lake mainly depends upon the characteristics of its catchment.

↳ unhabitated upland hilly areas - relatively pure & good quality water

↳ lowland - Contaminated, still water - plenty of algae, weed & other vegetable growth imparting bad smell, taste & color to the water

↳ Sufficient quality of water available, it should be analysed & treated as it can be a useful source of water supply

(d) Ponds

↳ artificial; formed by digging of ground & are filled up with water in rainy season.

↳ quantity of water is generally very small & often it contains impurities.

↳ generally not suitable for drinking purposes & it can be used only for bathing, washing of clothes or for animals.

(e) Impounded Reservoir

↳ a storage reservoir or an artificial lake by constructing a bund, weir or dam across the river, which can store the excess water that flows in the river during the periods of high flows for use during the periods of low flows or droughts.

↳ water need to be properly analysed & treated before supplying to the public.

↳ main sources of water supply for big cities.

↳ storage reservoirs are created not only for water supply but also for other purposes such as irrigation, hydro-power generation, navigation, flood control etc.

2. Ground Sources

↳ These are those sources of water which exist below the ground surface.

↳ quality of ground water is generally good because of its natural filtering capability.

(a) Springs

↳ natural outflow of groundwater which appears the ground surface as a current or stream of flowing water;

(i) Gravity springs - results from water flowing under hydrostatic pressure.

* Depression Springs

→ formed due to overflowing of the water table, where the ground surface intersects the water table.

* Contact Springs

→ created by a permeable water bearing strata/formation over lying a less permeable or impermeable formation that intersects the ground surface.

* Artesian 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.

(ii) Non-gravity springs

→ includes volcanic springs & fissure springs.

→ Volcanic springs are associated with volcanic rocks & the fissure springs result from fractures extending to great depths in the earth's crust.

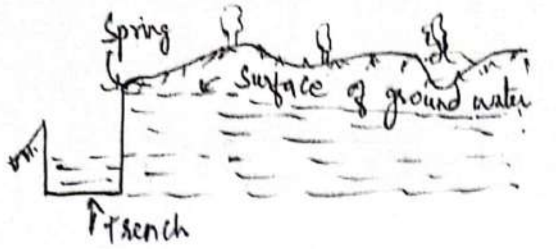


fig: Depression Spring

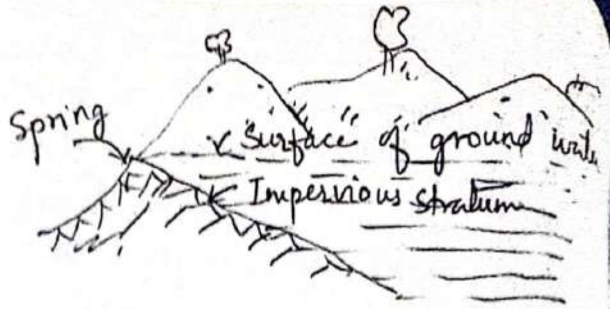


fig: Contact or Surface Spring

fig: Artesian Spring.

(b) Wells

↳ hole or shaft, usually vertical, excavated in the ground for bringing groundwater to the surface.

(i) Open wells or Dug wells (2) Tube wells

(c) Infiltration Galleries

↳ horizontal or nearly horizontal tunnel usually rectangular in cross-section & having permeable boundaries so that groundwater can infiltrate into the same.

↳ generally provided in highly permeable aquifers with high water table so that adequate head is available for gravity flow of groundwater into the gallery.

↳ frequently located near a perennial recharge source & hence it is usually placed along the bank, or under bed of river.

↳ quality of water is usually good due to natural treatment as the water moves through the sand media. However, water quality should be analysed to determine its suitability for drinking purpose.

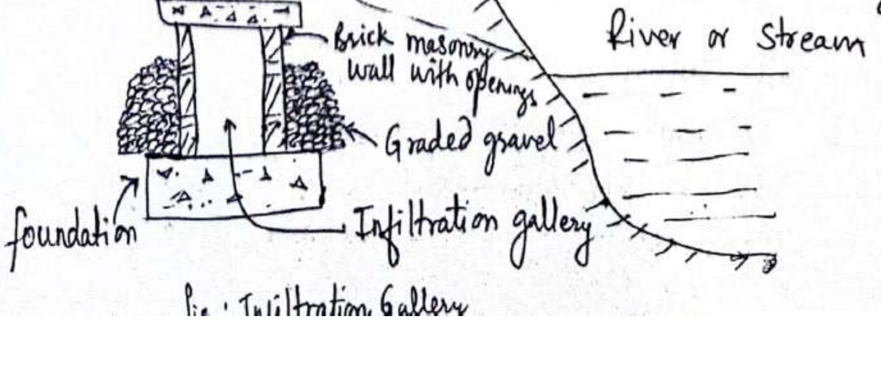


fig: Infiltration Gallery

(d) Infiltration Wells

- Shallow wells constructed in series along the banks of a river to collect the water seeping through the banks of river.

Ground Water Occurrences and Prospecting

- The water which is available below the ground surface is termed as ground water or subsurface water.
- main source of groundwater is precipitation.
- a portion of rain falling on earth's surface that infiltrates into ground travels down and when checked by impervious layer to travel down further, forms groundwater.
- amount of infiltration depends on rainfall characteristics such as rainfall intensity, soil characteristics such as porosity of the soil and soil cover.
- the groundwater held in the geological formation does not remain static but moves in the lateral & vertical directions to some point of escape appearing as springs & wells or reappears to join rivers, lakes, oceans, etc.
- the occurrence of groundwater & its transmission largely depends on the type of water bearing formation and the geological characteristics of the region.

Major types of geological formations :

a) Aquifer

- A geologic formation that contains sufficient permeable material which permits storage as well as transmission of water. eg. unconsolidated sands & gravels
    - (i) Unconfined Aquifers - water table serves as the upper surface of the zone of saturation. / free / phreatic or non-artesian aquifer
    - (ii) Confined Aquifers - groundwater is confined under pressure greater than the atmospheric by overlying relatively impermeable strata. artesian

b) Aquiclude

- geologic formation of relatively impermeable material which permits storage of water but is not capable of transmitting water in sufficient quantity. eg. clay

c) Aquifuge

- geologic formation of relatively impermeable material which neither contains nor transmits water. eg. solid granite

Ground water prospecting.

↳ involves various methods to locate suitable quality & quantity groundwater for extraction.

Prospecting Methods

- Surface Methods
  - Esoteric
  - Geomorphologic
  - Geological & structural
  - Surface geophysical
  - Soil & Micro-biological
  - Remote sensing
- Sub-surface Methods
  - Test drilling
  - Borehole geophysical logging techniques

Resistivity Surface

↳ Prospecting includes geological, meteorological, hydrogeological & hydro-chemical site analysis, along with an analysis of existing wells sites in the area.

↳ searching the quality & quantity of ground water.

Chemical characteristics & properties of ground water

	Characteristics	Ground Water
1.	Temperature	relatively constant
2.	Turbidity	low or nil (except in karst soil)
3.	Color	due to all dissolved solids
4.	Mineral content	Largely constant, higher than in surface water from same area.
5.	Divalent Fe & Mn in sol^n	Usually present
6.	Aggresive CO_2	often present
7.	Dissolved O_2	usually none
8.	Silica & nitrates	level often high
9.	Minerals & organic micro pollutants	usually none but accidental pollution lasts for a long time
10.	Living Organisms	Iron bacteria frequently found
11.	Chlorinated Solvents	often present
12.	H_2S, NH_4	often present

* Recharge of ground water

- Ground water recharge is a technique by which infiltrated water passes through the unsaturated region of groundwater & joins the watertable
- It is based upon soil type, land use, land cover, geomorphology, geophysical and climate (viz. rainfall, temperature, humidity etc) characteristics of a region.
- recharged naturally by rain and snow melt & to a smaller extent by surface water (rivers & lakes).
- Artificial method of ground water recharge has emerged as slow natural replenishment of ground water reservoir is not able to keep pace with the excessive persisted exploitation of groundwater.

Artificial recharge technology

Direct

1. Surface
   - Flooding / Water spreading
   - Basins or percolation tanks
   - Stream augmentation
   - Ditch & furrow system
   - Over Irrigation.
2. Sub-Surface
   - Injection wells or recharge wells
   - Recharge pits & Shafts
   - Dug well recharge
   - Bore hole flooding
   - Natural openings, Cavity fillings.
3. Combination
   - Basin or percolation tanks with pit shaft or wells.

Indirect

- Induced recharge from surface water source.
- Aquifer modification

Advantages

- Subsurface storage space is available free of cost & inundation (flooding) is avoided.
- Evaporation losses are negligible & temperature variations are minimum.
- Quality improvement by infiltration through the permeable media.
- No adverse social impacts such as displacement of population, loss of scarce agricultural land etc.
- Environment friendly technology; control soil erosion & flood like situations.
- Water stored in soil profile is relatively immune to natural & man-made catastrophes.

* Ground Water Recovery.

↳ Water resources management technique for actively storing water underground during wet periods for recovery when needed, usually during dry periods.

↳ principle of ground water recovery involves collecting water at times of higher precipitation or high river flow into surface water impoundments, and allowing it to percolate into the aquifer.

- ground water remediation
① Biological ② Chemical ③ Physical

removal of pollutants & ground water

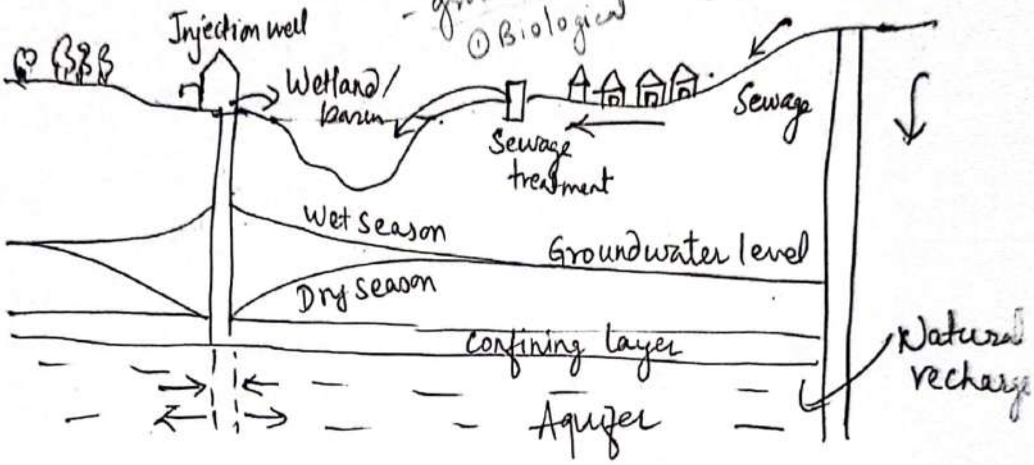


fig: Ground water recovery.

* Tube Well Design

(a) Diameter of well

↳ diameter should be large enough for the accomodation of pump.

- Discharge = Q.
- Permissible velocity (v) in well pipe = 1.5 - 4.5 m/s
- Cross-sectional area of tube well (A) = Q/V
- Diameter of tube well (d) = $\sqrt{\frac{4A}{\pi}}$

(b) Well Depth

- depth of well & the number of aquifers it has to penetrate depends on the litho logical log of the area.
- bearing of the soil - advised by geologist.

(c) Design of well screen

length of

- Homogeneous confined aquifer : 70 - 80% of aquifer thickness
- Non-homogeneous confined & unconfined aquifer ; screen for most permeable ~~strata~~ strata
- Homogenous unconfined aquifer : at bottom

Slot size for naturally formed well ; 40-70% of the size of the formation materials.

If D10 < 0.25 mm & uniformity coefficient (Cu) < 3, artificial gravel pack is required.

- Prepare gradation curve of gravel pack.
- Cu of gravel pack material < 2.5.
- D30 of gravel pack = 4 to 6 times D30 of aquifer material
- Slot size = D10 of gravel pack
- Width of slots = 1.5 to 4 mm
- Length of slots = 5 to 12.5 cm
- Screen diameter

Entrance velocity near the well = 3 to 6 cm/s

Entrance velocity, V_c = yield / total area of opening.

$$Q = P\pi D L V_c$$; p = percentage of open area of the strainer

→ Tube well is a long pipe sunk into the ground with a strainer which allows water to pass through but prevents sand from coming in.

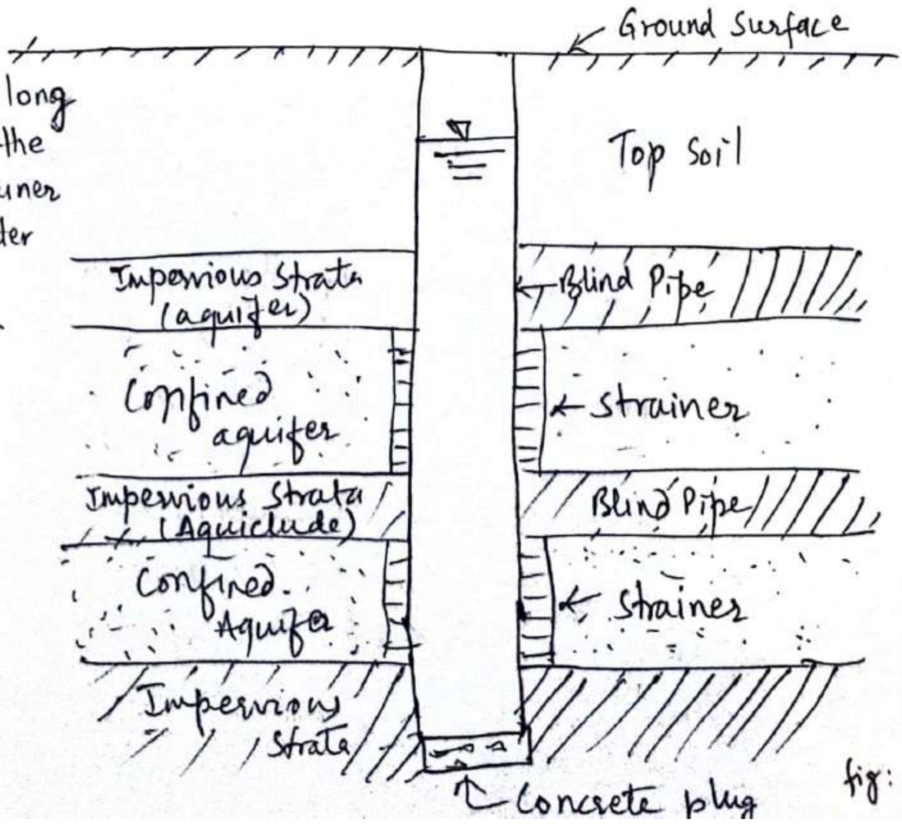


fig: Strainer type

* Selection of Water Sources

(i) Location.

- The source of water should be near to the community as far as possible. This will reduce the pipe length required & hence ~~minimize~~ minimize the system cost.
- If there are both the surface & ground sources are available near to the community, the use of surface source should be preferred.
- The location of water source should be such that the water can be conveyed through gravity from the source to the consumer areas without pumping.

(ii) Quality of water

- The quality of water available at the source should be wholesome, safe and free from pollution of any kind.
- If safe water is not available, it should be cheaply treated. The treatment of water should be avoided as far as possible by selecting the source with good water quality.

(iii) Quantity of water

- The quantity of water available in the source during the driest period should be sufficient to cater the demands of the community such as domestic, commercial, industrial, public, fire fighting, etc.
- There should be sufficient extra ~~quality~~ quantity of water at the source for future expansion of the community.

✓ Water Right Problems
✓ Reliability of the Source

(iv) Cost

- Cost should be taken into account while selecting the source of water.
- Cost of the water supply system depends on many factors such as systems of supply, elevation of the community, distance between source and community, topography of the area, etc.
- Cost of the system should be minimized so that water can be supplied to the consumers at affordable price.

The water source should be selected considering the above points & the source which will give sufficient quantity of water with good quality requiring less treatment at affordable cost should be selected.

✓ Technical Criteria ✓ Socio-economic criteria
✓ Environmental " ✓ Institutional "

to contaminate the river water.
- As such, the river water must be properly analyzed & treated before supplying to the public.

(b) Streams

- natural drainage channel found in the mountainous regions.
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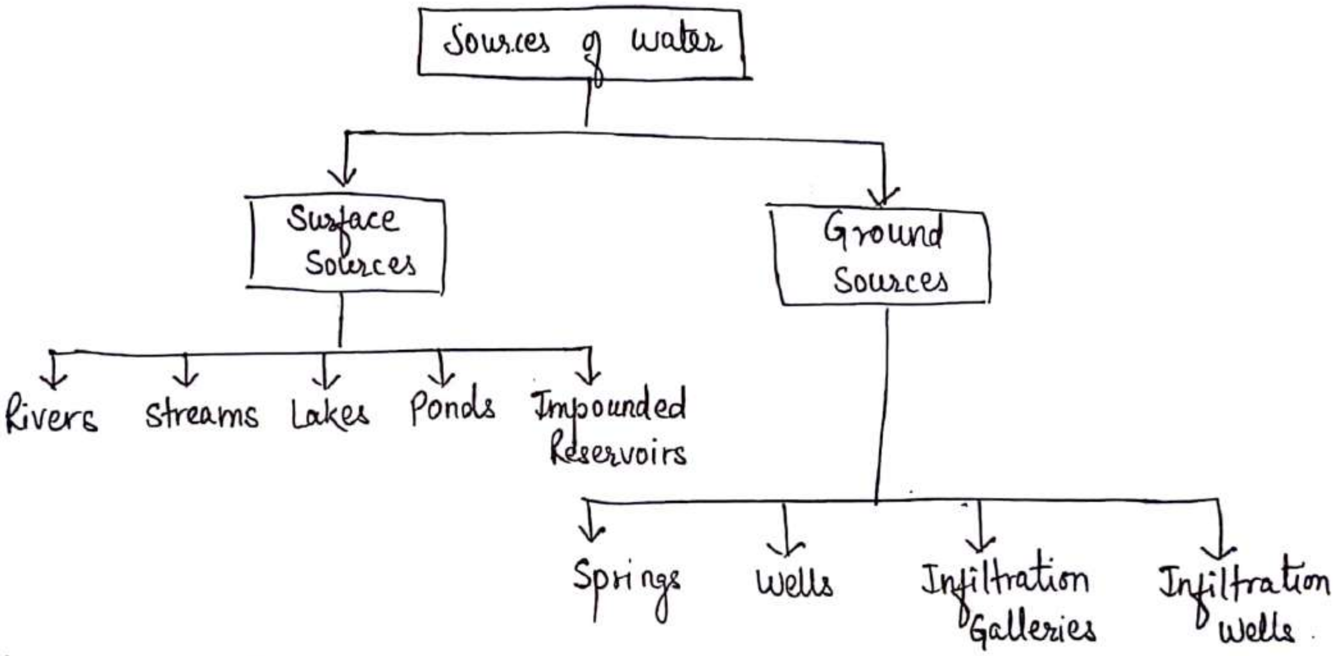

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5.1.3. Quality of Water

Types and sources of water pollution

↳ Water pollution is the contamination of water sources by substances which make the water unusable for drinking, cooking, cleaning, & other activities.

Types of water pollution

(a) Surface water pollution

↳ Referring to all water sources above ground, such as rivers, lakes, seas and oceans, surface water pollution can occur both naturally, accidentally and intentionally.

(b) Ground water pollution

↳ Contaminate aquifers below the soil.
↳ usually caused by highly toxic chemicals & pesticides from farming that seep into the ground to contaminate wells & aquifers below the surface.

(c) Microbiological pollution

↳ naturally occurring form of water contamination caused by micro-organism
↳ Humans are most susceptible to this kind of pollution in places where there is no adequate water treatment systems.

(d) Oxygen-depletion pollution

↳ Consumption of oxygen by micro-organisms results in depletion of Oxygen layers, which causes aerobic micro-organisms to die & anaerobic micro-organisms to thrive. These organisms produce damaging / harmful toxins like sulphides & ammonia.

(e) Nutrient Pollution

↳ Excess of nutrients can upset the delicate imbalance of water-based ecosystems..
↳ Fertilizers contain high concentration of nutrients, can cause algal blooming in rivers, lakes & coastal areas, that can block out sunlight & inhibit the growth of other organisms.

(f) Suspended Matter Pollution

↳ Improperly discarded waste, such as fragments of plastic, rubber, can find themselves into water sources & persist for a long time.
↳ Too robust & too big to dissolve & mix with molecules, they simply float in surface & prevent penetration of sunlight & oxygen.

(g) Chemical Pollution

- Chemical can infiltrate both underground water sources & of surface sources.
- Much of the chemical contamination comes from the pesticides and fungicides used in farming, but metals & solvent from industrial sites are also leading contributers.

Sources of Water Pollution

(i) Industrial Waste

- Industries produce a tremendous amount of waste, which contains toxic chemicals & pollutants.
- Though regulated, some industries & industrial sites donot have proper waste management systems. In those, the waste is dumped into nearby freshwater.
- The toxic chemicals may change the color of water, increase the number of minerals, called eutrophication, change the temperature of water, & pose a severe hazard to water organisms.
- also make water unsafe for human consumption.

(ii) Sewage and Wastewater

- Harmful chemicals, bacteria & pathogens can be found in sewage & wastewater even when it's been treated.
- The pathogens & bacteria found in those causes health related issues.

(iii) Agriculture

- Chemical fertilizers & pesticides are used to protect crops from insects & bacterias. They are useful for plant growth. However, when those chemicals are mixed up with water, they produce harmful pollutant for plants & animals.

(iv) Oil Leaks and Spills

(v) Global warming.

- causes water temperature to rise, which can kill water-dwelling animals

(vi) Radio-active waste

(vii) Marine dumping → dumping garbage into the waters of ocean

(viii) Mining activities → emit large amount of metal waste & f sulph from the rocks.

Point & Non-Point Sources of water pollution

Point source

- A point source is a single, identifiable source of pollution, such as a pipe or drain.
- enters the water from an easily identified & confined place.

eg. discharge from commercial & industrial business, agriculture pollumtants, municipal point sources such as waste water treatment plants, landfills, utility stations, etc.

* High temp. discharges, micro-organisms, nutrients.

Non- Point sources

- No single ~~pont~~ point from which the pollution comes; it comes from everyone & everywhere.
- Non-point source pollution occurs as water moves across the land or through the ground & picks up natural & human-made pollutants, which can be then deposited in lakes, rivers, wetlands, & even groundwater.
  - → sediments, nutrients & toxins.
- difficult to trace the exact origin of pollutants

eg. illegal discharges, illegal dumping of solid or liquid waste, agricultural operations, soil sediments, construction debris, improper grading, vehicle & equipment washing, improper storage of solid waste, solvents, detergents etc.

⇒ Storm water pollution.

Effects of pollution (river, lake and reservoir)

- Destruction of bio-diversity - aquatic life
- Contamination of food ~~chain~~ chain
- Lack of potable water
- Disease
- Infant mortality
- Chemical effects.
- Economic loss

Pollution of ground water

- Groundwater pollution (or contamination), occurs when unwanted substances called pollutants, seep from the land surface into the groundwater during the groundwater recharge process.

Causes of groundwater pollution /Sources

(i) Naturally occurring (Geogenic) Chemicals.

- compounds of arsenic & fluorine.
- poisonous & quite lethal in nature. (Anaerobic condition)
- hypomineralization of the tooth enamel - dental fluorosis

(ii) Poor sanitation System

(iii) Improper Sewage Disposal

(iv) Excessive use of fertizers & Pesticides

(v) Leakage from industrial pipes & other industrial releases.

(vi) Overpumping of groundwater

- may release arsenic into the water & also cause land subsidence (sudden sinking of land).

(vii) Improper landfill practices

Ways to prevent groundwater pollution

(i) Use of precautionary principle

↳ avoiding harm using precautionary measures. from the view of uncertainities.

(ii) Monitoring quality of groundwater

↳ measuring groundwater parameters like pH, flow rate, water level, etc.

(iii) Land Zoning or Marking.

↳ to ensure a better focus on specific areas for preventing groundwater pollution.

↳ Zoning aquifer vulnerability maps & source protection maps.

(iv) Via statuary regulations

(v) Educating others → Creating awareness

Impurities in Water.

A) Acc. to characteristics

i) Physical impurities

ii) Chemical impurities

iii) Bacteriological impurities.

B) Acc. to its state.

① Suspended impurities

② Colloidal impurities

③ Dissolved impurities

* Hardness of ~~Soft~~ Water

↳ Hardness is the characteristics of water which prevents the formation of sufficient lather of foam with soap.
↳ Caused by the presence of bicarbonates, sulphates, chlorides & nitrates of calcium, magnesium & strontium.

Effects of hardness

↳ Excess amount of hardness is undesirable.

(i) It consumes more soap.
(ii) It forms scales in boilers
(iii) It modifies color in the dyeing industry
(iv) Causes corrosion & incrustation of pipes
(v) It makes food tasteless.

Types of hardness

(i) Temporary Hardness ↳ caused by presence of bicarbonates of calcium, magnesium & strontium

↳ can be removed by boiling the water or by adding lime in the water.

(ii) Permanent Hardness

↳ caused by the presence of sulphates, chlorides & nitrates of calcium, magnesium & strontium.

↳ non-carbonate hardness.

↳ removed by lime soda & zeolite methods.

→ Hardness of water is expressed in ppm or mg/l as $CaCO_3$.

CH = carbonate hardness

NCH = non-carbonate hardness

Alkalinity

↳ The alkalinity of water it is its capacity to neutralize a standard Solution of acid.

OH^- concentration $>$ H^+ concentration = Alkaline

→ caused due to presence of bicarbonate (HCO_3^-), carbonate (CO_3^{--}) & hydroxide (OH^-)

Total alkalinity = Carbonate alkalinity + Bicarbonate alkalinity

Total alkalinity = Carbonate alkalinity + Hydroxide alkalinity

Relation between hardness & alkalinity

① Total hardness (TH) $>$ alkalinity then

$$CH = \text{alkalinity}$$
$$NCH = TH - \text{alkalinity} = TH - CH$$

② Total hardness (TH) $\leq$ alkalinity, then

$$CH = TH$$
$$NCH = 0$$

* Living Organisms in Water

- contains various types of living organisms.

(a) Algae (b) Bacteria (c) Viruses (d) Worms

Algae

- unicellular photosynthetic plants which grow in water.
- self nourishing
- impart unpleasant taste and odour to water.
- also causes apparent colour and turbidity in water.
- some are pathogenic; produce endotoxins that cause gastroenteritis.
- 90-95% of algae can be removed effectively by coagulation & sedimentation.
- Excessive growths of algae in water may be controlled by application of copper sulphate or chlorine.

Viruses

- infectious agents of both plants & animal cells.
- ultramicroscopic in size measuring 10 to 500 milli microns.
- parasite & require host cells for their activity & multiplication.
- plays a significant roles in the spread of water borne diseases.
- inactivated by disinfection.

Worms

- Known as helminths & are classified in two groups, the nematodes or round worms and flat worms.
- either parasitic or free living.
- removed by controlling turbidity through effective coagulation and filtration.

Bacteria

- Minute single cell organisms which are universally found in natural waters.
- microscopic in size.
- less sensitive to cold than heat.
- Most bacteria are harmless; while some may cause disease, taste & odours, pipe corrosion, & pipe blockage.

Types of bacteria

(i) According to Oxygen need

(a) Aerobic bacteria — need oxygen to live.

(b) Anaerobic bacteria - Survive in the absence of oxygen

(c) facultative bacteria - can live & multiply with or without oxygen.

(ii) According to shape

(a) Cocci bacteria - round, oval or spherical

(b) Bacilla bacteria - straight or rod shaped.

(c) Spirilla bacteria - Curved rods, comma shaped or helical

(iii) Acc. to diseases causing characteristics

(a) Pathogenic - capable of causing diseases

(b) Non-pathogenic - not capable.

(iv) Acc. to the life process

(a) Saprophytic bacteria - which live on dead or decaying organic matter of plants or animals. non-pathogenic

(b) Parasite bacteria

↳ live & multiply on or within the body of living organisms

↳ pathogenic or non-pathogenic

(v) Acc. to temperature at which they thrive

(a) Psycrophillic bacteria - survive bet^n 10 to 20°c

(b) Mesophillic bacteria - survive between 20 to 40°c

(c) Thermophillic bacteria - survive between 40 to 65°c

→ difficult to detect in water supply because of their small numbers.

→ indirect evidence of pathogenic bacteria in water is obtained by testing the water for coliforms or E-coli.

→ presence of coliforms & E-coli indicate the pollution of water.

↓ indicator organisms.

* Water Related Diseases

↳ Water in many ways (consumption, penetration of organisms, insufficiency) is associated with cause of diseases ; such diseases are known as water related diseases.

(a) Water borne deiseases (b) Water Washed diseases
(c) Water based diseases (d) Water Vector diseases.

Water borne diseases

↳ diseases contracted through the consumption of water, either by drinking or use in food preparation,

↳ Poor water quality is responsible for the cause of diseases.

eg. Cholera , Typhoid fever, Diarrhea , Dysentry

Water Washed Diseases

↳ diseases whose transmission results from a lack of sufficient clean water for frequent bathing, hand washing & washing clothes & household utensils.

↳ Stem from basically poor sanitation practices ,

eg. Bacillary dysentry , Scabies & Ascariasis

Water Based Diseases

↳ diseases which are transmitted when people have contact with infected water.

eg. Schistosomiasis (Bilharziasis) - infection with blood fluke worms

Water Vector Diseases.

↳ those that are transmitted by insects which breed in or near water.

↳ host (man & animals), a parasite that causes the diseases (protozoa, virus or worm) & a carrier or vector (insect, fly or mosquito).

eg. Malaria, Arboviruses & Filariasis

Transmission routes

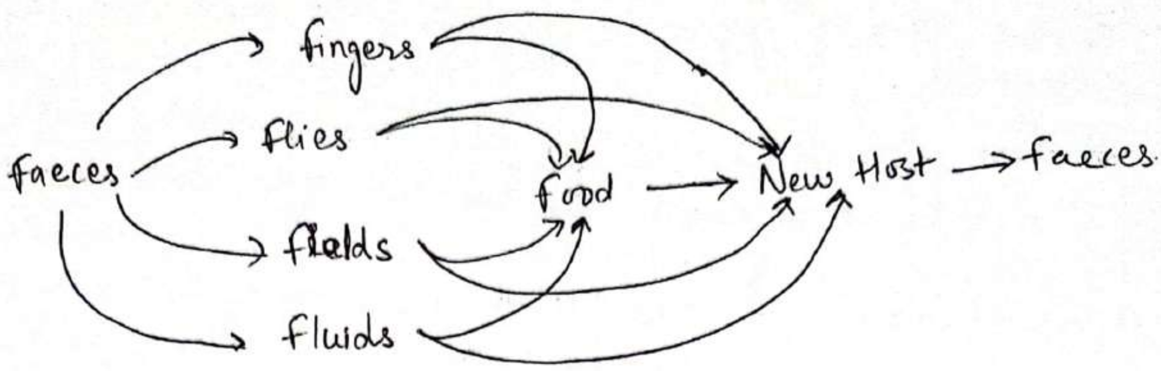


fig: F - diagram.

Preventive Measures

- Safe human excreta disposal
- Personal hygiene
- Domestic hygiene & animal management
- food hygiene
- Water hygiene / consumption of safe water
- Safe wastewater disposal & drainage,
- Thorough health education program.

WHO has identified three priority measures.

- safe disposal of excreta
- Maintaining drinking water free from fecal contamination; and
- Hand washing after defecation, before feeding, eating and preparing food and after handling excreta of babies.

Physical, chemical and biological test of Water

- carried out to find out the quality of water by determining the various types of impurities present in the water with their concentration.
- Analysis of water ; done for both raw & treated water
  - raw water ⇒ to enable the selection of water treatment process if necessary.
  - treated water ⇒ to determine the efficiency of the treatment process & suitability of treated water for drinking purpose

~~Phys~~

Physical test of water

- carried out to determine the physical impurities & the corresponding physical characteristics of water.
- includes the tests for temperature, color, taste and odour, turbidity of water.

(i) Temperature

- Temperature has an effect on the physical properties of water such as density, viscosity, vapour pressure, surface tension & saturation value of gases dissolved in water.
- affects the rate of chemical & biological activity.
- desirable temperature of water is 10 to 15.6°C.
- temp. above 25°C is considered objectionable while temp. above 35°C is considered unsuitable for public water supply.
- The temperature is measured with ordinary thermometer graduated in 0.1°C ranging from 0 to 50°C.

(ii) Color

- It describes the state of a solution and is measured by the ability of the solution to absorb light.
- caused by dissolved organic material from decaying vegetation such as leaves, planktons, peats, logs & other organic & inorganic matters.
- expressed in units of platinum cobalt scale.
- Pure water is colorless. Apparent color = due to dissolved & colloidal material
  True color = due to dissolved materials only.
- Colored water is aesthetically objectionable for drinking.
- Permissible 5 unit, 15 unit - tolerable. Measured by means of a tintometer or colourimeter.

(iii) Taste and odour

- Caused due to presence of dead or living organisms, dissolved gases and mineral substances.
- No measurement for taste; it can be perceived only.
- Intensity of odour is measured in terms of threshold number.
- The water supplied to the consumers should be free from objectionable taste & odour.

(iv) Turbidity

- measure of resistance to the passage of light through it.
- Caused by suspended matter such as clay, silt, finely divided organic and inorganic matter, soluble organic compounds, vegetable fibers and micro-organisms.
- important consideration from aesthetic, filterability & disinfection view.
- Turbid water has muddy or cloudy appearance & is aesthetically unattractive.
- expressed in parts per million (ppm) or milligram per liter (mg/l) on silica scale.
- also expressed in JTU (Jackson Turbidity Units), Formazyn Turbidity Units (FTU) or Nephelometric Turbidity Units (NTU).
- permissible turbidity is 5 NTU for drinking water, but the turbidity up to 10 NTU may be tolerated.

Chemical Tests of Water

- Carried out to determine the chemical impurities and the corresponding chemical characteristics of water.
- includes the tests for pH, solids, hardness, dissolved gases etc.

Solids

- solids present in water are either dissolved solids or suspended solids.
- expressed in ppm or mg/l.
- The quantity of total solids present in domestic water should be less than 500 ppm but is acceptable up to 1000 ppm.

pH

↳ pH value of hydrogen ion concentration is the measure of acidity or alkalinity present in water.

$$pH = -\log_{10}[H^+] = \log_{10}\left(\frac{1}{[H^+]}\right)$$

$[H^+] \times [OH^-] = 10^{-14}$ → complete pH scale ranges from 0 to 14.

Tuberculation – by acidic water
Incrustation – alkaline water

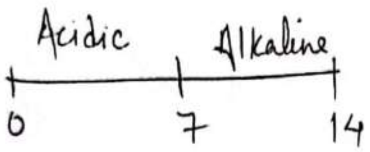


fig: pH scale

→ pH value of pure water is 7.

→ pH of drinking water should be in between 6.5 to 8.5.

→ Methods of determining pH value of water
  a) Colourimetric method
  b) Electrometric method.

Biological tests

↳ Carried out to determine the presence of micro-organisms in water.

↳ The pathogenic micro-organisms are harmful to the human health & are responsible for many types of diseases.

↳ During the biological tests, the concentration of coliforms or E-coli are tested rather than pathogens because pathogens are present in small numbers & their testing is time consuming & expensive.

↳ The coliforms & E-coli should be nil in the drinking water.

Methods

(a) Multiple tube fermentation technique

(b) Membrane filter fermentation technique

Multiple Tube fermentation Technique

- requires use of multiple numbers of standard fermentation tubes called Durham tubes for the determination of the coliform group and E-coli bacteria.

(i) Presumptive Test

- this technique is based on the ability of coliform group of bacteria to ferment lactose broth at 37°C & produce gas.
- Incubating tubes at a temperature of 37°C for 24 hrs.
- Observe gas → if gas present in tubes = presence of coliform group
  no gas is present = absente of coli form group.
- Samples showing negative results are discarded & positive samples are taken for confirmed test.

(ii) Confirmed Test

- presence of gases in tubes during presumptive test does not necessarily indicates the presence of coli form group, therefore confirmed test is required.
- consists of growing cultures of coli-form group of bacteria on media which suppress the growth of other organisms.
  → brilliant green lactose broth – fermentation tubes.
  → 37°C for 24 hrs. < gas story.

(iii) Completed Test

/ Endo or Eosin methylene blue agar.

- done to demonstate with certainty that the organisms showing positive results in the confirmed test are really members of the coli form group.

Membrane filter fermentation Technique

- most recent method for detecting the colli form group of bacteria and measuring their concentration.
- Sterile membrane filter to retain e-coli when water is filtered through.
- Incubating at 37°C for 20 hrs.

Water quality Standard

	Parameters	Unit	Max^m Concentration NDWQS	WHO
1.	Turbidity	NTU	5(10)*	5
2.	pH		6.5 - 8.5	6.5-8.5
3.	Color	TCU	5(15)	5
4.	Taste & odour		would not be objectionable	
5.	Total dissolved solids	mg/L	1000	
6.	Electrical conductivity	μS/cm	1500	
7.	Iron	mg/l	0.3(3)	0.3
8.	Manganese / Aluminium	mg/l	0.2	0.1
9.	Arsenic	mg/l	0.05	0.01
10.	Cadmium	mg/l	0.003	0.003
11.	Chromium	mg/l	0.05	0.05
12.	Cyanide	mg/l	0.07	0.07
13.	Flouride	mg/l	0.5-1.5*	1.5
14.	lead	mg/l	0.01	0.01
15.	Ammonia	mg/l	1.5	1.5
16.	Chloride	mg/l	250	250
17.	Sulphate	mg/l	250	250
18.	Calcium	mg/l	200	25
19.	Magnesium	mg/l		20
20.	~~Sulphate~~ sodium	mg/l		150
21.	Potassium	mg/l		12
22.	Nitrate	mg/l	50	10
23.	Copper	mg/l	1	2
24.	Total Hardness	mg/l	500	500
25.	Total Alkalinity.	mg/l		500
26.	Mercury	mg/l	0.001	0.001
27.	Residual chlorine	mg/l	0.1-0.5	
28.	E Coli	CFU/100ml	0	

* Impurities Present in Water & their Causes & Effects

→ Based on its characteristics the impurities present in water can be classified as follows.

(i) Physical (ii) Chemical (iii) Bacteriological

* Physical Impurities

→ those impurities which affect the physical characteristics of water such as temp, colour, odours, taste and turbidity.

→ Presence of physical impurities in water makes it unobjectionable to drinking.

* Presence of algae, organic matter, industrial waste, sewage, minerals, ~~mine~~ micro-organisms — colour, odour & taste.

• Suspended & colloidal matters such as sand, silt, clay = Turbidity.

* Chemical Impurities.

→ affect the chemical characteristics of water such as suspended & dissolved solids, pH, hardness, mineral content, chloride, nitrogen, salts etc.

→ presence of chemical impurities in excessive amount may cause various diseases

* Bacteriological Impurities

→ those impurities which affect the bacteriological characteristics of water such as pathogenic & non pathogenic microorganisms present in water.

→ Based on its state of presence

(i) Suspended (ii) Colloidal (iii) Dissolved.

* Suspended Impurities

→ These are dispersion of solid particles that are large enough to be removed by ~~sedim~~ filtration or settling.

→ Causes turbidity in water. → remain in suspension in water

→ Clay, algae, fungi, organic & inorganic matter, bacteria etc.

* Colloidal Impurities

→ very finely divided dispersion of particles in water.

→ So small that these cannot be removed by ordinary filters and are not visible to naked eye.

→ electrically charged and remain in continuous motion.

→ silica, glass, Al_2O_3, Fe_2O_3

→ removed by chemical coagulation, sedimentation & filtration.

* Dissolved Impurities
→ is in dissolved state in simple atoms or complex molecular compounds.
→ organic compounds, inorganic salts and gases.
→ removal of the dissolved substance requires a phase change from the liquid such as distillation, precipitation, adsorption, or extraction.

Impurities in water, their causes & effects.

Type	Cause	Effects
Suspended Impurities	Bacteria	Some causes disease.
	Algae & Protozoa	Color, odour, taste & turbidity
	Clay & silt	Turbidity.
Dissolved Impurities	(a) Salts of Calcium & Magnesium	
	Bicarbonate	Hardness & Alkalinity
	Carbonate	" "
	Sulphate	Hardness
	Chloride	Hardness.
	(b) Salts of Sodium	
	Bicarbonate	Softening & Alkalinity
	Carbonate	" " "
	Fluoride	Dental fluorosis
	Chloride	taste.
	(c) Metals & Compounds	
	Iron oxide	Taste, red color, hardness & corrosiveness
	Manganese	Black or brown color
	Lead	Cumulative poisoning
	Arsenic	Toxicity
	Silver	Discolouration of skin & eye
	Nitrate	Blue baby diseases in infant.
Suspended Organic Impurities	Vegetable	Color, taste & acidity
	Animal (dead)	Harmful diseases germs & alkalinity
Dissolved Organic Impurities	Vegetable	Produce bacteria
	Animal (dead)	Pollution of water & diseases germs

5.1.4 Quantity of Water

- first step in the design of water supply system of a community is the determination of the quantity of water required or water demand of community for various purposes.
- the estimation of water demand or the quantity of water required for a community requires the following three factors to be known:

(a) Per capita demand of water or rate of demand.

- Average quantity of water ~~de~~ consumption or water demand for various purposes per person per day.
- expressed in liters per capita per day (lpcd)

(b) Base and Design period

- Period required for survey, design and construction of a water supply system is base period. (normally 2 to 3 years)
- The future period or the number of years for which a provision is made while planning and designing a water supply project is called design period.

Selection basis of design period

(i) Population growth rate (birth, death, migration factors)

(ii) Development of community → rapid development, shorter design period.

(iii) Useful life of component structures
- design period should not exceed the useful life of component structures.

(iv) Availability of fund
- shorter design period for limited fund & vice-versa.

(v) Rate of interest on borrowings

(vi) Availability of water at source.

(c) Population

Types of Water Demands

↳ various types of water demand, depending on the purpose of use.

(i) Domestic Demand

↳ includes the water which is required for use in private residences, apartment houses, etc., for drinking, cooking, bathing, washing of clothes, washing of utensils, washing & cleaning of houses & residences, lawn watering, gardening and sanitary purposes.

↳ amount of domestic depends on the living conditions of the consumers.

↳ The domestic water demand in Nepal is generally taken as follows

- 112 lpcd for fully plumbed houses
- 65 lpcd for partly plumbed houses
- 45 lpcd for rural areas served by PSP

(ii) Livestock Demand

↳ includes the water consumed by domesticated animals like horses, cows, pigs, sheep, goats, chickens etc.

↳ depends on the type of animals.

- 45 liters/animal/day for big animals such as cows, horses etc.
- 20 liters/animal/day for medium sized animals such as pigs, sheep, goats, etc and
- 20 liters/100 birds/day for birds such as chickens, ducks, etc.

(iii) Commercial demand

↳ includes the water demand of commercial establishment such as educational institutions, offices, hotels, hospitals, restaurants etc.

↳ depends on nature & type of commercial establishments.

- 10 liters/pupil/day for day-scholars in educational institutions
- 65 liters/pupil/day for boarders " " ,
- 500-1000 liters/day for offices
- 2500 liters/bed/day for hospitals with bed
- 2500 liters/day for hospital without bed & health clinics
- 200 liters/bed/day for hotels with bed
- 500-1000 liters/day for hotels without bed
- 500-1000 liters/day for restaurants.

(iv) Public / Municipal Demand

- ↳ includes the quantity of water required for public or muncipal utility purposes such as watering of public parks, road washing, sprinkling of water on dusty roads, cleaning sewers, large markets etc.
- ↳ No specific guideline value in Nepal for municipal demand.
- ↳ provision of 5 to 10% of total consumption is made for these demands.
- ↳ considered in urban communities only.

(V) Industrial Demand

- ↳ quantity of water required depends upon the type of industry. (20-25%.)

(vi) fire Demand

- ↳ quantity of water required for fire-fighting purpose.

Emperical formulas

a) $Q = 100\sqrt{P}$; Indian w/s Kl/day

b) $Q = 5663\sqrt{P}$; Buston's l/min

c) $Q = 3182\sqrt{P}$; Kuchling's

d) $Q = 1136\left(\frac{P}{5} + 10\right)$; freeman's

e) $Q = 4637\sqrt{P}\left(1 - 0.01\sqrt{P}\right)$; National Board of fire

P = population in thousands.

(vii) Loss and Wastage.

- ↳ Includes the water lost due to leakage in mains, valves & other fittings, worn or damaged meters, theft of water through unauthorized water connections, & loss & waste of water due to other miscellaneous reasons.

→ 15% of Total supply.

Total Water demand = DD + LD + MD + FD + ID + WLD + CD

Variation in Demand of Water

→ Rate of demand of water does not remain constant but varies fr[om] season to season, day to day and hour to hour in a day.

(a) Seasonal Variations (b) daily Variations (c) hourly variati[ons]

Seasonal Variations

↳ rate of demand of water varies from season to season.

↳ Summer Season > Winter Season.

↳ Variation ~~of~~ in rate of demand due to seasonal variation is very low, generally neglected in Nepal.

$$\text{Max}^{m} \text{ season demand} = \text{Seasonal peak factor} \times \text{Annual Average demand}$$

* Seasonal peak factor is assumed as 1 in Nepal.

Daily Variations

↳ demand of water also varies day to day.

↳ due to change in the day to day climatic conditions, or due to the festival day or due to the day being holiday.

• Maximum daily demand = daily peak factor × Annual average demand.

Daily peak for = 1.1.

Hourly Variations.

→ varies from hour to hour of the day.

→ max^m morning & evening.

$$\text{Max}^{m} \text{ hourly demand} = \text{Hourly peak factor} \times \text{Average Annual demand}$$

peak factor = 3.

Factors affecting demand of Water

1. Size and type of community

→ Bigger the community such as town or cities, higher is the rate of demand of water and vice versa.

↳ Urban area - larger per capita consumption as water is supplied through private connections while rural area has less per capita consumption as water is supplied through public stand posts.

2. Climatic Conditions

↳ Water requirement is more in communities having hot climate and dry climate than at communities having cold climate.

3. Standard of living.

↳ Higher the standard of living, greater will be the demand of water.

4. System of supply.

↳ Rate of demand is less in the intermittent system of supply because only limited water is supplied in this system.

5. Pressure in the distribution System.

↳ Consumption of water increases with the increase in pressure in the distribution system. (due to loss of water

6. Sewerage System

→ Provision of sewerage system increases the rate of demand of water.

7. Metering

↳ either metered or non-metered.

↳ Non-metered → more wastage.

8. Cost of water

↳ Lower cost = high demand

9. Quality of water

↳ Poor quality water results in a reduction in use.

10. Age of Community.

→ Older, more stable → less water usage

developing communities → more as construction of new houses

Population forecasting.

a) Arithmetical Increase Method

$$P_n = P + nI$$

P = present population

I = avg. increase in population for a d

b) Geometrical Increase Method

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

r = Average percentage increase in population.

c) Incremental Increase Method

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

d) Decreased rate of growth or changing rate of increase method

$$P_n = P\left(1 + \frac{r_n - r'}{100}\right)\left(1 + \frac{r_n - 2r'}{100}\right) - - \left(1 + \frac{r_n - nr'}{100}\right)$$

5.1.5. Intake Works

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

Site Selection of an Intake

Intake
- 1. Submerged, Exposed
- 2. Wet, Dry
- 3. River, Reservoir, Spring

(i) The site for locating the intake should be as far as possible near the treatment plant so that the cost of conveying water would be less.

(ii) The intake must be located in the pure water zone of the source so that water of best possible quality is withdrawn from the source, which will reduce the load on the treatment plant.

(iii) The intake must never be located ~~the~~ at the downstream or in the vicinity of the point of disposal of the wastewater of the city.

(iv) As far as possible, the intake should never be located near or in the navigation channel, because there are chances of water of intake being polluted due to discharge of refuse & wastes from ships and boats.

(v) The intake should be located so as to ensure the supply of water even under worst conditions ie. when the level of water in the source is lowest even then sufficient quantity of water should be available in the intake.

(vi) The site for locating the intake structure should be such that there is sufficient scope for future additions and ~~substractions~~ expansion ie it would permit greater withdrawal of water if required in future.

(vii) The intake site should remain easily accessible during floods and it should not get flooded.

(viii) In case of mendering river the intake should not be located on curves. If ~~to mendering~~ be located on curves, it should be located in concave bank

(ix) The site for the location of the intake should be so selected that it is least affected by scouring, silting and storms.

(x) Site of intake should be well connected by good approach roads.

(xi) In the selection of intake site, the natural causes such as wind current, seasonal variations in quality & quantity of water, climatic conditions etc. should also be studied to ensure maximum stability & safety to the intake works.

Characteristics of River Intake

- Consists of a masonry or R.C.C. intake tower (or intake well or jack well) which is provided with several inlets called penstock for withdrawing water from the river.
- penstocks are located at different levels to permit the withdrawal of water even when the water level in the river drops.
- provided with a screen to prevent the entry of floating debris
- provided with valves to control the entry of water through them.
- Penstocks discharge water into the intake tower from where it is pumped to the treatment plant by the pumps installed in the controller room at the top.
- Requirement of pumping from intake depends on the topography of the area. (required only when the level of the intake is lower than the community). It should be avoided.

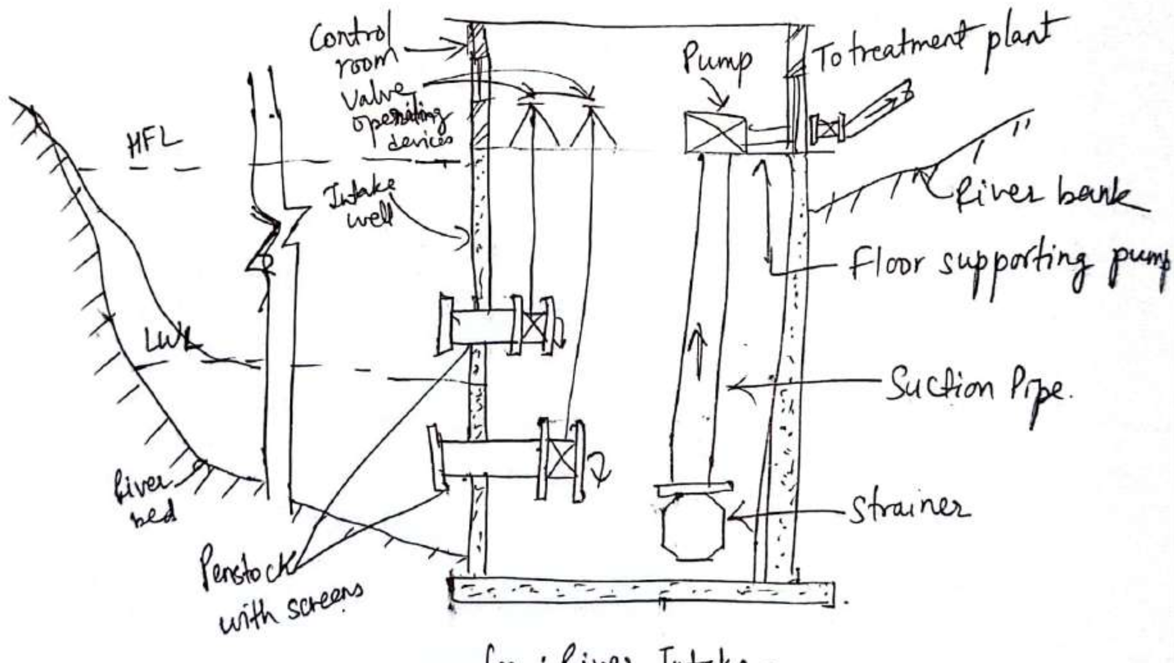
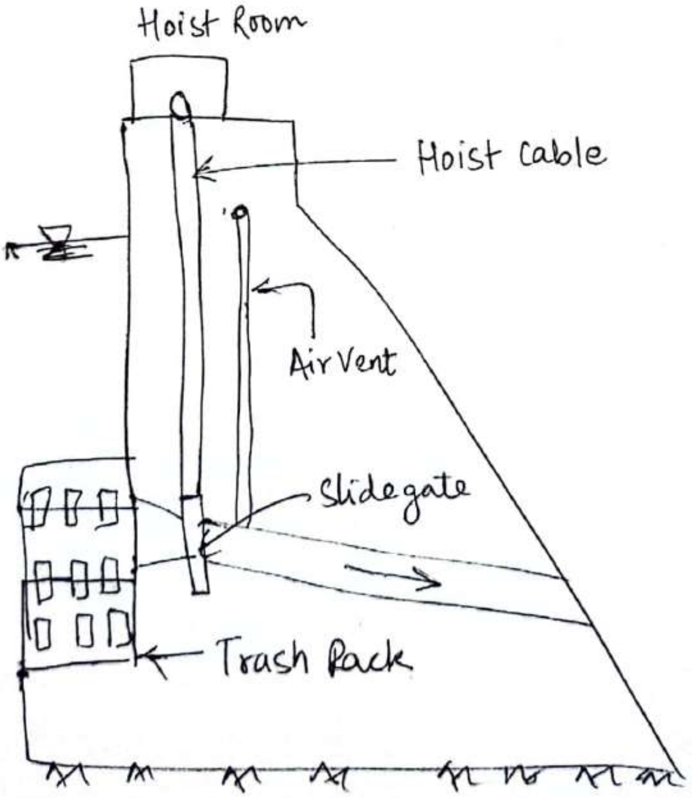


fig : River Intake.

- Wet type river intake because the water is always filled in the sump well of the intake tower & is wet all the time.
- Can be made dry intake by connecting the penstock to the suction pipe of the pump directly & not allowing water to fall in sump well
- The river intake should be so located that even during the low water level in the river water remains available at the intake in sufficient quantity.
- For considerable variations in water levels in river during summer & other seasons, a weir or barrage may be constructed across to raise the water level in the river, thereby ensuring the availability of water at the intake in sufficient quantity at all times.

Reservoir Intake

- In the case of reservoir, the type of intake to be provided depends on the type of dam constructed to create the reservoir.
- commonly constructed dams for creating reservoirs are earth dams and gravity dams.
- These are located near the upstream face of the dam where maximum depth of water is available.
- When the flow in the river is not guaranteed throughout the year, a dam is constructed across it to store water in the reservoir so formed.
- Consists of an intake tower constructed on the slope of dam at such a place where intake can draw water in sufficient quantity even in driest period.
- Intake pipes are fixed at different levels, so as to draw water near the surface in all variations of water levels.



Spring Intakes

- provided to abstract water from a spring source.
- Springs are generally located on hill slopes where an impervious layer outcrops.
- Spring intake also prevents outside water & other source of pollutants from entering into the water supply system. The intake thus protects the water from getting contaminated.

→ The water outlet points of the spring should be properly identified before construction is initiated. Very low yield spring source (<0.05 lps) should not be tapped for gravity flow schemes.

→ Spring intake generally consists of two chambers, namely collection chamber and valve chamber. (chamber are usually made from the locally available materials such as stone masonry; however can be made from brick, concrete & other materials also).

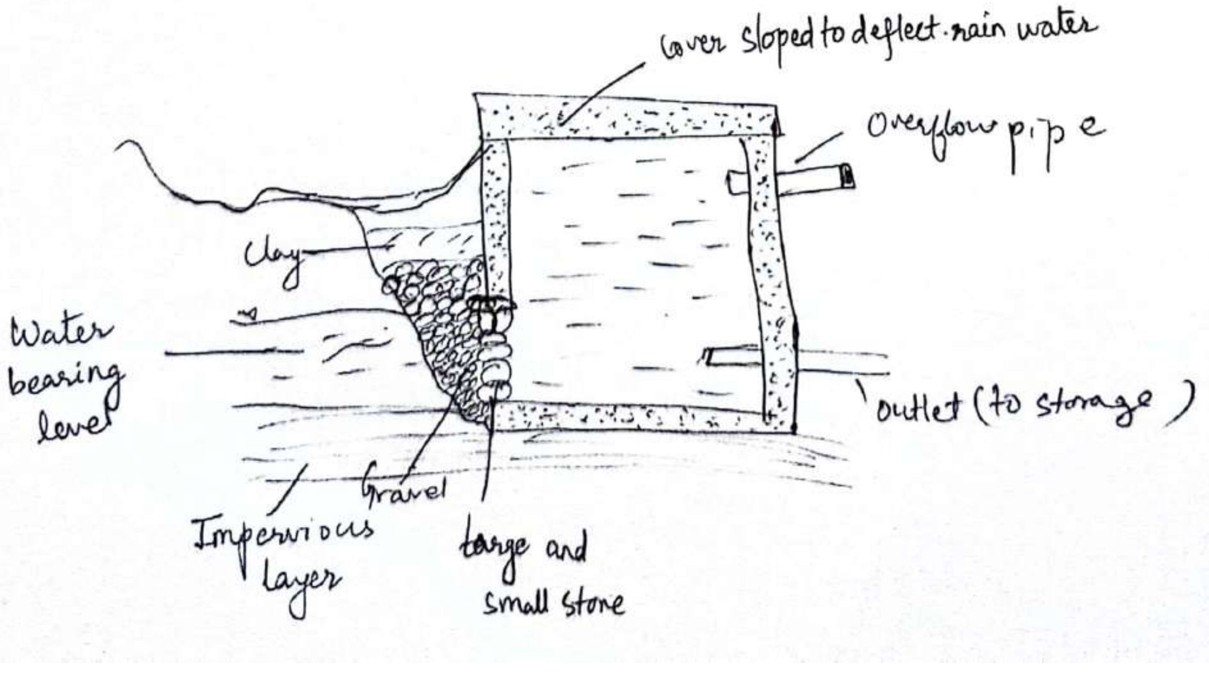
→ Heavy intake structure should be avoided to avoid its settlement.

→ Collection chamber will acts as a sedimentation tank & will remove suspended particles and turbidity of water to a certain extent as spring water is generally free from turbidity as it emerges from the springs.

→ Spring with safe water should be selected during the source selection.

→ Washout pipe & outlet pipe. ; washout valve & outlet valve.

→ Proper drainage should be provided around the spring source to divert the run off water & prevent it from damaging the intake.



Various types of hand pumps including Suction hand pump, Submersible hand pumps

⇒ Hand pumps are manually operated pumps; they ~~or~~ use human power and mechanical advantage to move fluids or air from one place to another.

→ used for both community supply and self supply of water and can be installed on boreholes or hand dug wells.

→ used for shallow depths.

Types

1) Pitcher Pump – for wells below 25 feet.

2) Piston Pump – for wells over 25 feet.

3) Suction Pump – farms and homesteads, repeated pumping is required

4) Lift pump – Raise water to a height of up to 60 m.

5) Treadle pump. – type of suction pump.

6) Rope pump – rotary pump which can lift water from depths of up to 35 meters.

7) Submersible Hand Pumps

↳ also known as deep set hand pump.

↳ plunger is provided below the ground water table.

↳ Centrifugal type

5.1.6 Water treatment

- Water treatment is a process of making the water suitable for the intended purpose by removing the impurities present in water.

desired outcomes of water treatment

- Palatable – has no ~~pleasant taste~~ unpleasant taste
- Safe – should not contain any pathogenic organisms or chemicals which is harmful.
- Clear – low turbidity
- Colourless and odourless – aesthetically pleasing
- reasonably soft – doesnot consume excessive soap & detergents
- non-corrosive – to prevent leaching from pipes or tanks.
- low organic content – to prevent biological growth in pipes or tanks.

Objectives of water treatment

- Raw water may contain suspended, colloidal & dissolved impurities. The purpose of water treatment is to remove all those impurities which are objectionable either from taste & odour point of view or public health point of view.

The objectives of water treatment are:

(i) to remove colour, dissolved gas and murkiness of water

(ii) to remove objectionable taste and odour

(iii) to remove disease producing micro-organisms so that water is safe for drinking purpose

(iv) to remove hardness of water

(v) to make it suitable for a wide variety of industrial purposes such as stream generation, brewing, dyeing etc.

Treatment Process.

→ The water treatment process should be selected depending on type and concentration of impurities to be removed from water.

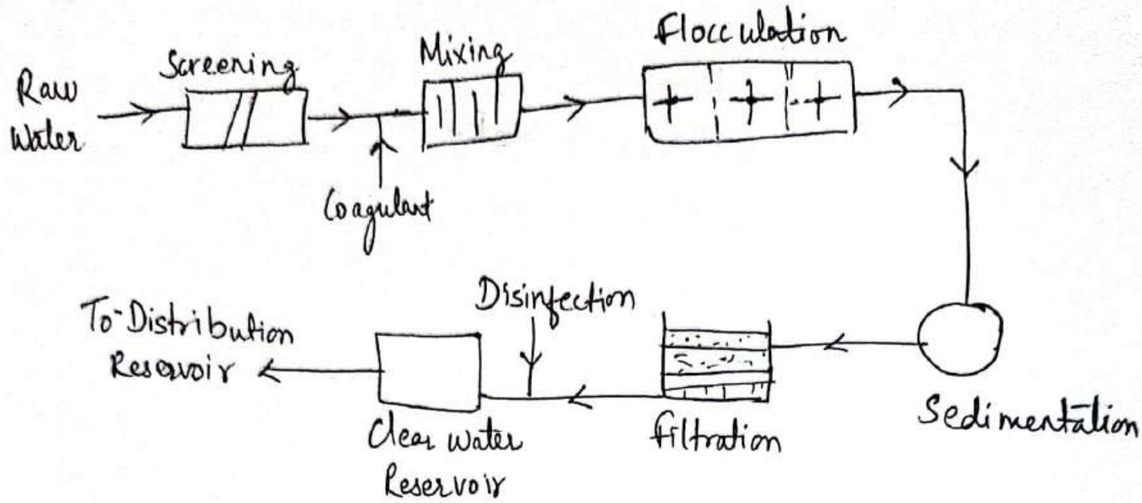


fig: Schematic layout of water-treatment plant.

Treatment Process	Impurity Removal
1. Screening	Large suspended and floating material
2. Plain sedimentation	Coarse and heavy suspended particles
3. Sedimentation with coagulation	fine suspended particles & colloidal matter
4. Filtration	Very fine suspended impurities and colloidal, micro-organisms.
5. Dis-infection	Pathogenic micro-organisms.
6. Softening	Hardness removal
7. Aeration	Color, odour & taste, Iron & Manganese
8. Removal of Iron & Manganese	Iron & Manganese
9. Removal of color, odour & taste	Color, odour & Taste

Screening

- Screening is the process of removing large suspended and floating debris such as sticks, branches, leaves etc. by passing water through screens.
- Screen serve as a protective device for the remainder of the plant rather than as a treatment process.
- Screen may be located at the intake structure, raw water pumping station, or the water treatment plant itself.

Screen may be of two types based on the size of materials removed as follows;

(a) Bar Screens (b) fine Screens

Bar screens

- intended to intercept only grosser floating materials. (25mm dia) (10 x 50mm)
- mostly in the form of steel bar grill which is either circular or rectangular in shape.
- A trough is constructed downstream of bar screen to store the screening material that have been screen out.
- Trough is perforated at the bottom so that water squeezing out of screening materials drops down into the water & the materials dries up soon.
- The screening materials are sent for disposal after few days ~~strog~~ storage in the trough.

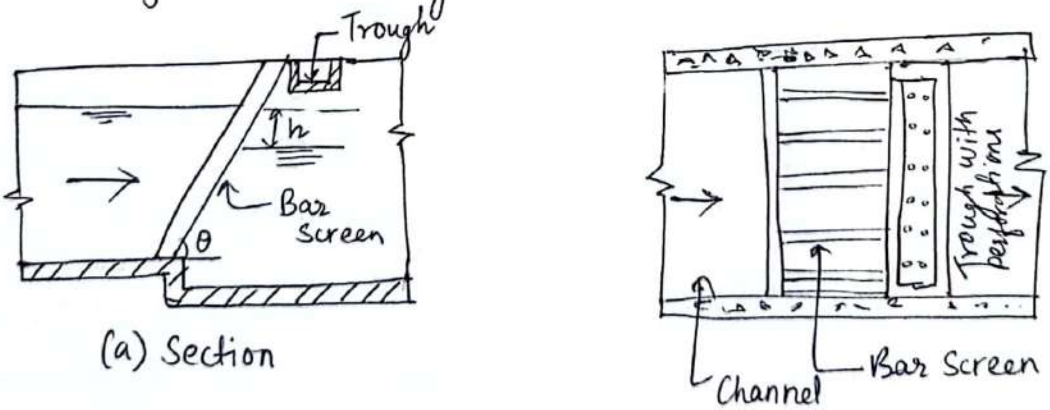


fig: Bar Screen

Fine Screens

- used at surface water intakes, sometimes alone & sometimes following a bar screen.
- generally made of wire mesh (6mm or more).
- generally not used in water treatment as it is frequently clogged & create difficulty in operation & maintenance.
- used when water is relatively clean & no other treatment except screening is employed.

Plain Sedimentation

↳ process in which water is retained in a tank or basin so that the suspended particles present in water may settle under the action of gravity without addition of any chemical.

↳ removes coarse and heavy suspended particles such as sand and silt. (sp. gravity 1.2 & above)

↳ effective in removing colour, odour, taste & turbidity associated with the suspended particles.

Theory of settlement.

↳ phenomena of settling down of particles at the bottom of sedimentation tank is known as hydraulic subsidence & every particle has its own hydraulic settling value which will cause its hydraulic subsidence.

↳ The hydraulic subsidence or settling of particles in a sedimentation tank is affected by following factors;

(i) Velocity of flow of water
(ii) Size & shape of particles
(iii) Specific gravity of particles
(iv) Viscosity of water
(v) Surface overflow rate
(vi) Detention period
(vii) Inlet & outlet arrangements; + (viii) Effective depth of settling zone

Discrete particles – particles which donot change in size, shape or weight during settling.

→ All the particles in suspension in water are assumed as discrete particles.

$$V_s = \sqrt{\frac{4}{3}\frac{gd}{C_D}(S-1)} \quad ; \quad \overset{\text{Drag coeff.}}{C_D} = \frac{24}{Re} + \frac{3}{\sqrt{Re}} + 0.34$$

Re = Reynold's number $= \frac{\rho V_s d}{\mu}$ (μ = absolute or dynamic viscosity)

Nature of settling of discrete particles

(i) Laminar

(ii) Transition

(iii) Turbulent

$$V_s = 418(\cancel{S-1})\,d^2\left(\cancel{3T+70}\right)$$

$$V_s = 418(S-1)d^2\left(\frac{3T+70}{100}\right)$$

① For Laminar flow & $Re \leq 1$, Particle size ≤ 0.1 mm. Stoke's law

$$V_s = \frac{g d^2}{18 \nu}(S-1) \qquad \nu = \text{Kinematic viscosity } (\downarrow \text{ with } \uparrow \text{temp}).$$

② For Transition & $Re > 1$ to 1000, Particle size > 0.1 to 1mm

$$V_s = \sqrt{\frac{4}{3}\frac{gd}{C_D}(S-1)} \qquad C_D = \frac{24}{Re} + \frac{3}{\sqrt{Re}} + 0.34$$

Newton's law

③ For turbulent flow & $Re > 1000$ & Particle size > 1 mm

$$V_s = \sqrt{3.33 g d (S-1)}$$

Ideal Sedimentation Tank

↳ A sedimentation tank which aims to achieve as nearly as possible the ideal conditions of equal velocity at all points lying in the each vertical in the settling zone during it design.

Inlet zone.

→ uniformly distributes the incoming flow over the cross-section of the tank and enters the settling zone without causing any disturbance to the settling particles.

Settling zone

↳ settling of the particles take place.
↳ flow is assumed steady & the particles are uniformly distributed throughout the cross-section normal to the flow direction.
↳ the particles that donot reach the sludge zone escape to the outlet zone.

Sludge Zone

↳ provided for the collection of the particles that have settled.
↳ It is assumed that all the particles reaching this zone are effectively removed from suspension.

Outlet Zone

↳ Collects the clarified water coming from the settling zone & discharges through effluent channel.

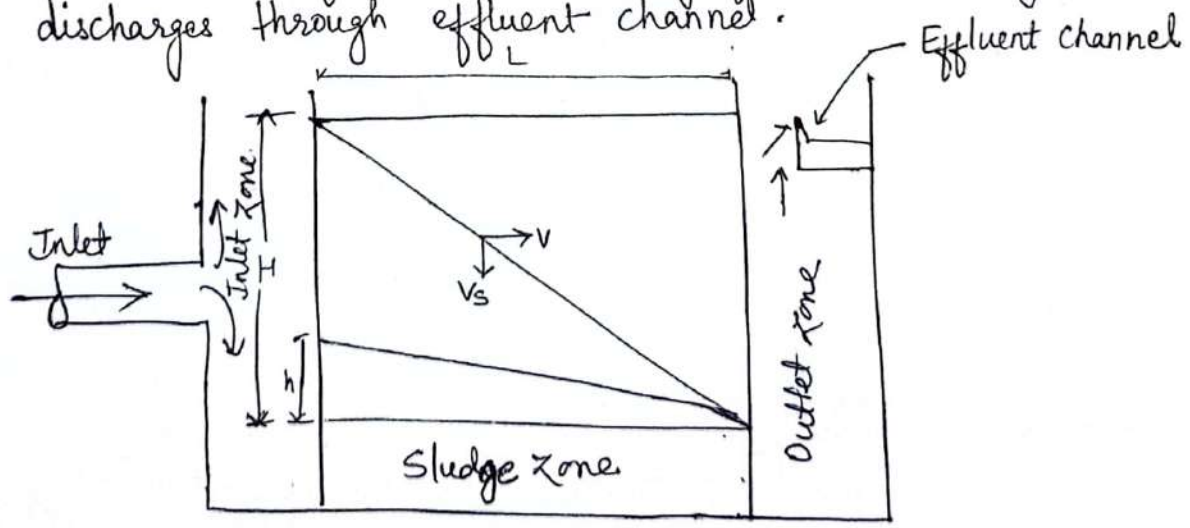


fig: Ideal Sedimentation Tank

Types of Sedimentation Tank. - Depending upon the method of operation:

i) Draw and fill sedimentation tank

ii) Continuous flow sedimentation tank - more used

Design of sedimentation tank

uniform flow velocity
particles uniformly distributed

(i) Velocity of flow

- should be designed in a way that max^m settling of suspended particles is caused in the tank.
- does not uplift or scour the settled particle.
- 150 to 300 mm/minute

(ii) Detention time/Period > settling velocity

- 4 to 8 hours for plain sedimentation tanks
- 1 to 4 hours for sedimentation tanks using coagulants

(iii) Flowing through Period

- actual time taken by the water to pass through a sedimentation tank.
- atleast 30% of detention time

(iv) Surface Overflow Rate (SOR)

- quantity of water passing per unit time / discharge per unit of plan area of a sedimentation tank. (Q/BL)
- 15 to 30 $m^3/day/m^2$ - plain sedimentation
- 30 to 40 $m^3/day/m^2$ - with coagulants

(v) Tank Dimensions

- Circular or rectangular in shape.
- Effective depth = 2.5m to 4m.
- free board = 0.5m to 1m
- storing of slude = 0.5m to 1m

Rectangular tank → max^m width = 12m, length/width = 3 to 5
→ max^m length = 30m ; 100 m used

Circular → max^m diameter = 30m ; 60m used

(vi) Inlet & Outlet arrangements

- weir, notches, orifices.

* Sedimentation with Coagulation

↳ The settling down and removal of fine suspended particles and colloidal matters by chemically assisted sedimentation is called sedimentation with coagulation.

↳ Certain chemicals called coagulants are added to raw water & thoroughly mixed with it which causes an insoluble, gelatinous, flocculant precipitate called floc.

↳ The process of adding a coagulant to raw water & mixing it thoroughly is known as coagulation, and the process of formation of floc is called flocculation.

Operations (dry & wet)

1. Feeding & mixing of coagulant (baffle walls, hydraulic jump method)
2. Flocculation
3. Sedimentation.

Common Coagulants.

1. Aluminium Sulphate (alum) [$Al_2(SO_4)_3 \cdot 18H_2O$]
2. Iron Salts [$FeSO_4 \cdot 7H_2O$, $FeCl_3$, $Fe_2(SO_4)_3$]
3. Chlorinated copperas [$FeCl_3 \cdot Fe_2(SO_4)_3$]
4. Sodium aluminate [$Na_2Al_2O_4$]

The dosage of coagulants depends upon :
(i) turbidity of water (ii) its color (iii) pH value (iv) time of settlement
(v) temperature of water

→ Optimum dose of coagulant is determined by Jar test.

Design Criteria for flocculators.

(i) Depth of tank : 2 to 4.5 m
(ii) Detention period : 10 to 40 minutes, normally 30 minutes
(iii) Velocity of flow : 0.2 to 0.8 m/minute
(iv) Total area of paddle ; 10 to 25 % of cross-sectional area of the tank.
(v) Outlet flow velocity to settling tank : 0.15 to 0.25 m/s.

* filtration   Color, odour, turbidity, Pathogenic bacteria

↳ process of passing water through thick layers of porous media i.e. a layer of sand supported on a bed of gravel.

Theory of filtration → effects produced in water during filtration

(i) Mechanical straining

↳ Particles of suspended matter that are of size larger than the size of the interstices or voids between the sand grains cannot pass through these interstices, and are therefore arrested and removed by the action of mechanical straining.

↳ cannot remove colloidal matter or bacteria too small to be strained

(ii) Sedimentation and Adsorption

↳ interstices betn the sand grains acts as a minute sedimentation tanks in which the particles of the suspended matter settle on the side of sand grains. These particles adhere to the sand grains because of following two reasons

(a) due to the physical attraction between the particles & sand grains

(b) due to presence of a gelatinous coating formed on the sand grains by previously deposited colloidal matter & bacteria.

↳ Thus by action of sedimentation & adsorption, colloids, small particles of suspended matter & bacteria are removed.

(iii) Biological Metabolism

↳ growth & life processes of the living cells are known as biological metabolism.

↳ Bacteria, organisms utilize organic impurities (algae, plankton etc) & convert them into harmless compounds by the complex bio-chemical reactions.

↳ The harmless compounds so formed are deposited at the surface of the sand in the form of a layer which contains a zoological jelly in which the biological activities are at their highest.

↳ This layer further helps in absorbing & straining out the impurities.

↳ the bacteria not only break-down the organic impurities & convert them into harmless compounds, but also destroy each other & maintain a balance of life in the filter.

(iv) Electrolytic Action

- explained by ionic theory i.e. when two substances with opposite electric charges comes in contact with each other, the electric charges are neutralized & in doing so, new chemical substances are formed.
- Sand grains of filter are charged with electricity of some polarity.
- Thus, when particles of suspended & dissolved matter having electricity of opp. polarity come into contact with sand grains, they neutralize each other & it results in changing characteristics of water.
- After this, electrical power of sand grains gets exhausted & at that time, it is necessary to clean the filter & restore it with this property.

* Necessity of filtration.

- Screeening & Sedimentation do not effectively remove fine floc particles, color, dissolved minerals & micro-organisms. In filtration, water is passed through a filter medium in order to remove particulates ~~not~~ matter not previously removed by sedimentation.
- To remove turbidity & colloidal matter of non-settleable type.
- Bacterial content of water is considerably reduced.

Slow Sand filters.

- earliest type of filters; low filtration rate; requires large areas of land & correspondingly large quantity of sand.
- suitable when land, labour and filter sand are readily available at low cost.
- Raw water having low turbidity (< 50 NTU) can be directly fed to SSF without any pretreatment.
- for raw water with high turbidity, plain sedimentation is needed to reduce turbidity within reasonable limit so that the filters are not unduly loaded.

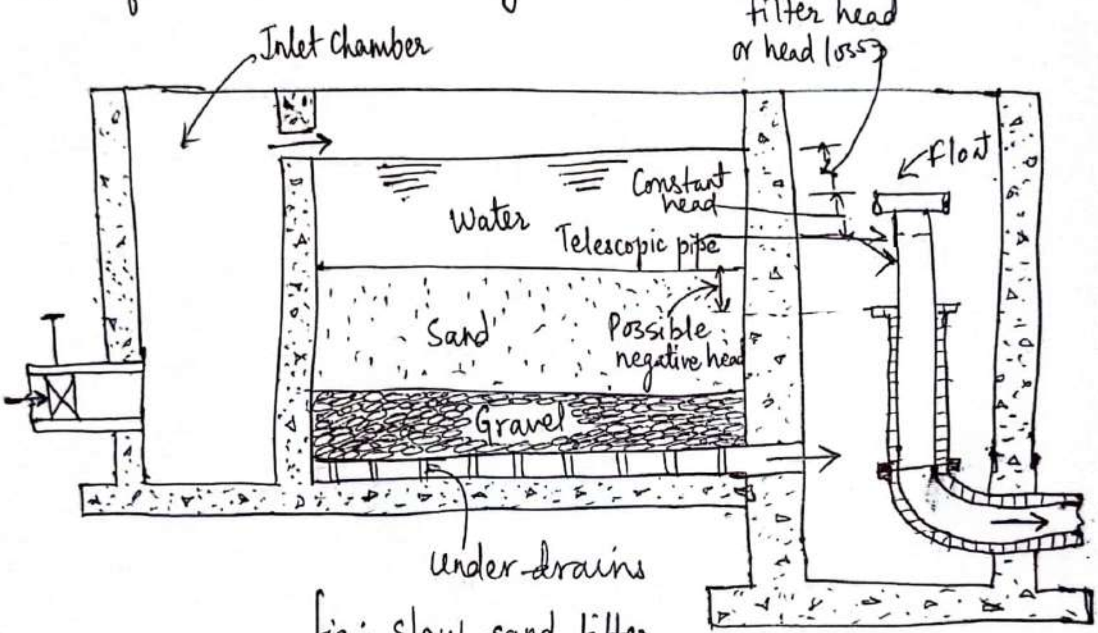


fig: slow sand filter.

Parts

(i) Enclosure tank
(ii) Filter Media
(iii) Base Materials
(iv) Under-drainage System
(v) Appurtenances

Enclosure tank

- Open water-tight rectangular tank made of stone or brick masonry or concrete.
- 2.5 to 4.0 m depth
- 50 to 1000 m^2 surface area
- 100 to 200 liter/hr/m^2 – filtration rate

Filter Media

- Consists of sand layer 90 to 110 cm thick.
- Effective size of sand varies from 0.25 to 0.35 mm with a common value of 0.3 mm.
- uniformity coefficient, C_u = 3 to 5. / 2 to 3
- finer the sand bed, better will be the turbidity removal efficiency as well as bacteria removal efficiency, but lower will be the filtration rate & vice-versa.
- finer sand is suitable when pre-treatment of water is not done or poorly done.
- Sand should not contain ~~&~~ more than 2% of calcium & magnesium computed as carbonate.

Base Material

- The sand layer is supported on base material which consists of 30 to 75 cm thick gravel bed.
- gravel bed is graded & it is laid in layers, each of 15 cm thickness

	Thickness	size
Top layer	15 cm	3 to 6 mm
Intermediate layers	15 cm	6 to 20 mm
	15 cm	20 to 40 mm
Bottom layer	15 cm	40 to 65 mm

Under drainage system

- Consists of a central drain & lateral drains.
- filter material & base material are supported over the under-drainage system which collects the filtered water & delivers it to the clean water reservoir.

Appurtenances

→ installed for effective working of SSF. Includes.

(a) Vertical air pipe through the layers of sand.
(b) devices for controlling the depth of water above the filter media
(c) devices for measuring loss of head through the filter media
(d) devices for maintaining constant rate of flow through the filter.

Working of Slow Sand filter

- Water from the sedimentation tank is allowed to enter the filter through the inlet chamber.
- depth of the water over the filter media should neither be too small nor too large (generally kept equal to the thickness of the layer of sand).
- The water passes through the filter media & during this process it gets purified & is passed through the under drains to the outlet chamber from where it is taken to clear water storage tanks
- operated up to a max^m filter head of 75 cm or equal to 65 to 85% of the thickness of the sand bed.

Cleaning of SSF

- water in the filter tank is drained off.
- Top layer of sand is scrapped manually & removed through a depth of 15 to 30mm.
- Scrapped sand is either removed manually or hydraulic ejector. for washing — washed sand is dried & stored for future use.
- After this, filter is again put for operation.
- filter tank is refilled with filtered water from below until the sand bed is completely covered with water.
- prevents entrapping of air in sand bed.
- filter is operated at 1/5 of the normal rate of filtration for 12 to 15 hours & filtered water is diverted to the wash water drain.
- after this, diverted to clear water storage tanks.

→ SSF requires cleaning after one to three months depending upon the impurities present in raw water.

- In each cleaning, some depth of filter sand is removed due to which the thickness of the sand bed goes on decreasing & the process is continued till the thickness of the sand bed reaches a minimum value of 600 mm.
- When this stage is reached, the top of sand bed is provided with a fresh layer of clean new sand or the old washed sand, up to its original level.

Efficiency of Slow Sand filter

(a) Bacterial Load.

- highly efficient in the removal of bacterial load from water
- removes about 98 to 99 % of bacterial load from raw water & 99.50 to 99.90 % when pre-treatment has been given to the raw water.
- for complete removal of bacteria, disinfection is essential.

(b) Turbidity

- remove turbidity to the extent of about 50 NTU.
- for Water having higher turbidity, it is necessary to give preliminary treatment to bring down its turbidity below 50 NTU.

(c) Colour

- less efficient in the removal of colour of raw water.
- removes about 20 to 25% colour of raw water.
- not suitable for raw water having higher colour content.

(d) Colloidal Matter

- not highly efficient in the removal of colloidal matter.

Rapid Sand filters

- most commonly used filters in large water supply schemes.
- raw water is usually fed to the RSF only after it has been treated through sedimentation with ~~cog~~ coagulation.

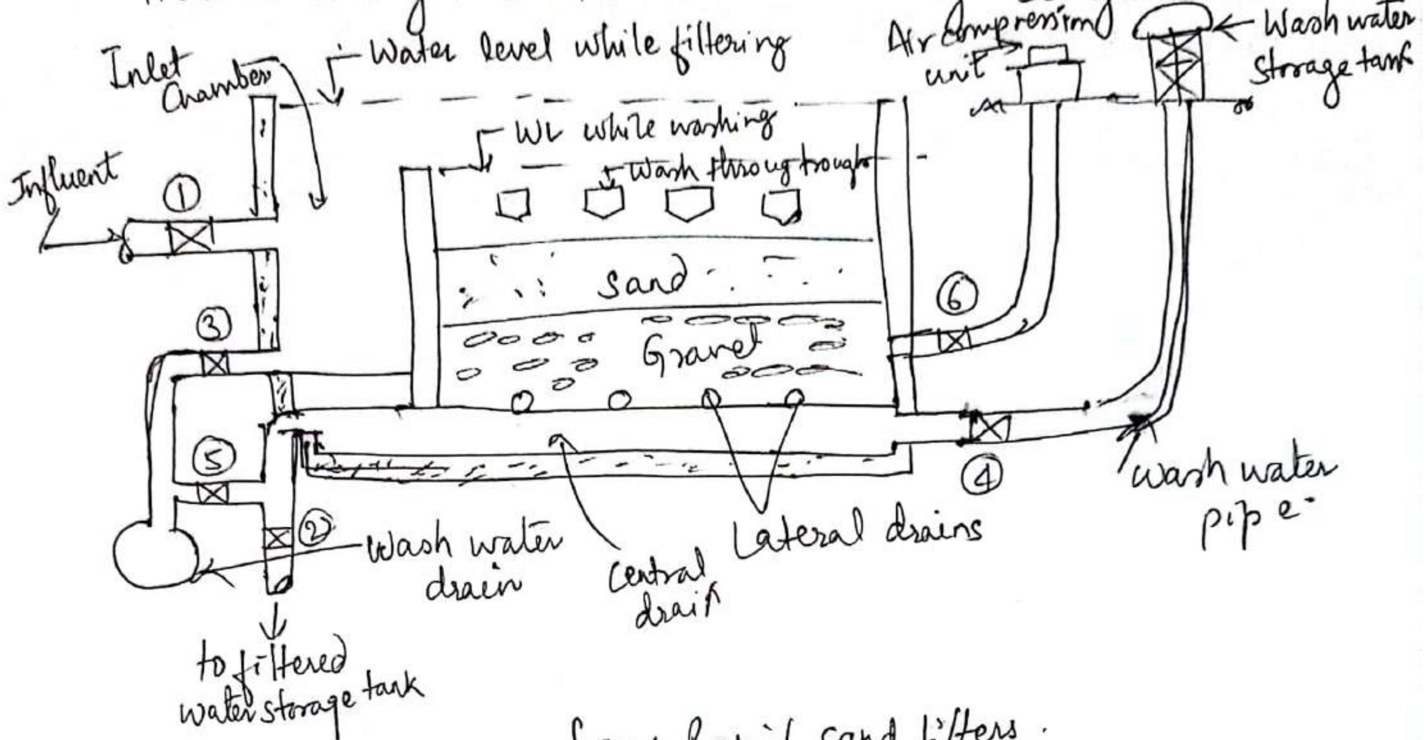


fig : Rapid sand filters.

(a) Enclosure tank
(b) filter Media
(c) Base materials
(d) Under-drainage system
(e) Appurtenances.

Enclosure Tank.

- open watertight rectangular tank constructed of stone or brick masonry or concrete.
- depth of tank = 2.5 to 5.0 m
- Surface area = 10 to 50 m^2
- length to width ratio = 1.25 to 1.35
- Rate of filtration = 3000 to 6000 liter/hr/m^2

Filter Media

- Consists of sand layer of 60 to 75 cm.
- Effective size of sand varies from 0.45 to 0.70 mm.
- → Uniformity coefficient, C_u = 1.3 to 1.7 ; 1.5

Base Material

- sand layer is supported by 45 to 60 cm thick gravel bed.

	depth	Size
Top Layer	15 cm	2 to 6 mm
Intermediate Layers	15 cm	6 to 12 mm
	15 cm	12 to 20 mm
Bottom layer	15 cm	20 to 50 mm

Under-drainage System

- collects the filtered water uniformly over the area of gravel b
- provides uniform distribution of backwash water without disturbing gravel bed & filter media
  - (a) Perforated pipe system
  - (b) Pipe & strainer system.

Appurtenances.

- (a) Wash water trough
- (b) Air compressors
- (c) Rate control device.
- (d) Miscellaneous accessories
  - L head loss indicators.
  - L meters for measuring the flow rates

Efficiency of RSF

a) Bacterial load

- less efficient in the removal of bacterial load.
- 80% to 90% of bacterial load.

b) Turbidity.

- 35 to 40 NTU.

c) Colour

- highly effective in colour removal.
- intensity of colour can be brought down below 3 on cobalt scale.

d) Iron and Manganese

→ RSF remove oxidised or oxidizing iron, though it is less efficient in removing manganese.

* ## Working and Back Washing of RSF.

The working & back washing of RSF is controlled by six valves.

Valve 1 - Inlet Valve } opened for normal working of filter.

Valve-2 - filtered water storage tank. }

Valve 3 - Wastewater Valve, to drain water from inlet chamber

Valve 4 - wash water storage tank valve.

Valve 5 - Wastewater valve to drain water from outlet pipe

Valve 6 - compressed air valve.

Back Washing.

→ With more & more material being trapped in the sand bed, the pores are clogged and the loss of head through the filter bed becomes excessive. The filter is then backwashed to remove the trapped material. The back washing of a filter is usually done when the loss of head through it has reached the maximum allowable value which is between 2.5 to 3m.

The backwashing of a RSF is carried out by passing air and water upwards through the filter bed.

Sequence of operation

① Close valve 1. — Allow the filter to operate till the water level reaches the edge of the wash water trough.

② Close valve 2.

③ Open valve 6, to allow compressed air to pass through the filter bed for about 2 to 3 minutes in the upward direction. This will break up the surface scum & loosen the dirt.

④ Close valve 6.

⑤ Open valve 4 to allow wash water to pass through the filter bed in the upward direction.

Open valve 3 to carry dirty wash water through inlet chamber to wash water drain. Continue washing till water appears fairly clean.

⑥ Close valve 4

⑦ Close valve 3, after the water in the filter has drained down to the edge of wash water trough. Allow short period to permit ~~to~~ materials to settle.

⑧ Open Valve 1 slightly, and open valve 5 to allow the filtered water to flow to the wash water drain for a few minutes.

⑨ Close valve 5 and open valve 2. Open valve 1 fully. The filter is now back in service.

→ Water used for backwashing should be filtered water.

→ Backwashing every 1 to 3 days (normally 15 minutes)

*7 Comparison between SSF and RSF.

S.N.	Item	SSF	RSF
1.	Rate of filtration	100 to 200 $l/hr/m^2$	3000 to 6000 $l/hr/m^2$
2.	Loss of Head	15cm initial to 100cm final	30cm initial to 3m final
3.	Size of bed	Requires large area (50 to 1000 m^2)	Requires small area. (10 to 50 m^2)
4.	Coagulation	Not required	Essential
5.	Filter media of sand	Eff. size : 0.2 - 0.35mm Cu : 2 to 3 Depth : 105cm, reduced to not less than 30cm by scrapping.	Eff size : 0.35 to 0.6mm Cu : 1.2 to 1.7 Depth : 75cm, not reduced by washing
6.	Base material of gravel	Size : 3 to 65mm Depth : 30 to 75cm	Size : 3 to 40mm Depth : 60 to 90 cm
7.	Method of cleaning	Scrapping of top layer to 15mm to 25mm	Agitation & back washing with or without compressed air
8.	Efficiency.	Very efficient in the removal of bacteria but less efficient in the removal of colour and turbidity.	less efficient in removal of bacteria, more efficient in removal of color & turbidity.
9.	Economy	High initial cost	Cheap & economical
10.	Flexibility	Not flexible in meeting variations in demand	Quite flexable for resonable fluctuations in demand
11.	Supervision	Not essential	Essential
12.	Depreciation Cost.	Relatively ~~high~~ low.	Relatively high
13.	Bed slope	1 : 100	1 : 50

Disinfection

- treatment by which the disease producing bacteria present in water are killed.

Methods of disinfection

(i) Boiling method
(ii) Excess lime Method
(iii) Iodine treatment
(iv) Bromine treatment
(v) Ozone treatment
(vi) Potassium Permanganate treatment
(vii) Silver treatment
(viii) Ultraviolet ray treatment

Boiling Method.

- most effective in the complete sterilization of water, since boiling of water for about 15 minutes kills all the bacteria and micro-organisms.
- not possible on large scale for public water supplies due t economic reasons.
- Kill only existing bacteria & cannot take care of future contaminati
- adopted f on individual basis to disinfect the water for domestic & drinking purposes during the contamination of public water supply & epidemics breakout.

Excess lime treatment

- Bacteria & E-coli cannot survive in water when its pH is greater than 9.5.
- Enough amount of lime is added in water to raise the pH above 9.5 so that bacteria & E-coli are killed & disinfection is achieved
- Amount of lime to be added in water for disinfection is about 10 to 20 ppm.
- The excess lime needs to be removed from water by recarbonation or suitable methods before supplying the water to consumers.
- Bacteria are also killed when the water is highly acidic with pH value being below 3.
- The dis-infection of water can also be achieved by the addition of acid in water & lowering its pH to less than 3.

Iodine Treatment

- I_2 when added to water forms hypoiodous acid (HIO) which dissocates to form hypoiodite ion (IO).
- Both the iodine & hypoiodious acid are equally good disinfectant
- I_2 reacts with less organic matter & is stable in water.
- doesnot react with ammonia to form iodamines but it oxidizes ammonia,
- usual does of iodene is about 8 mg/l & contact time is about 5 minutes.
- more costly & hence it is limited to small water supplies such as swimming pools, army troops, field visits, etc.

Bromine Treatment

- forms hypobromous acid (HOBr) when added to water.
- less effective & higher cost, not commonly used for disinfection of water in large public water supplies.

Ozone Treatment

- O_3 breaks down to normal oxygen (O_2) and nascent oxygen (O)
- The nascent oxygen (O) is very effective in oxidizing the organic matters and is also very powerful in killing the bacteria.
- the dosage of ozone required is about 2 to 3 ppm to obtain residual ozone of 0.10 ppm & the contact period is about 10 minutes.

Potassium Permanganate Treatment

- $KMnO_4$ is a powerful oxidizing agent which oxidizes the taste producing organic matter & is effective in killing cholera bacteria.
- less effective in killing other bacteria & viruses.
- used for disinfection in rural areas.
- The normal does of potassium permangante ($KMnO_4$) is 1 to 2 mg/l with a contact period of 4 to 6 hrs.

Silver Treatment

- effective in destroying bacterial spores algae present in comparatively clear water.
- Contact time varies from 10 to 60 minutes.
- Since silver is costly, this method is limited to small installations or private individual houses.

Ultra-Violet Ray Treatment

- offers an effective method of disinfection of water since the light is effective in killing both the active bacteria as well as spores.
- UV rays are invisible rays which are mostly found in Sunlight.
- The treatment with sunlight requires large exposure area and long time.
- Thus, UV rays are generated by machines.
- This method is costly & hence it is not commonly used in public water supplies.
- It is used in small installations such as private buildings office buildings, institutions, swimming pools, etc.

→ of all the various methods of dis-infection, dis infection by using chlorine or chlorination is commonly used.

CamScanner

Chlorination

- In this method of disinfection, chlorine (or its compounds) is used as disinfectant.
- Cheap, reliable & presents no great difficulty in handling.
- Nascent Oxygen theory - chlorine in water produces nascent oxygen which oxidizes unicellular organisms & kills them.
- Enzymatic hypothesis theory - Chlorine first penetrates through the cell wall of the organisms and then react inside with the enzymes which are essential for bacterial life. As enzymes become ineffective, the bacteria gets destroyed.

Action of Chlorine

When chlorine is added to water, the following reactions takes place

$$Cl_2 + H_2O \longleftrightarrow HOCl + H^+ + Cl^- \text{ (Hydrolysis)}$$

$$HOCl \longleftrightarrow H^+ + OCl^- \text{ (Ionization)}$$

It is the hypochlorous acid (HOCl) and the hypochlorite ions (OCl^-) which accomplish disinfection of water.

Chlorine demand

The amount of chlorine consumed in killing pathogenic organisms as well as oxidation of inorganic and organic materials present in water is known as chlorine demand of water.

Residual Chlorine

- Amount of chlorine remaining in water after chlorine demand has been fulfilled.
- The amount of unreacted chlorine left in water as a residual chlorine will serve as a disinfectant to kill the pathogenic organisms present in water in the distribution system.

Chlorine demand = Amount of chlorine added to water − Residual chlorine after specified contact period

Dosage of Chlorine

- Amount of Chlorine required to be added to the water supply which leaves a residual chlorine of about 0.2 mg/l at the end of 10 minutes

Contact period. (time taken to kill the pathogenic organisms after the application of chlorine)

Forms of chlorination

↳ depends upon the stage of treatment at which chlorine is applied to water & also upon the expected results of application of chlorine :

Plain Chlorination

↳ only chlorine treatment & no other treatment is given to raw water.

↳ helps to remove bacteria and color from water & also controls the growth of algae.

↳ The usual dose of chlorine for plain chlorination is between 0.5 & 1 ppm.

Pre-Chlorination

↳ When chlorine is added to raw water before any treatment, it is known as pre-chlorination.

Advantages

(i) It helps in reducing the quantity of coagulants required because of the oxidization of organic matter.

(ii) It helps to improve coagulation.

(iii) It reduces taste & odour of water.

(iv) It controls the growth of algae in sedimentation tank as well as in filters.

(v) It reduces the bacterial load on filters.

(vi) It helps in maintaining filter media clean.

(vii) It prevents putrefaction of sludge in the settling tank.

for prechlorination, the dose of chlorine should be such that water has residual chlorine of 0.1 to 0.5 ppm when it enters the filter plant.

Post - Chlorination

↳ indicates the application of chlorine to water after all treatments for purification of water are completed.

↳ Standard form of chlorination in which chlorine is added to water as it leaves filters & before it enters distribution system.

↳ The dose of chlorine should be such that residual chlorine of about 0.1 to 0.2 ppm appears in water at the point of its entry into the distribution system.

Double chlorination

- Refers to the application of chlorine to water at two points in the purification process.
- adopted when raw water is highly contaminated and contains large amount of bacterial life.
- Consists of pre-chlorination in which chlorine is applied before raw water enters sedimentation tank and post-chlorination in which chlorine is added to water after it leaves filters & before it enters distribution system.

Break-point chlorination / Free residual chlorination

- The application of chlorine to water with chlorine dose equal to or slightly higher than that at which break point occurs is called break point chlorination.
- The breakpoint in the chlorination of water may be defined as the point on applied residual chlorine curve at which all, or nearly all, the residual chlorine is free chlorine.

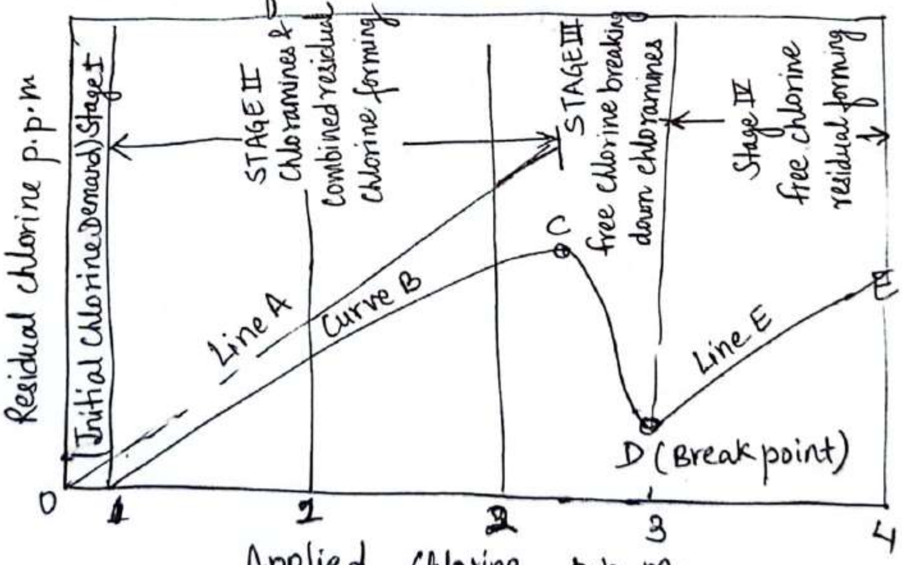


fig: Break point chlorination

When chlorine is added to water, the following two actions take place:
(i) it kills bacteria present in water, thus disinfection is accomplished.
(ii) it oxidizes the organic matter present in water i.e. chlorine demand is satisfied.

Line A = when water has no chlorine demand, any chlorine added to such water will appear as residual chlorine.

→ water generally have some chlorine demand, relationship betn residual chlon & applied chlorine is shown in fig: (indicated by curve B)

↳ Shape of curve B results from the fact that when chlorine is first applied it performs the function of killing bacteria & reacts with the compounds such as ammonia, proteins, amino acids & phenols that may be present in water, to form chloramines & chloro-derivatives which constitute the combined available chlorine.

↳ With increase in applied chlorine, the residual chlorine also increases & the curve B goes on rising till point C is reached where the amount of residual chlorine is reported to be maximum.

↳ At this stage, with further increase in the applied chlorine there is sudden decrease in the residual chlorine where the applied chlorine breaks down chloramines by changing them to nitrogen compounds, thus reducing the residual chlorine as a lot of applied chlorine is utilized in oxidization of the organic matter present in water. Accompanied by bad smell & taste.

→ At point D, the bad smell & taste suddenly disappears & the oxidization of the organic matter is also complete.

↳ further at point D, the residual chlorine has its minimum value which reveals the true residual free chlorine since chlorine demand has been satisfied.

↳ Further increase in the applied chlorine beyond point D results in an increase in residual chlorine as represented by line E.

↳ Point D on the curve is known as break point because any chlorine that is added to water beyond this point breaks through water and appears as residual chlorine.

Advantages

→ It will remove taste & odour.

→ It will have adequate bactericidal effect.

→ It will leave desired chlorine residual.

→ It will complete the oxidation of ammonia & other compounds.

→ It will remove manganese. | 3 to 7 ppm generally

Super-Chlorination

- Application of chlorine to water beyond the stage of break point.
- The dose of chlorine applied to water for super-chlorination should be such that the residual chlorine content after breakpoint may be 0.5 to 2ppm.
- followed by a retention period of 30 to 60 minutes.
- Presence of excess chlorine in water imparts unpleasant taste & odour.
- As such when super-chlorination is practiced, it becomes necessary to remove excess chlorine by any method of de-chlorination when ~~the~~ before water is supplied to the consumers.
- usually adopted when there's pandameic / epidemic in locality.

Dechlorination

- Process of removing excess chlorine from water.
- avoid chlorinous taste from water before distributing to the consumers.
- Chemicals used for dechlorination are sodium thiosulphate ($Na_2S_2O_3$), sodium meta bisulphate ($Na_2S_2O_5$), sodium sulphate (Na_2SO_3), sodium bisulphite ($NaHSO_3$), ammonia (NH_4OH) and sulphur dio-xide (SO_2)
- Activated carbon method
- treating water with magnesium ~~wat~~ metal, by prolonged storage of water particularly when exposed to sunlight, & by aeration.

Softening

↳ process of removing hardness from water.

Removal of Temporary Hardness

↳ caused due carbonates & bicarbonates of calcium, magnesium & strontium.

Removed by. (a) boiling method (b) Lime treatment method

Boiling Method

$$Ca(HCO_3)_2 + Heat \longrightarrow CaCO_3\downarrow + CO_2\uparrow + H_2O$$

$$Mg(HCO_3)_2 + Heat \longrightarrow MgCO_3\downarrow + CO_2\uparrow + H_2O$$

→ not economically feasible & hence is not used in practice.

Lime Treatment Method

↳ hydrated lime $Ca(OH)_2$ is added to water.

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3\downarrow + 2H_2O$$

$$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow MgCO_3\downarrow + CaCO_3\downarrow + 2H_2O$$

→ Calcium carbonate $CaCO_3$ and magnesium carbonate $MgCO_3$ are formed which are insoluble in water, & hence can be removed in the sedimentation tanks & filtration units.

Removal of Permanent Hardness.

→ Caused due to sulphate, chlorides & nitrates of calcium, magnesium & strontium.

<u>Methods</u>

(a) Lime Soda Method (b) Zeolite Method

(c) Deionization Method.

* Lime Soda Method

- lime [$Ca(OH)_2$] and sodium carbonate [Na_2CO_3] or soda ash is added to the raw water.
- slow agitation for 30 to 60 minutes.

$$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3\downarrow + H_2O$$

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3\downarrow + 2H_2O$$

$$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow CaCO_3\downarrow + MgCO_3 + 2H_2O$$

Temporary hardness

$$MgCO_3 + Ca(OH)_2 \longrightarrow CaCO_3 + Mg(OH)_2\downarrow$$

$$MgSO_4 + Ca(OH)_2 \longrightarrow Mg(OH)_2\downarrow + CaSO_4$$

$$CaSO_4 + Na_2CO_3 \longrightarrow Na_2SO_4 + CaCO_3\downarrow$$

$$MgCl_2 + Ca(OH)_2 \longrightarrow Mg(OH)_2\downarrow + CaCl_2$$

$$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + 2NaCl$$

→ $CaCO_3$ & $Mg(OH)_2$ are insoluble in water & are ~~precipated~~ ~~precipititated~~ precipitated out.

<u>Advantages</u>

- Simple & economical process.
- amount of coagulant will be reduced for coagulation process.
- increases pH value of water which decreases corrosion of pipes.
- Suitable for turbid & acidic waters for which zeolite process cannot be used.
- Iron and manganese are removed to some extent.
- mineral content of water is reduced.
- Pathogenic bacteria are killed to some extent.
- The process is better for extremely ~~be~~ hard water, particularly those high in magnesium hardness.

Disadvantages

- Large quantity of sludge is formed which creates difficulty in its disposal.
- Process requires skilled supervision for its successful operation.
- requires recarbonation of sedimentation effluent to prevent incrustation of pipes & clogging of sand filters.
- does not remove the hardness to zero level, hence cannot be utilized in the dyeing industries.

Zeolite Method

- In this method ion exchange resin or ion exchanger which is commonly known as zeolite is used for the removal of hardness present in water.
- $2\,SiO_2\,Al_2O_3Na_2O$.
- Sodium ion present in zeolite ~~wi~~ is exchanged with calcium or magnesium ion present in the hardness of water & in doing so the hardness in water is completely removed.

$$2SiO_2\,Al_2O_3\,Na_2O + 2Ca(HCO_3)_2 \rightarrow 2SiO_2Al_2O_3CaO + 4NaHCO_3$$

$$2SiO_2\,Al_2O_3Na_2O + 2CaSO_4 \longrightarrow 2\,SiO_2\,Al_2O_3CaO + 2Na_2SO_4$$

$$2SiO_2\,Al_2O_3Na_2O + 2CaCl_2 \longrightarrow 2SiO_2\,Al_2O_3\,CaO + 4NaCl$$

$$2SiO_2\,Al_2O_3Na_2O + 2Mg(HCO_3)_2 \longrightarrow 2SiO_2Al_2O_3\,MgO + 4NaHCO_3$$

$$2SiO_2\,Al_2O_3\,Na_2O + 2\,MgSO_4 \longrightarrow 2SiO_2\,Al_2O_3MgO + 2Na_2SO_4$$

$$2SiO_2\,Al_2O_3\,Na_2O + 2MgCl_2 \longrightarrow 2SiO_2\,Al_2O_3MgO + 4NaCl$$

- By zeolite process the hardness of water is reduced to zero. *

Regeneration of zeolite

- Due to continuous use of zeolite the sodium present in it is exhausted after which hardness will not be removed.
- At this stage zeolite needs to be regenerated for effective removal of hardness.

$$2SiO_2\,Al_2O_3\,CaO + 4NaCl \longrightarrow 2\,SiO_2Al_2O_3Na_2O + 2CaCl_2$$

$$2SiO_2\,Al_2O_3\,MgO + 4NaCl \rightarrow 2SiO_2Al_2O_3Na_2O + 2MgCl_2$$

Advantages

- The sludge is not formed and hence there is no problem of sludge disposal.
- Zeolite unit is compact in design & hence it requires small space.
- Unit can be operated easily.
- It is possible to get zero hardness in the effluent. which is useful for water softening plant for boilers & textile industries.
- Water of any desired hardness can be achieved by mixing the effulent of zero hardness & raw water in required proportions.
- process is independent of change in quality of raw water.
- free from danger of excess chemicals in the effluent as no chemicals are added to water.
- initial cost & operating cost of the process are low.

Disadvantages

- unsuitable for highly turbid water because suspended particles get deposited around the zeolite.
- unsuitable for water containing iron & manganese.
- Unsuitable for acidic water which irreversibly substitute hydrogen for sodium in the zeolite.
- Zeolite softeners should be operated carefully to avoid injury or damage to the zeolite, to the equipment or to the quality of water.
- There is likelihood of growth of bacteria on the bed of zeolite. It should therefore be flushed annually with chlorinated water.

* Deionization Method

- Cations are exchanged. ∴ Ca, Mg & Na present in water are replaced by hydrogen & thus hard water is softened.

$$H_2Z + CaSO_4 \rightarrow CaZ + H_2SO_4$$

$$H_2Z + CaCl_2 \rightarrow CaZ + \cancel{CaCl_2}\ 2HCl$$

$$H_2Z + MgSO_4 \rightarrow MgZ + H_2SO_4$$

$$H_2Z + MgCl_2 \rightarrow MgZ + 2HCl$$

Miscellaneous Treatment Methods

Aeration

- Process of bringing water in intimate contact with air.
- During aeration the gas transfer between the water and air takes place.
- The water absorbs the oxygen from the air and releases the carbon dioxide and other gases from the water.

Purposes of Aeration

(i) It removes tastes and odours caused by gases due to organic decomposition.

(ii) It increases the dissolved oxygen content of the water.

(iii) It removes hydrogen sulphide, and hence odour due to this is also removed.

(iv) It decreases the carbondioxide content of water, and therby reduces its corrosiveness and raises its pH value.

(v) It converts iron and manganese from their soluble states to their insoluble states, so that these can be precipated & removed.

(vi) Due to agitation of water during aeration, bacteria may be killed to some extent.

(vii) It is also used for mixing chemicals with water, as in the Aeromix process & in the used of diffused compressed air.

Methods of Aeration

(a) Free fall aerators or gravity aerators

(i) Cascade aerators

(ii) Inclined apron aerators

(iii) Slat tray aerators

(iv) Gravel bed aerators

(b) Spray aerators

(c) Air diffuser basins

Removal of Iron and Manganese

- generally present in water either in suspension as hydrated oxides or in Solution as bicarbonates.
- Iron present in water in suspension as hydrated oxides can be removed by normal treatment methods of Coagulation, Sedimentation and filtration.
- Iron present in solution as bicarbonates requires special treatment methods.

Iron < 0.3 mg/l
Manganese < 0.2 mg/l } as per NDWQS.

Effects

- produces unpleasant taste & odour in water.
- causes staining of plumbing fixtures, Clothing & textiles.
- Iron & manganese may deposit in the pipes leading to its blockage.
- Water becomes red & brown in color.
- There may be growth of bacteria in water mains.
- Causes corrosion of plumbing works.

Treatment Methods

Aeration followed by Sedimentation & filtration

$$4Fe(HCO_3)_2 + 2H_2O + O_2 \longrightarrow \underset{\text{insoluble}}{4Fe(OH)_3\downarrow} + 8CO_2$$

$$6Mn(HCO_3)_2 + 3O_2 \longrightarrow 6MnO_2\downarrow + 2CO_2 + 2H_2O$$

Base exchange Method

- removed by means of manganese zeolite
- As raw water passes through the bed of zeolite, the iron & manganese ions substitute the sodium ion present in the zeolite thus by removing iron & manganese from water.

Chlorination followed by sedimentation & filtration

- removed by their oxidation using chlorine & then followed by sedimentation & filtration.

Removal of Colour, odour & Taste

- Water used for drinking should be free from colour, odour & taste. The objectionable colour, odour & taste in water may be due to
  - (i) Organic & vegetable matter
  - (ii) Industrial waste & domestic sewage.
  - (iii) Dissolved gases
  - (iv) Dissolved mineral matter
  - (v) Micro-organisms.

- Removed by coagulation followed by filtration, Pre-chlorination, Super-chlorination followed by dechlorination, Ozonation, Aeration, Ion exchange method.

Special Methods

(a) Treatment by activated carbon

(b) Use of copper sulphate

Treatment by activated carbon

- Activated carbon is produced by heating carbonaceous materials like coke, ignite, saw dust, paper mill waste, etc. in a clossed vessel at high temperature.
- It is then activated by passing air or stream for the removal of hydrocarbons which may otherwise interfere with the adsorption of organic matter.
- Activated carbon can be applied for the treatment of water in two ways; either as filter media or as fine powder feed.

Filter media = bed of activated carbon is placed instead of sand bed in Rapid sand filters or pressure filters & filtered water is then passed through the bed of activated carbon which will absorb the organic compounds & removes color, odour & taste.

Powder form — applied to either raw water or added along coagulation mixing tank or at a point where water enters the filters.

→ Usual dose varies from 5 to 20 mg/l.

Use of Copper Sulphate ($CuSO_4$)

- generally available in powder form or crystal form
- may be directly applied in distribution pipes or open reservoir.
- dose may vary from 0.3 to 0.6 mg/l
- does not make water unfit for drinking purposes or for industrial purposes, but it may prove detrimental to certain type of fish.

Removal of Arsenic (< 0.05 mg/l)

1. Pre-treatment
   - (i) Oxidation by oxygen, ozone and chemicals
   - (ii) Photochemical oxidation
   - (iii) Biological Oxidation - Utilizes Fe or Mn oxidizing bacteria or both to enhance oxidation.
   - (iv) In-situ Oxidation
     - → introducing oxygen to water extracted from the arsenic-contaminated well, which is later circulated back into the same well.
2. Coagulation ~~foll.~~ and flocculation followed by filtration.
3. Adsorption and Ion-Exchange. (HCL)
   - → Cost effective process
4. Nanoparticles technology.
   - → Iron-based particles namely Iron oxide NPs & Zero valent iron NPs.
5. Reverse Osmosis

Reservoirs and Distribution System

- Reservoirs are the tanks or basins which are used to store the water for various purposes.
- The larger the capacity of the reservoir, the better will be reliability of water supply system.

Types of reservoirs (As per purpose)

(a) Clear water reservoir (b) Service reservoir

Clear Water Reservoir

- used to store the water that has been treated and clear.
- provided at the end of the water treatment process within the water treatment premise.
- generally located below the ground so that water can be conveyed by gravity from the treatment unit to the reservoir.
- The clear water reservoir should have capacity of 14 to 16 hours of daily water demand.

Service Reservoir

- Used in a distribution system to provide storage to meet fluctuation in demand of water, to provide storage for fire fighting & emergencies such as breakdowns, repairs etc. & to stabilize pressures in the distribution system.
- should be located near to the community as far as possible to supply the water to the consumers in shortest possible time with minimum loss of head in the pipes.
- Covered to avoid contamination & prevent algae growths.

→ **Types w.r.t ground**

(a) **Surface Reservoir**

→ Constructed at ground level or below ground level.

(b) **Elevated Reservoir**

→ constructed at an elevation from ground level.

→ for the purpose of holding water supply at a certain height to provide sufficient pressure in the water distributed system.

→ reduces the quantity of pumping required.

Sizing of Reservoir. (Mass Curve Method, Peak Demand Method)

The storage capacity of the service or distribution reservoir is based on the following three requirements :

(i) Balancing Reserve

↳ Demand of water always keeps on varying from hour to hour, but treatment water always comes out of treatment plant at a constant rate.

↳ It is that quantity of water required, that is stored in the reservoir for balancing the variable demand in the distribution System. → calculated by means of mass curve or hydrograph indicating hourly rate of consumption.

(ii) Breakdown Reserve

↳ It is that quantity of water required that is stored in the reservoir to utilize for breakdown periods.

↳ generally not more than 25 percent of total storage.

(iii) Fire Reserve

↳ Water stored in the distribution reservoir for firefighting purpose.

Reserve storage, $R = [F-P]T$
(liters)

F = fire demand in l/min
P = reserve fire pumping capacity (l/min)
T = duration of fire (min)

→ Capacity of balancing ~~ser~~ reservoir depends on the inflow from the source to the reservoir & water demand of the area.

Cases of reservoir size determination

Case	Inflow to the Reservoir	Outflow from the reservoir
A	Continuous	Continuous
B	Continuous	Intermittent
C	Intermittent	Continuous
D	Intermittent	Intermittent

→ When a storage or distribution reservoir is to be designed for the purpose of balancing the flow its storage capacity can be determined by two methods.
(i) Mass Curve Method (ii) Hydrograph method. / Peak dem

* Mass Curve Method

→ A mass curve of demand is the cumulative demand curve, and is obtained by continuously adding the hourly demands and plotting these against time (hours) of the maximum day.

→ fig(a) shows the mass demand curve CAB in thick line

→ A mass demand curve continuously rises. The steepness of the mass curve indicates a higher rate of demand, while flat portion shows the lower rate of demand.

→ Line CD is the line indicating cumulative pumping at uniform rate. If pumping is to be done for all the 24 hours, the mass curve CD for pumping will be obtained by joining two ends C and D of the mass curve of demand.

In order to determine the required storage capacity, draw tangents through lowest point & highest point B, parallel to pumping rate line CD. The highest vertical distance BE between these two tangents will then give the required capacity of the equalizing reservoir.

This is so because at A (6 A.M), there is excess supply equal to AA' which should be store, while at B (at 8.30 PM) there is deficit BB' which must be drawn from the storage that is replenished by midnight. The required storage capacity will thus be the sum of morning excess AA' and evening deficiency BB'.

$$S = E_p + E_d$$

Where,

S = Storage capacity required
E_p = maximum excess of supply through pumping
E_d = maximum excess of demand (or max. deficiency)

* Hydrograph Method

→ Hourly demand rate is not contant throughout the day. The demand is more during morning and evening and less during the other parts of the day.

→ fig (b) shows a hydrograph of hourly demand for the maximum day. For a uniform 24 hr pumping, the pumping rate will be equal to the mean hourly demand, shown by the line PQ. The required storage is then obtained by planimetering or determining the area betn curve BEC

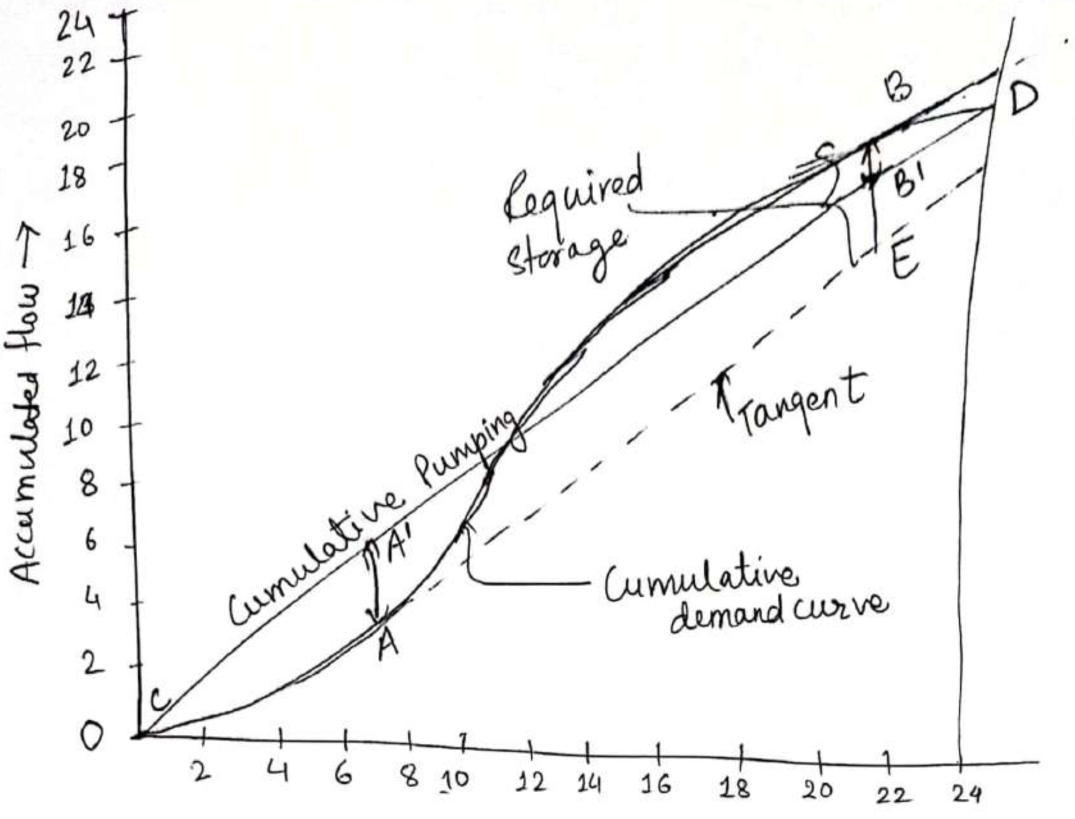
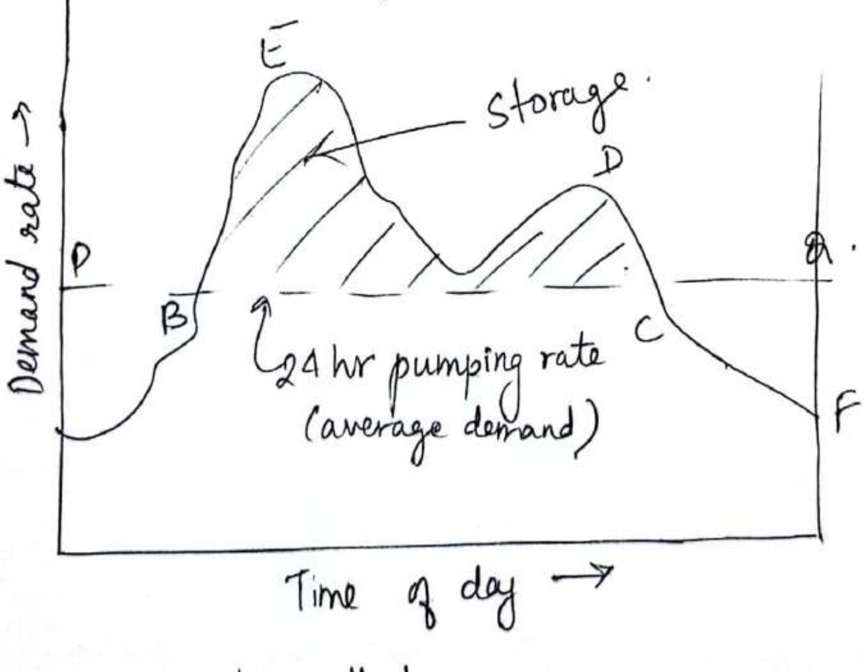


fig: Mass curve method



Hydrograph method

Layout of Water Supply System – Network of pipelines that conveys water to consumers in community.

→ depends on the layout of the roads in the community.

(a) Dead End System (b) Grid Iron System

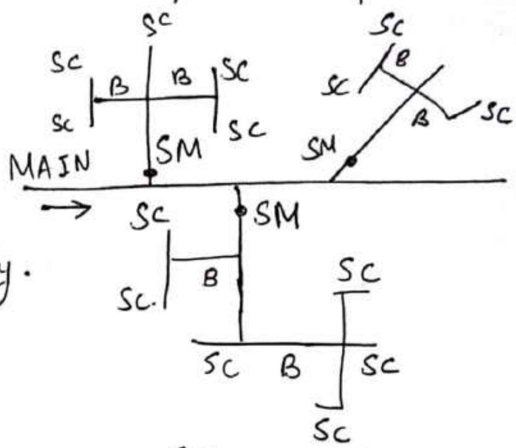
(c) Ring System (d) Radial System

Dead End System

→ consists of one supply or trunk main, from which sub mains are taken.

→ Branches are taken from sub mains & lastly service connections are given to consumers from branches.

→ adopted in towns or cities which have developed in haphazard manner without proper planning.



SM = Sub main
B = Branch
SC = service connection
• = Cut off valve.

Advantages

→ design calculations are simple & easy. It is possible to determine the discharge & pressure in each pipe very accurately.

↳ Cheap & economical design.

↳ laying of pipe is simple.

↳ number of cut off valves employed in the System is less.

Disadvantages

↳ Stagnation of water & accumulation of sediments at dead ends.

↳ Large number of scour valves are required at dead ends.

↳ In case of repairs to any of the pipe sections in the system, the whole of the portion beyond that point to the end will be required to cut off completely.

Grid Iron Systems.

↳ Mains, sub mains & brances are interconnected forming loops & water can be made to circulate continuously through the whole of the distribution system.

→ Improvement over the dead end system.

Advantages

→ free circulation of water, without stagnation or sediment deposit.

→ Due to interconnection, water is available at each point with minimum loss of head.

→ In case of repairs, only very small area of the distribution system is affected.

→ Enough water is available in the streets for fire fighting.

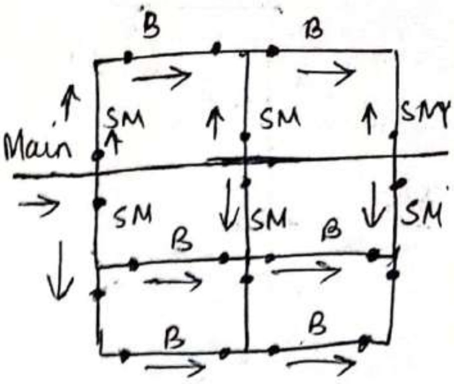


fig : Grid Iron System

Disadvantages

→ A large number of cut off valves are required.

→ requires longer pipe lengths.

→ Analysis of discharge, pressure & velocities in the pipeline is difficult & cubersome.

→ cost of pipe laying is more.

Ring System

→ Layout of main pipe - laid to form a closed ring around the area to be served.

→ Submains takes off from the main pipelines & run on the interior of the area.

→ Most suitable for the towns & cities having well planned streets & roads.

Radial System

→ Reverse of the ring system with water flowing towards the outer periphery instead of from it.

→ In this system, the entire area is divided into a number of small distribution zones & in the center of each zone a distribution reservoir is provided.

→ provides the efficient & quick service at high pressure with less loss of head.

→ most suitable for cities & towns having roads laid out radially.

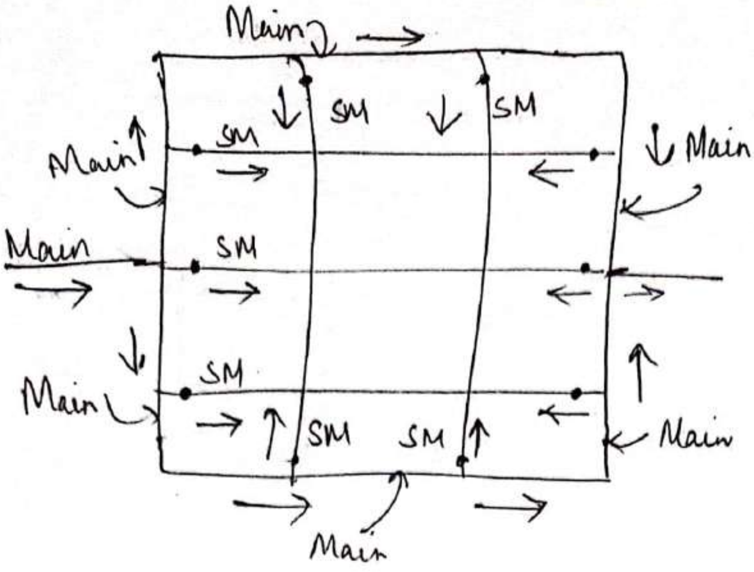


fig : Ring System

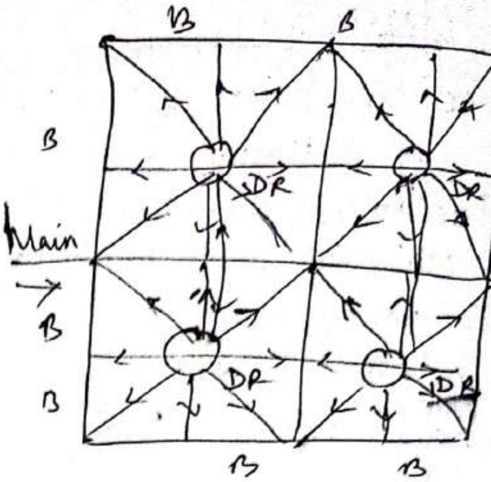


fig : Radial System.

Pipeline Design : Design criteria, design of transmission & distribution System (including pipe networks).

→ Design of distribution system involves the determination of sizes of pipes to be used in the distribution system to carry the required discharge under a known pressure difference between the inlet & the exit sections of the pipe which depends upon the topography of the area.

→ Design of the distribution requires the knowledge of pipe hydraulics, design criteria & steps of the design process which are described below.

Pipe Hydraulics

(continuity eqn or Bernoulli's equation)

→ Determination of size of pipe considering energy or head losses in pipes.

Major losses – caused by friction , $h_f = \frac{flv^2}{2gd}$

Minor losses – Loss of head due to

a) Loss of head due sudden enlargement in pipe ; $h_L = \frac{(V_1-V_2)^2}{2g}$

b) Sudden contraction in a pipe – $0.5\,V^2/2g$

c) at entrance – $0.5\,V^2/2g$

d) exit – $V^2/2g$

e) Gradual contraction or enlargement in a pipe $K \cdot \frac{(V_1-V_2)^2}{2g}$

f) Bend – $K \cdot V^2/2g$

g) various pipe fittings such as valves, couplings etc. $K \cdot V^2/2g$

Design Criteria

→ The main three design criteria that must be fulfilled are velocity, pressure & pipe size.

Velocity

→ Velocity of flow in the pipe should be neither too low nor too high.

→ At low velocity the suspended particles present in water will settle down in the pipe thus by causing the obstruction to the flow of water & clogging the pipes.

→ The high velocity of flow is not desirable because the abrasion of the suspended particles with the interior surface of pipe will be causing the erosion of pipes.

Recommended velocity of flow in the pipes is given a.

Minimum Velocity = 0.3 m/s

Maximum Velocity = 3.0 m/s

For the untreated water the minimum velocity of 0.6 m/s may be adopted.

Pressure

→ neither too low nor too high.

→ Low pressure – low flow of water or it will not rise up to desired height

high pressure – requires higher pressure rating pipes to prevent it from bursting.

For system with private connection, minimum pressure	=	15.0 m
" " without " " , " "	=	5.0 m
At public stand post, desirable pressure	=	15.0 m
" " " " , minimum pressure	=	5.0 m
" " " " maximum "	=	55.0 m

Pipe Size.

↳ The pipe size available commercially in the market should be recommended.

Design Steps.

→ Various steps involved in the design of distribution system are ;

✓ **Maps and Surveys**

↳ topographical map of the entire project area

↳ Two types of surveys
- Technical Survey - contour plan, cross-sections.
- Social Survey - data collecting water demand.

✓ **Tentative layout**

⇒ System of layout to be adopted is decided & a tentative layout of the distribution area is then marked showing the alignments of all the mains, submains & branches as well as the positions of the proposed water supply components.

✓ **Discharge in pipelines**

↳ Based on population or population density, per capita water demand, type & numbers of commercial, industrial & institutional capacities, fire & other requirements, the desired discharge to be carried in each pipeline is computed.

→ transmission line = designed for max^m daily demand
distribution system = designed for max^m hourly demand or peak demand.
Peak demand varies from 2 to 4.

· **Calculation of pipe diameters.**

↳ calculated for known design discharge based on the available head.

↳ Darcy Weisbach or Hazen Williams formulae.

↳ The commercially available pipe diameter which is equal or slightly higher in size should be adopted.

↳ Design criteria on min^m pressure & velocity in pipes should be maintained

✓ **Computation of residual pressure and velocity.**

↳ Residual pressure ~~in~~ the distribution system is computed using the pressure available in the upstream points, ground levels, design discharge & head loss in the pipe.

↳ Velocity is computed for the design discharge after selecting the diameter of pipe.

↳ Residual pressure & velocity should conform the design criteria; else diameter of pipe is revised until the design criteria is satisfied.

Design of Pipe Networks

A. Branched System

1) Determine the population served by each station
2) Determine the discharge to be carried by each station
3) Compute allowable head loss in the pipe. It depends on the ground levels, residual head pressure available in the upstream point & minimum pressure head to be maintained in the pipe.
4) Calculate the pipe diameter of pipe in section. Use Darcy Weishback or Hazen Williams equation.

$$h_f = \frac{f l V^2}{2gd} = \frac{f l Q^2}{12.1 d^5} \quad \text{Darcy}$$

$$h_f = \frac{10.68 L}{d^{4.87}} \left(\frac{Q}{C}\right)^{1.852}$$

5) Calculate head loss in each pipe section
6) ~~Calculate~~ Check residual pressure & velocity. should be within limit of design criteria. If not, recalculate changing the diameter of pipe.

B. Looped System

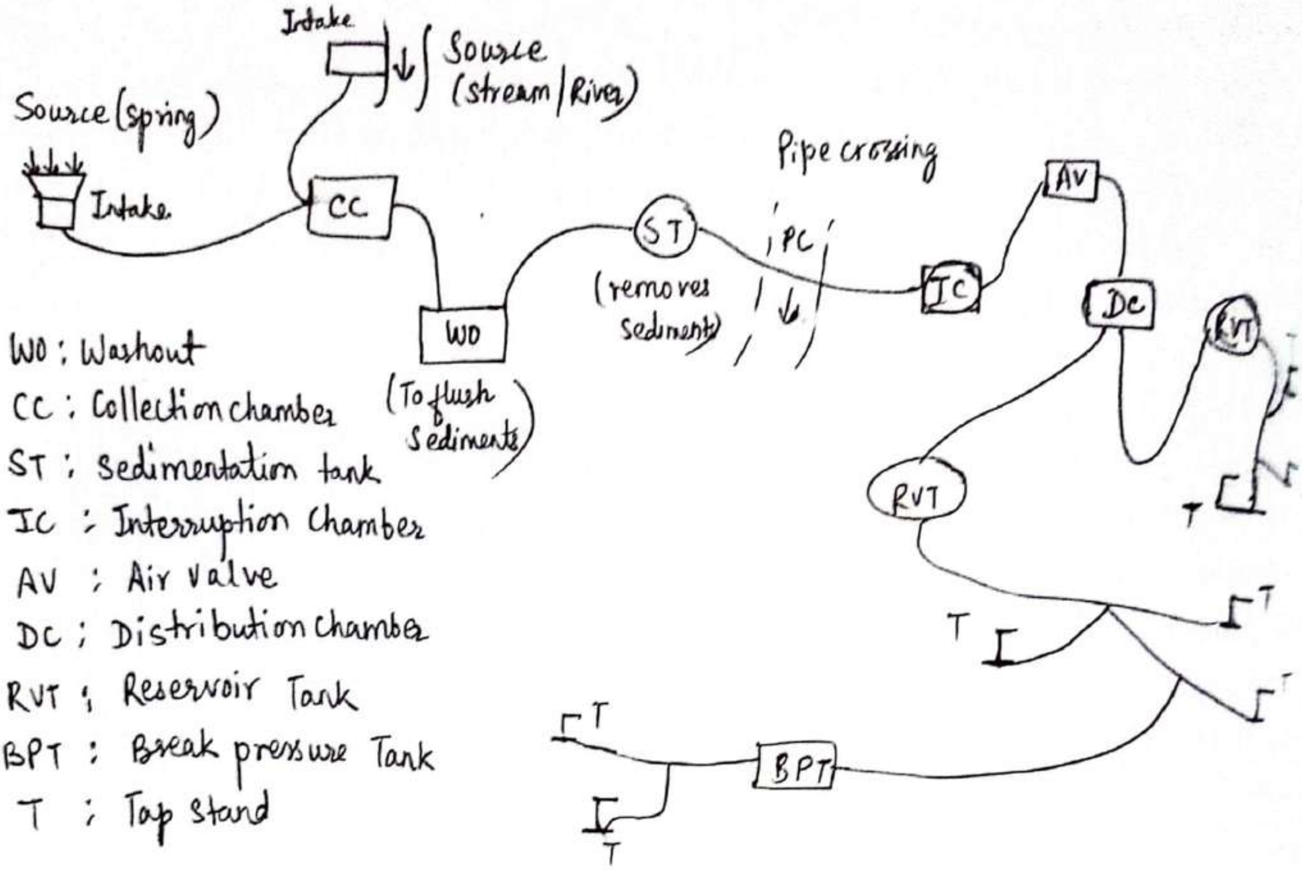
Hardy Cross Method

i) In each pipe of network, there is relationship between the head loss in the pipe & quantity of water flowing through it.
ie. $h_f = kQ^n$. k & n are constants

ii) At each junction, the algebraic sum of the quantities of water entering & leaving the junction zero. ie. $\Sigma Q = 0$

iii) The algebraic sum of head losses of all the pipes in a loop is zero. ie. $h_f = 0$
→ Head loss due to flow in clockwise dirⁿ must be equal to the loss of head due to flow in anticlockwise direction.

Design Specific of gravity flow rural water Supply System in Nepal



WO : Washout
CC : Collection chamber
ST : sedimentation tank
IC : Interruption Chamber
AV : Air valve
DC : Distribution chamber
RVT : Reservoir Tank
BPT : Break pressure Tank
T : Tap stand

Pipeline design procedure in gravity flow rural water supply system

1. Survey Work
→ Profile levelling, head difference, residual head etc.

2. Calculate the safe yield of source (Q_s)
* Discharge measurement of source by :
Bucket Method, Float Method, Notch/weir method, Salt dilution Method & velocity using current meter.
* Safe yield = 0.9 * measurement yield & ≥ 0.1 l/s for reliab

3. Population forecasting

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

Select growth rate
Select base period = 2-3 year
Select design period : for r ≥ 2, 15 years & r < 20 years (yr<1

4. Calculate average demand (Q_{AV})

↳ Domestic + livestock + Institutional

5. Take peak factor (P_f)

- 1 for transmission
- 3 for public & institutional connection
- 1 for private connection.

6. Calculate design discharge (Q_d) = P_f * Q_{AV}

7. Find the capacity of RVT considering the following consumption pattern.

Time	05-07	07-12	12-17	17-19	19-24
% of demand	25	35	20	20	0

8. Take residual head

a. For CC | DD | IC | RVT : Max. 15m, Min. 5m, Exceptional min 3.5m

b. For Taps : Max 15m, Min 5m, Exceptional Min. 3.5m, Exceptional Max. 35m

c. For pipe line : Min 5m. Exceptional min : 3.5m, max^m as per pipe series.

HDPE Series

4 kgf/cm²	6 kgf/cm²	10 kgf/cm²	GI pipe.
40m	60m	10m	160m

9. Consider limiting velocity in the pipeline.

a) Generally max for 6kgf/cm² - 2.3 m/s, 10kgf/cm² - 2.8 m/s

b) Absolute min 0.3m/s & absolute max 3m/s

c) Uphill : 0.5 to 2 m/s

d) Downhill : 0.4 - 2.5 m/s

10. Choose pipe series & diameter according to discharge & allowable head loss for sufficient residual head from table & check for velocity.