Water Supply Engineering

Chapter 4

Quality of Water

Lecture 6 (Week 6)

Water related diseases and Transmission routes, Preventive measures, Examination of water (Physical, Chemical, Biological)

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Learning Objectives:

- Classify and differentiate types of water-related diseases and understand their transmission routes.
- Describe preventive measures to control water-related diseases.
- Perform physical, chemical, and biological examinations of water.
- Interpret results using Most Probable Number (MPN) method.
- Understand and apply water quality standards for drinking purposes.

4.4 Water related diseases

- The improper disposal of excreta makes the water contaminated and unsafe. 80% of infectious diseases are associated with insufficient and unsafe water.
- Diseases also transmitted through penetration of organism through the skin.
- Water-related diseases are illnesses caused by pathogenic microorganisms, parasites, or chemical contaminants transmitted through water. These diseases are classified based on their transmission routes (World Health Organization [WHO], 2017).

Types

1. Water borne diseases
2. Water washed diseases
3 Water based diseases
4. Water vector diseases

4.4.1 Water-Borne Diseases

Water-borne diseases occur due to the ingestion of water contaminated with pathogenic bacteria, viruses, or protozoa. These diseases are primarily transmitted through the fecal-oral route. (Centers for Disease Control and Prevention [CDC], 2021).

The transmission of such disease occurs when the pathogen is in water. Such water when drunk, the consumer is infected. These are also known as water quality diseases. Quality is measured in terms of two types of contamination:

- Chemical: waterborne chemical diseases > ingestion of water containing toxic substances in harmful concentration (e.g . arsenic, fluoride, nitrate, iron etc…
- Microbiological: fecal oral route > feces contaminate water supplies and trigger diseases of microbiological nature.

Major Water-Borne Diseases:

1. Cholera (Vibrio cholerae)

-Symptoms: Severe watery diarrhea, vomiting, dehydration.

- Source: Contaminated water with fecal matter (WHO, 2019).

- Prevention: Safe water supply, proper sanitation, oral rehydration therapy (WHO, 2019).

2. Typhoid Fever(Salmonella typhi)

- Symptoms: High fever, abdominal pain, weakness.

- Source: Fecal contamination of water (CDC, 2021).

- Prevention: Vaccination, water chlorination (WHO, 2017).

3. Hepatitis A

- Symptoms: Jaundice, fatigue, nausea.

- Source: Contaminated water or food (WHO, 2020).

- Prevention: Improved sanitation, vaccination (CDC, 2021).

4.4.2 Water-Washed Diseases

These diseases result from poor hygiene and inadequate water supply for washing. They are not necessarily transmitted through water ingestion but due to lack of clean water for sanitation (United Nations Children's Fund [UNICEF], 2021).

Examples:

1. Trachoma (Chlamydia trachomatis)
   - Symptoms: Eye infection leading to blindness.
   - Prevention: Face washing, improved water access (WHO, 2022).
2. Scabies
   - Symptoms: Itchy skin rash caused by mites.
   - Prevention: Regular bathing and clean water supply (UNICEF, 2021).

4.4.3 Water-Based Diseases

These are caused by parasites that spend part of their life cycle in water before infecting humans (WHO, 2018). These are transmitted when people have contact with infected water. These diseases are also known as water contact diseases.

Examples:

1. Schistosomiasis (Bilharziasis) (Snail fever)

- Causative Agent: Schistosoma
- Symptoms: Itchy skin ,Fever, Damage to brain, lungs,Cough,Damage to the abdomen, liver or spleen after five years ,Paralysis of the lower body
- Transmission: Skin contact with contaminated freshwater.
- Prevention: Avoiding contaminated water, snail control (WHO, 2018).

2. Dracunculiasis (Guinea Worm Disease)

- Causative Agent: Dracunculus medinensis

-Transmission: Drinking water containing infected copepods.

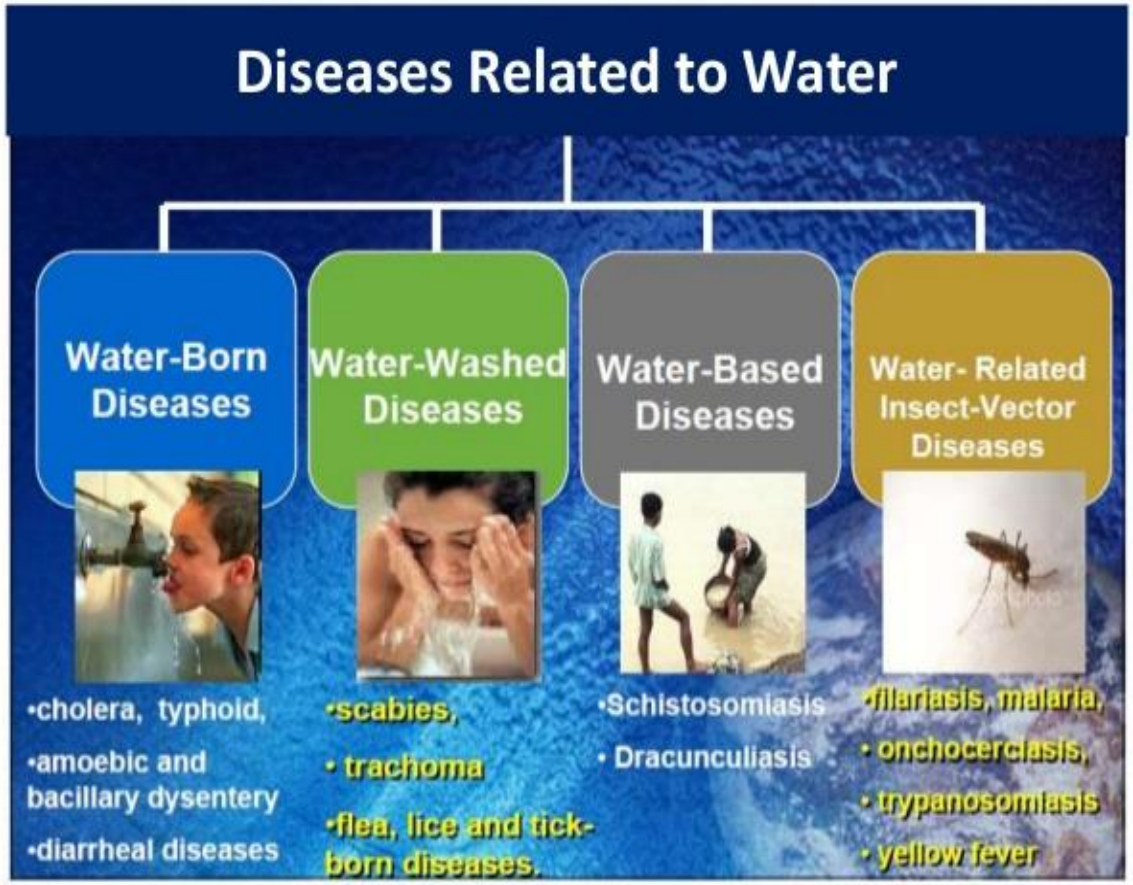
4.4.4 Water-Vector Diseases

These diseases are transmitted by insects that breed in or near water (WHO, 2021).

The transmission of these diseases is complex because they involve at least three living things- a host (man and animals), a parasite that cause diseases (protozoa, virus or worm) and a carrier vector (insect, fly or mosquito). These diseases are also known as water site insect carried diseases.

Examples:

1. Malaria
   - Vector: Anopheles mosquitoes breeding in stagnant water.
   - Prevention: Insecticide-treated nets, larvicides (WHO, 2021).
2. Dengue Fever
   - Vector: Aedes aegypti mosquitoes.
   - Prevention: Eliminating standing water (CDC, 2022).



Source: www.slideshare.net

4.4.5 Transmission Routes

- Due to inadequate and improper disposal of human wastes and to contaminated water supplies.
- The transmission of diseases through the fecal-oral route is significant transmission mechanism in which some of feces of an infected individual are transmitted to the mouth of a new host through one of variety of routes.
- This mechanism works through a variety of routes shown by F-Diagram (The "F-diagram" (feces, fingers, flies, fields, fluids, food), showing pathways of fecal–oral disease transmission.)) as shown in figure:

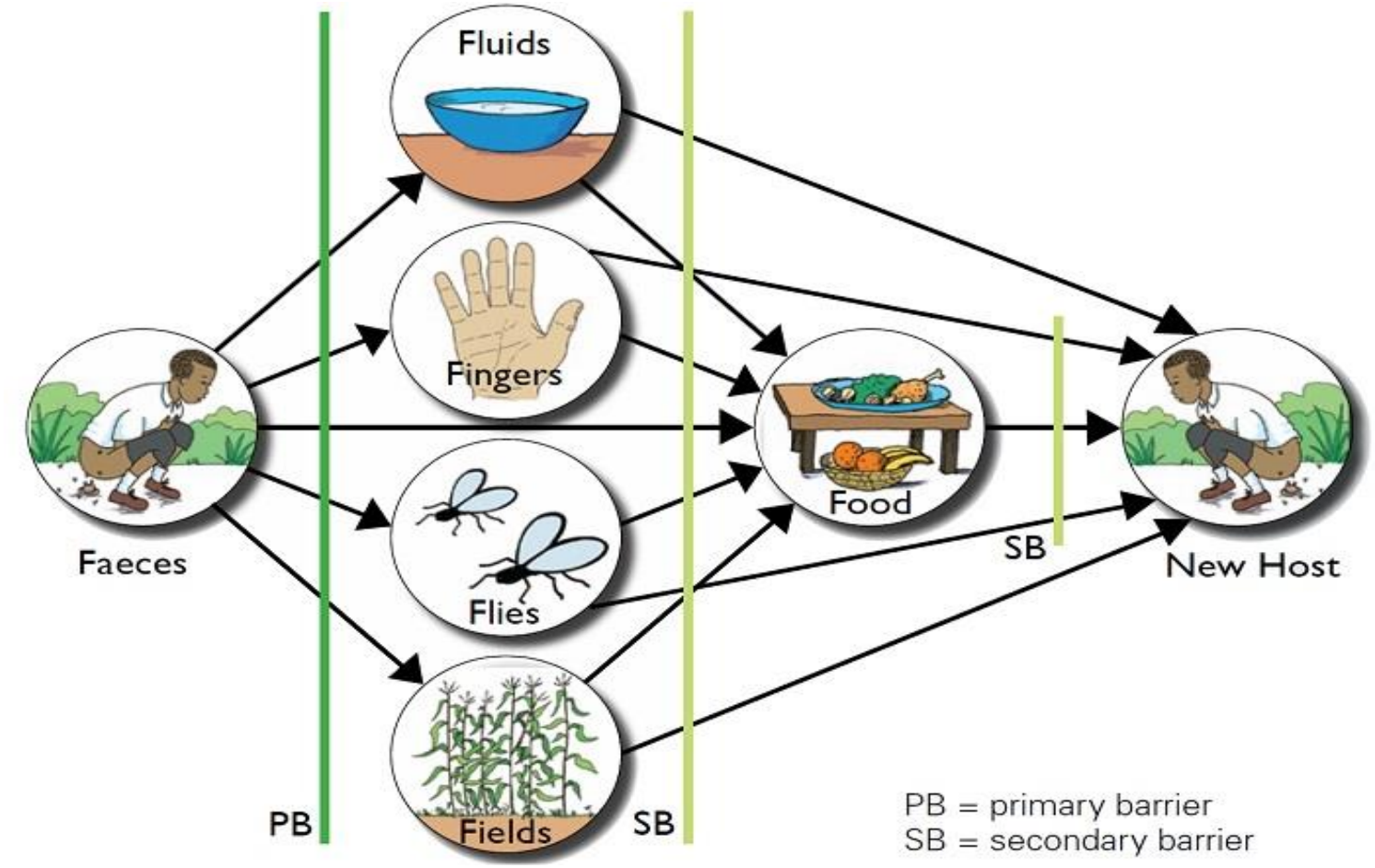


Figure 1:showing pathways of fecal–oral disease transmission (WHO,2017)

Transmission Pathways (The 5 F's)

The fecal-oral route of disease transmission occurs through five primary pathways, known as the **"5 F's"**:

1. **Feces** – Source of pathogens (bacteria, viruses, parasites).
2. **Fluids** – Contaminated water (e.g., drinking, cooking, or bathing water).
3. **Fingers** – Poor hand hygiene after defecation or contact with feces.
4. **Flies** – Mechanical vectors carrying pathogens from feces to food.
5. **Food** – Contaminated due to unclean handling, irrigation with wastewater, or exposure to flies.

2. Key Barriers to Break the Transmission Cycle

(A) Primary Barriers (PB) – Prevent initial contamination:

- **Sanitation systems** (toilets, sewage treatment).
- **Safe water supply** (piped water, protected wells).

(B) Secondary Barriers (SB) – Block transmission after contamination occurs:

- **Handwashing with soap** (after defecation, before eating).
- **Food hygiene** (proper cooking, washing, covering food).
- **Fly control** (waste management, insecticides).

3. Water-related diseases spread through:

- 1. Fecal-oral route (e.g., cholera, hepatitis A).
- 2. Skin penetration (e.g., schistosomiasis).
- 3. Vector-borne transmission (e.g., malaria).
- 4. Inhalation (e.g., Legionnaires' disease) (WHO, 2017).

4. Prevention Strategies

Transmission Route	Intervention
Fluids (Water)	Boiling, chlorination, filtration
Fingers (Hands)	Handwashing stations, hygiene education
Flies	Waste covering, insecticide use
Food	Proper storage, cooking, clean preparation
Fields (Soil)	Safe excreta disposal, sanitation infrastructure

1. The **5 F's (Feces, Fluids, Fingers, Flies, Food)** summarize fecal-oral transmission.
2. **Primary barriers (PB)** target the source (feces/water), while **secondary barriers (SB)** interrupt human exposure.

3. Breaking the cycle requires **both infrastructure (PB)** and **behavioral changes (SB)**.

4.4.6 Preventive Measures for Water-Related Diseases

1. Identification of Transmission Mechanisms

- Understanding how pathogens spread is crucial for prevention. The fecal-oral route is the primary transmission pathway for waterborne diseases, involving:
- Contaminated water (drinking, cooking)
- Poor sanitation (open defecation, unsafe wastewater disposal)
- Unhygienic practices (lack of handwashing, improper food handling)

Source: WHO (2019). *Guidelines on Sanitation and Health*.

2. Barriers to Disrupt Disease Transmission

(A) Primary Barriers

Goal: Prevent pathogens from entering the environment.

1. Safe Human Excreta Disposal
    - Use of toilets with septic tanks/sewage systems to avoid open defecation.
    - Community sanitation programs (e.g., CLTS–Community-Led Total Sanitation).
2. Safe Wastewater Disposal & Drainage
    - Proper drainage systems to prevent stagnant water (breeding sites for vectors).
    - Treatment of sewage before discharge into water bodies.
3. Domestic Hygiene & Animal Management
    - Keep animal waste away from living and water sources.
    - Secure garbage disposal to avoid attracting flies/rodents.

Source: UNICEF (2021). *WASH in Health Care Facilities*.

(B) Secondary Barriers

Goal: Block exposure to pathogens already in the environment.

1. Personal Hygiene
    - Handwashing with soap (after defecation, before eating).
    - Proper use of toilets (cleaning, maintenance).
2. Water Hygiene
    - Drink only filtered/boiled water (removes pathogens).
    - Fetch water from clean sources (protected wells, treated supply).
3. Food Hygiene
    - Wash fruits/vegetables with safe water.
    - Cook food thoroughly to kill pathogens.

Source: CDC (2021). *Waterborne Disease Prevention*.

3. Key Preventive Measures

Measure	Action Required	Impact
Safe Excreta Disposal	Use toilets, avoid open defecation	Reduces fecal contamination
Personal Hygiene	Handwashing, clean clothing	Prevents person-to-person spread
Proper Toilet Use	Regular cleaning, maintenance	Limits environmental contamination
Filtered Water	Boiling, chlorination, filtration	Eliminates waterborne pathogens
Food Hygiene	Proper washing, cooking	Prevents foodborne infections

Safe Wastewater Disposal	Sewage treatment, drainage	Reduces water pollution
Domestic Hygiene	Clean living spaces, waste management	Controls vectors (flies, rodents)
Clean Water Source	Use protected wells/piped water	Ensures safe drinking water

Source: WHO (2017). *Guidelines for Drinking-Water Quality*.

Conclusion

- Primary barriers focus on stopping contamination at the source (sanitation, wastewater management).
- Secondary barriers rely on hygiene behaviors (handwashing, water treatment).
- Combining both is essential for breaking the fecal-oral transmission cycle.

4.5 Examination of Water

Water quality is assessed through physical, chemical, and biological tests (American Public Health Association [APHA], 2017).

Examination of Water

- To find quality of water by determine different impurities
- To determine efficiency of different treatment process
- To determine suitability of water for drinking purpose

Types Of Examination

- Physical examination
- Chemical examination
- Bacteriological examination

4.5.1 Physical Examination of Water

1. Temperature

- Effects physical properties of water like viscosity, surface tension, density
- Rate of chemical activity, and biological activity
- Desirable temperature of drinking water = 10 to 15°C
- Anything above 35°C is considered unsuitable for public water supply
- Measured by ordinary thermometer
- Ideal range: 10–15°C (WHO, 2017).

2. Color

- Measured by ability of solution to absorb light
- Color is seen due to colloidal and dissolved impurities

- The color is expressed in units of platinum cobalt scale. 1 mg of platinum plus ½ mg of metallic cobalt dissolved in 1 L of distilled water is 1 color unit. For drinking water colour should not be greater than 5 ppm in platinum cobalt scale. Greater than 5 is tolerable but rejected if greater than 15 in platinum cobalt scale. The color is measured by means of tintometer or colour meter. 1 platinum cobalt scale = 1 ppm = 1 mg/l = TCU
- Fe_2O_3 = reddish brown
- MnO = blackish
- Pure water is colourless.

Measured in Hazen units (TCU).

Acceptable limit: <15 TCU (WHO, 2017).

3. Taste and Odour

- It is happens due the presence of organic matters, mineral substances, dissolved gases, live or dead microorganism.
- Odour is measured in terms of Threshold odour number (TON).
- For public water supply, the value of odour shouldn't exceed 3.
- It can also be measured by the instrument Osmoscope.
- Taste is measured by Flavor threshold number (FTN)
- Oduor & taste is objectionable and can be removed by aeration and chlorination in some extent.

4. Turbidity

- Measures water clarity.
- caused By suspended matters (clay, silt etc), organic and inorganic matters, plankton, other microscopic organisms etc
- Defined as measure of resistance to passage of light through water

- In silica scale (5 – 10 ppm) , 25 ppm is accepted , Greater than 25 ppm is rejected

In field: Turbidity Rod

In Lab:

(i) Jackson turbidity meter (ii) Baylis turbidity meter (iii) Hellige or Aplab turbidity meter (iv) Nephelometer

4.5.2 Chemical Examination of Water

1. pH

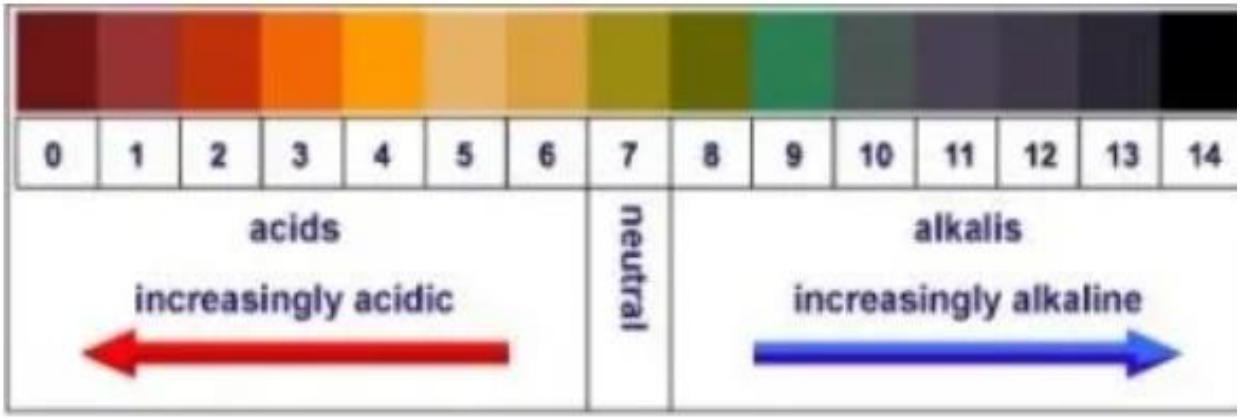
pH of water is a measure of amount of hydrogen ions that is present in the water. It determines if the water is alkaline or acidic in nature. pH stands for potential of hydrogen. As per the World Health Organization (WHO), value of pH for the water is 6.5 to 8.5. pH can be calculated mathematically as

pH = - log10 [H +]

Measuring pH

a. By colorimetric method

Take the pH standard solution and the water that is to be tested. Take the colorimetric paper. Dip this paper on the water sample. The obtained color is computed from the standard table and the respective pH value is recorded. This pH Value will conclude whether the sample of water is acidic or alkaline.



(theconstructor.org, n.d.)

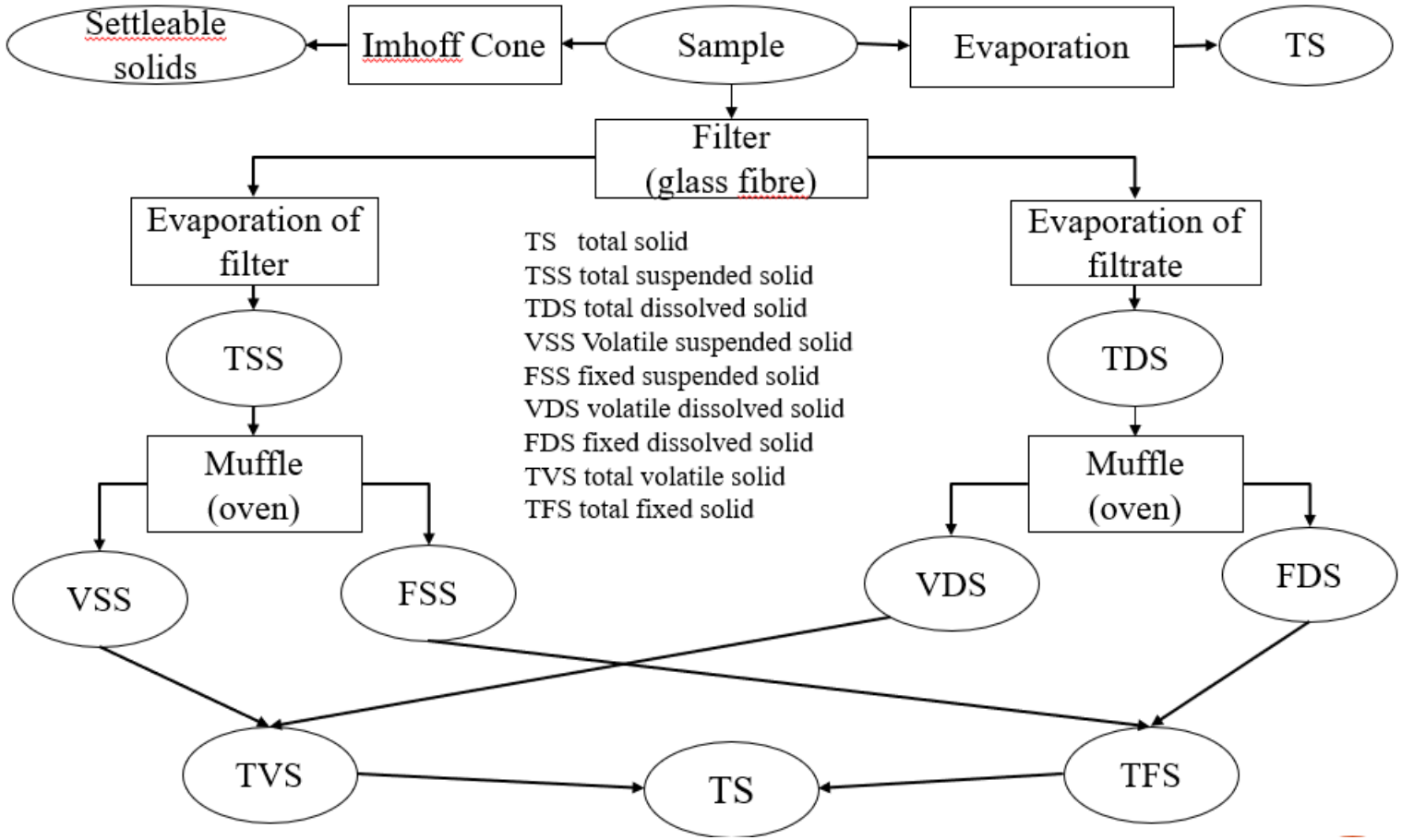
b. **By electrometric method**

- Electrode is first immersed in buffer solution of known pH for calibration
- Electrode is immersed in sample and reading is taken

- **Solids (SS)**

Solids are classified as total solids, dissolved solids and suspended solids.

- Measured by filtration and weighing.



3. Dissolved Solids (TDS)

- Acceptable limit <600 mg/L (WHO, 2017).

4. Total Solids (TS) = SS + DS

4.5.3 Biological Examination of Water

- It is carried out to determine the presence of microorganism in water.
- The pathogenic bacteria is responsible for many types of diseases
- During examination, the concentration of coliforms or E-coli are tested rather than pathogens.
- The E-coli and coliforms are indicator organism of contaminated water.
- The E-coli and coliforms are should be nil in water.
- For bacteriological analysis the following tests are done.
  - Total count or ager plate test
  - Multiple tube fermentation technique
  - Membrane filters technique.

Plate count test

- Total number of bacteria presents in 1 ml of water is counted.
- 1mlof sample of water is diluted in 99 ml of sterilized water and 1ml of dilute water is mixed with 10 ml of agar of gelatine (a culture medium used to cultivate bacteria).
- Incubated at 37°C for 24 hours or 20°C for 48 hours.
- Colonies of bacteria are counted by means of microscope or colony counter.
- The total number of bacteria per ml of diluted sample is then calculated by the product of no of colonies and dilution factor.

1. Multiple Tube Fermentation (MTF) Method

- Estimates coliform bacteria using lactose broth (APHA, 2017).

• Requires multiple standard fermentation tube- DURHAM TUBE for E-coli`

- This method includes 3 tests

a. Presumptive test
b. Conformed test
c. Completed test

a. Presumptive test

- This test is based on the ability of coliform group to ferment the lactose broth and producing of acids and gas.
- Different tubes are taken in multiples of 10
- Put standard fermentation tubes containing lactose broth and then kept in incubator at a temperature of 37°C for a period of 48 hours.
- Showing acid and sufficient gas is the indication of presence of e-coli group and result is positive.
- Positive result further requires further testing for conforming the presence of coliform bacteria in the sample

b. **Conformed Test**

- Sample showing the gas is carefully transferred to another fermentation medium containing brilliant green lactose bile broth and placed in the incubator at temperature 37°C for a period of 48 hours.
- If again gas formed there (in any amount) presence of e-coli is conformed then second step is follow

c. Completed Test

- This test is based on the ability of the culture grown in the conformed test again ferment the lactose broth.
- Take small portion on the plates containing MacConkey agar or Eosin-methylene blue ager of Endo agar and the plates are kept in the incubator at temperature 37°C for 24 hours in order to ensure the growth of single, discrete and pure colonies.
- The bacterial colonies or cultures grown in the conformed test are kept into lactose broth fermentation tubes and agar tubes and then the tubes are kept in the incubator at 37°C for a period of 24 hours.

2. Membrane Filtration Method

Procedure Overview:

1. **Filter Preparation:**

Utilize a sterile membrane filter with 80% porosity, featuring microscopic pores sized 5-10 micrometers (μm).

2. **Filtration Setup:**

Secure the membrane filter in a filtration funnel connected to a vacuum pump assembly.

3. **Sample Processing:**

   - Pass approximately 20 mL of the water sample through the membrane under vacuum pressure to trap microorganisms.

4. **Culture Transfer:**

Carefully transfer the filter onto a petri

plate pre-prepared with M-Endo nutrient medium, which selectively promotes coliform growth.

5. **Incubation:**

Maintain the culture plate at 37°C (standard human body temperature) for 20 hours to allow colony development.

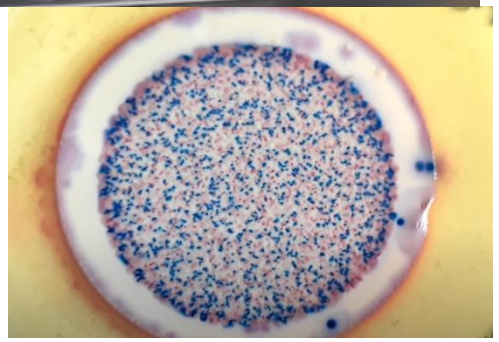
6. **Quantitative Analysis:**

➢ After incubation, enumerate the distinct coliform colonies under microscope observation.

Calculation Formula:

Coliform colonies per 100 mL

=(Number of colonies counted/Volume filtered (mL))×100



(©Sunil Rakhal,2021)

Key Features of the Method:

- **High Specificity:** M-Endo medium selectively differentiates coliforms by producing metallic sheen colonies.
- **Precision:** Membrane filtration concentrates bacteria from large volumes, improving detection sensitivity.
- **Standardization:** Complies with EPA/WHO guidelines for water quality assessment (APHA, 2017).

3. Most Probable Number (MPN)

Statistical estimation of bacterial concentration (APHA, 2017).

i) MPN index or number is defined as that bacterial density which is most likely to be present in water.

ii) To determine MPN index, bacteriological tests are carried out by taking standard samples of combination of three 10 ml, three 1 ml and three 0.1ml.

iii) The number of positive results of these tests is recorded and MPN index is determined.

iv) MPN index can be approximately calculated by following formula:

v) MPN/100ml = $\frac{Number\ of\ positive\ tubes}{\sqrt{ml\ in\ negative\ \times ml\ in\ all\ tubes}} \times 100$

4.6 Water quality standards for drinking purpose

- The standards for various types of water quality parameters such as turbidity, ph, color etc are known as water quality standard.
- If any of water quality parameters is higher than the standards, it should be brought down to equal or less than standards by treatment of water.

- The given table shows the maximum concentration of various water quality parameters that can be present in safe drinking water.

National Drinking Water Quality Standards, 2079

Compulsory Parameter

SN	Parameter	Unit	Maximum Concentration	Remark
Physical parameter				
1	Turbidity	NTU	5	NHBGV
2	pH		6.5-8.5	NHBGV
3	Color	TCU	5	NHBGV
4	Taste and Odor		Should not be offensive	NHBGV
5	Electrical Conductivity	uS/cm	1500	NHBGV
Chemical Parameter				
6	Iron	mg/L	0.30(3)	NHBGV
7	Manganese	mg/L	0.2	NHBGV
8	Arsenic	mg/L	0.05	NHBGV

9	Flouride	mg/L	0.5-1.5	HBGV
10	Ammonia	mg/L	1.5	NHBGV
11	Chloride	mg/L	250	NHBGV
12	Sulphate	mg/L	250	NHBGV
13	Nitrate	mg/L	50	NHBGV
14	Copper	mg/L	1	NHBGV
15	Zinc	mg/L	3	NHBGV
16	Aluminium	mg/L	0.2	NHBGV
17	Total Hardness	mg/L	500	NHBGV
18	Residual Chlorine	mg/L	0.1-0.5(3min-max)	HBGV(for system with chlorination only)
Microbiological Parameters				
19	E.Coli	CFU/ 100 ml	0	HBGV

Note:HBGV Health Based Guideline Value
NHGBV: Non-Health Based Guideline Value

Further testing based on risk and relevance

SN	Parameter	Unit	Maximum Concentration Limit	Remarks
Physical Parameter				
1	Total Dissolved Solids	mg/L	1000	NHBGV
Chemical Parameter				
2	Calcium	mg/L	200	NHBGV
3	Lead	mg/L	0.01	HBGV
4	Cadmium	mg/L	0.003	HBGV
5	Chromium	mg/L	0.05	HBGV

6	Cyanide	mg/L	0.07	HBGV
7	Mercury	mg/L	0.001	HBGV
8	Nitrites	mg/L	3	HBGV
Microbiological parameters				
9	Total Coliform	CFU/ 100 ml	0 (95% samples)	HBGV

WHO Guidelines for Drinking-water Quality (2022)

1. Physical & General Parameters Unit			
Parameter	**Unit**	**Guideline Value**	**Remarks**
Turbidity	NTU	≤1 (≤5 for non-piped)	Critical for disinfection efficiency
pH	-	6.5–8.5	Corrosivity control
Color	TCU	≤15	Aesthetic
Taste/Odor	-	Acceptable	No objectionable change
2. Chemical Contaminants **(A) Inorganic Substances**			
Parameter	**Unit**	**Guideline**	**Health Concern**
Arsenic (As)	mg/L	≤0.01	Carcinogenic (liver/bladder cancer)
Fluoride (F)	mg/L	≤1.5	Dental/skeletal fluorosis

Nitrate (NO_3^-)	mg/L	≤50	Methemoglobinemia (infants)
Lead (Pb)	mg/L	≤0.01	Neurotoxic
Mercury (Hg)	mg/L	≤0.001	Kidney damage
(B) Disinfection Byproducts			
Parameter	**Unit**	**Guideline**	**Remarks**
Chloroform	mg/L	≤0.3	Carcinogenic
Residual Chlorine	mg/L	0.2–0.5	Must persist in distribution
3. Microbiological Parameters			
Parameter	**Unit**	**Guideline**	**Critical Requirement**
E. coli	CFU/100mL	0	Immediate risk assessment if detected
Total Coliforms	CFU/100mL	0	Indicates treatment failure
Cryptosporidium	oocysts/L	≤0.1	Resistant to chlorine

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Thank You!!!