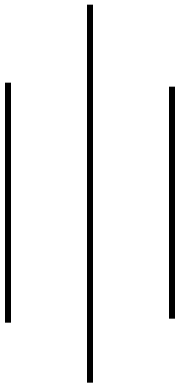
WATER SUPPLY ENGINEERING

(QUALITY OF WATER)



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4.1 Impurities in water, their classification and effects:

Pure water contains only two parts of Hydrogen and one part of oxygen by volume which is never found in nature. Water found in nature contains a number of impurities.

4.1.1 Classification of impurities according to its characteristics:

- Physical Impurities
- Chemical Impurities
- Bacteriological Impurities

Physical Impurities:

Physical impurities are those impurities that affect the physical properties of water. The physical properties include colour, odour, taste and turbidity.

Chemical Impurities:

Chemical impurities are those impurities that affect the chemical properties of water. The chemical properties of water include pH, solids, hardness, mineral content, chloride, nitrogen, etc.

Bacteriological Impurities:

Bacteriological impurities are those impurities that affect the bacteriological characteristics of water as pathogenic and non-pathogenic microorganisms present in the water.

4.1.2 Classification of impurities according to its state:

- Suspended impurities
- Colloidal impurities
- Dissolved impurities

Suspended impurities:

Suspended impurities are impurities with size more than one micron and can be visible by naked eyes. It includes:

- **Bacteria**: Pathogenic bacteria cause diseases.
- **Algae, Protozoa**: Affects taste, color and turbidity.
- **Clay, Silt**: Murkiness and turbidity.
- **Organic matters**: Vegetable – color, taste and acidity. Dead animals – Cause harmful diseases.

Colloidal impurities:

Colloidal impurities are impurities with size more than 10^{-3} micron and less than 1 micron. They are not visible to naked eyes. Acidic materials such as silica, glass, and most organic particles acquire negative charge whereas basic materials such as metallic oxides Al_2O_3 and Fe_2O_3 are positively charged.

Dissolved impurities:

Dissolved impurities are impurities with size greater than 10^{-5} micron and less than 10^{-3} micron.

1. **Salts of sodium:**

- **Bicarbonate**: Softening and alkalinity
- **Carbonate**: Softening and alkalinity
- **Fluoride**: Leads to mottled enamels
- **Chloride**: Affects taste

2. **Metal and Compounds:**

- **Iron oxide:** Gives red colour, affects taste and hardness and causes corrosiveness.
- **Manganese:** Gives black or brown colour.
- **Lead:** Causes cumulative poisoning.
- **Arsenic**: Causes toxicity.
- **Barium**: Toxic effect on heart and nerves.
- **Cadmium**: Toxic in nature.
- **Cyanide**: Fatal.
- **Boron**: Affects the central nervous system.
- **Selenium:** Highly toxic to animals.
- **Silver**: Discoloration of the skin.

3. **Gases:**

- **Oxygen:** Corrosiveness
- **Carbon dioxide:** Acidity, corrosiveness
- **Hydrogen sulphide:** Odor, acidity, corrosiveness

4. **Organic Matters:**

- **Vegetable**: Produce bacteria
- **Dead animals**: Causes pollution of water and causes diseases.

4.2 Hardness and Alkalinity

4.2.1 Hardness:

Hardness is the characteristics of water due to which sufficient lather is not formed with soap. It is due to the presence of bicarbonates, sulphates, chlorides and nitrates of calcium, magnesium, and strontium.

Effects of hardness:

- Consumption of more soap.
- Corrosion in pipes.
- Forms scale in boilers.
- Modification of color in dying industries.
- Choking or clogging of house plumbing.
- Bad taste of food.

Types of hardness:

Temporary hardness: Bicarbonates of calcium, magnesium and strontium causes temporary hardness. It is also known as carbonate hardness.

Permanent hardness: Sulphates, chlorides, and nitrates of calcium, magnesium and strontium causes permanent hardness. It is also known as non-carbonate hardness.

Total Hardness = Carbonate Hardness + Non-carbonate hardness = CH + NCH.

Determination of hardness:

Hardness in mg/l as $CaCO_3$ = ion concentration in mg/l * (Equivalent wt of $CaCO_3$/Eq wt of ion)

Equivalent wt of $CaCO_3$, Ca^{++}, Mg^{++} and Sr^{++} are 50, 20, 12.2 and 43.8 respectively.

Hardness

Grade	**Value**
Soft	0-75
Moderate	75-150
Hard	150-300
Very Hard	>300

Removal of hardness is discussed in Chapter 6.

4.2.2 Alkalinity:

The alkalinity of water is the capacity to neutralize a standard solution of acid. Waste water is normally alkaline in nature. Alkaline water is bitter in taste. The water with pH more than 7 is alkaline and less than 7 is acidic in nature. The presence of bicarbonate (HCO_3^-), carbonate (CO_3^-) and hydroxide (OH^-) causes alkalinity. The major form of alkalinity is the bicarbonate alkalinity. The carbonate alkalinity and bicarbonate alkalinity or carbonate alkalinity and hydroxide alkalinity can exist together. But bicarbonate alkalinity and hydroxide alkalinity do not exist together.

Total alkalinity = Carbonate alkalinity + Bicarbonate alkalinity

Or

Total alkalinity = Carbonate alkalinity + Hydroxide alkalinity

Determination of alkalinity:

Carbonate alkalinity in mg/l as $CaCO_3$ = CO_3^{--}concentration/0.6

Bicarbonate alkalinity in mg/l as $CaCO_3$ = HCO_3^- concentration/1.22

Hydroxide alkalinity in mg/l as $CaCO_3$ = OH^- concentration/0.34

4.2.3 Relation between Hardness and alkalinity:

Carbonate Hardness = Alkalinity

NCH = TH – CH when Alkalinity < TH

CH = TH

NCH = 0 when, Alkalinity >= TH

4.3 Living Organisms in Water

Living organisms either plant or animals exist in water. They may be microscopic as well as macroscopic. They may be unicellular or multi-cellular. They may be harmful or may not be harmful. Algae, Bacteria, Viruses, and Worms exist in the water as living organisms.

4.3.1 Algae:

Algae are unicellular photosynthetic plants which grow in water. They derive energy from inorganics substances as gases and salts dissolved in the presence of sunlight. They are self-

nourishing. Algae affect taste, odor, color and turbidity. Excessive growth of algae in water may be controlled by the application of copper sulphate or chlorine.

4.3.2 Bacteria:

Bacteria are unicellular prokaryotic organisms that reproduce by fission.

Classification

On the basis of shape:

- **Cocci**: Round, ovoid or spherical in shape.
- **Bacilla**: Straight or rod-shaped bacteria with square or rounded ends.
- **Spirilla**: Helical or spiral in shape.
- **Filamentous**: Length of 100 microns or larger.

On the basis of oxygen demand:

- **Aerobic:** Bacteria that survives in the presence of oxygen.
- **Anaerobic**: Bacteria that survives in the absence of oxygen.
- **Facultative**: Bacteria that lives and multiplies with or without oxygen.

On the basis of disease-causing characteristics:

- **Pathogenic:** Bacteria that causes disease.
- **Non-pathogenic:** Bacteria that does not cause disease.

On the basis of life process:

- **Saprophytic:** Bacteria that depends upon dead or decaying organic matter.
- **Parasitic**: Bacteria that lives and multiplies within the body of living organism.

On the basis of use of source:

- Heterotrophic
- Autotrophic

On the basis of temperature survival:

- **Psychrophilic bacteria**: 10-30^{o}C
- **Mesophilic bacteria**: 20-50^{o}C
- **Thermophilic bacteria**: 35-75^{o}C

Indicator organisms:

Pathogenic bacteria are present in small numbers in water supply and are difficult to detect. The presence of pathogenic bacteria can be indirectly checked by testing the water for coliforms or E-coli. The presence of E-coli in water indicates the pollution of water. So, coliforms are known as indicator organisms as their presence indicate probable pollution from excreta. They are also identified by a simple procedure which is quick and economical.

4.3.3 Viruses:

Viruses are known as obligatory parasites. They require the host for survival or multiplication. They consist of an outer protein coat enclosing a core of nucleic acid. Viruses cause hepatitis, jaundice, etc. They can be inactivated by disinfection.

4.3.4 Worms:

Worms are also known as helminths. Worms are classified into roundworms and flatworms. They can be removed by controlling turbidity through effective coagulation and filtration.

4.4 Water-Related Diseases

The water acts as a prime cause for various diseases. Such diseases are said to be water related diseases. It is classified as:

- Water borne diseases
- Water-washed diseases
- Water-based diseases
- Water vector diseases

4.4.1 Water borne diseases

The transmission of such disease occurs when the pathogen is in water. Such water when drunk, the consumer is infected.

1. **Diarrhoea:**

Symptoms:

- Watery stool
- Abdominal Discomfort
- Swollen intestine

2. **Dysentery:**

Caused by: Bacillary dysentery – Bacillus Sighella; Amebic dysentery – Entamoeba Hystolytica.

Symptoms:

- Intestinal Inflammation
- Abdominal Pain
- Intense diarrhoea

3. **Typhoid:**

Caused by: Salmonella Typhi.

Symptoms:

- Headache
- Fever
- Slow heart beat
- Swollen intestine
- Indigestion
- Constipation

Preventive Strategies:

- The quality of water needs to be improved.
- The source of water needs to be made clean.

4.4.2 Water Washed Diseases

The transmission of such disease depends on the quantity of water used, rather than the quality of water. Affects mainly the intestinal tract and the skin.

1. **Ascariasis**

Symptoms:

- Nausea and vomiting
- Diarrhoea
- Loss of appetite
- Abdominal discomfort

2. **Conjunctivitis**

Symptoms:

- Redness of eyes
- Pus in eyes
- Burning in eyes
- Blindness if not treated

3. **Bacillary Dysentery**

Symptoms:

- Diarrhoea
- Vomiting
- Fever
- Constipation

Preventive Strategies:

- Increase the water quantity.

4.4.3 Water Based Diseases

All these diseases are due to infections by parasitic worms.

1. **Schistosomiasis (Bilharziasis)**

Symptoms:

. Itchy skin

. Skin rash

. Fever

. Cough

. Damage to the abdomen, liver or spleen after five years.

. Damage to brain, lungs.

. Paralysis of the lower body.

Preventive Strategies:

- Reduce contact with infected water.

4.4.4 Water Vector Diseases:

These diseases are caused by insects that either breed in water or bite near water.

1. **Malaria**

Symptoms:

- Chills
- Fever
- Headache
- Nausea
- Heavy sweating

2. **Yellow Fever and Dengue (Arboviruses)**

Symptoms:

- Fever
- Headache
- Body ache
- Vomiting

3. **Filariasis**

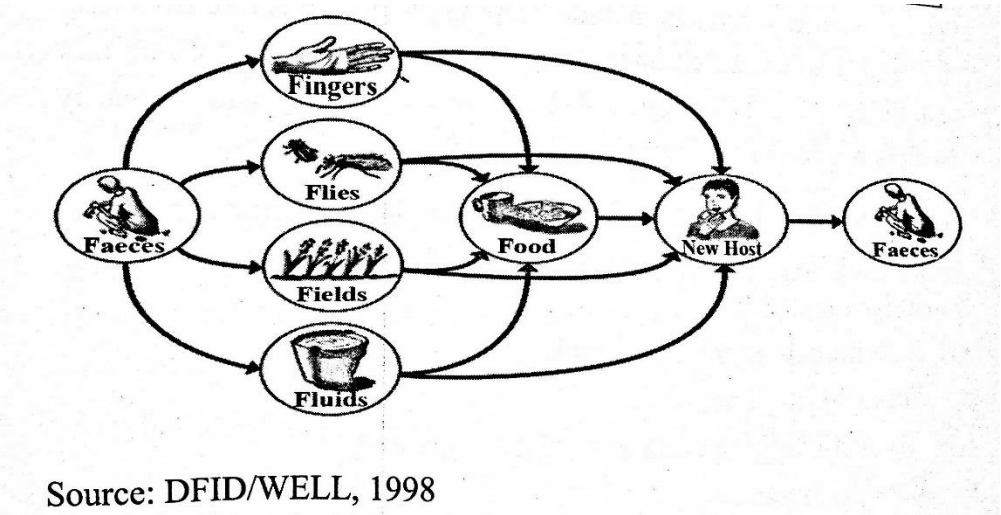
Symptoms:

- Fever
- Inflammation of lymph nodes

Preventive Strategies:

- Step to improve the surface water must be taken.
- Make an unfavorable environment for insects to breed on water. Kerosene may stop the breeding of mosquitoes in water.

4.4.5 Transmission Routes:



F-diagram

4.4.6 Preventive measures:

- Care on personal and food hygiene need to be given.
- Consumption of safe water needs to be practiced.
- Domestic hygiene and animal management,
- Human excreta needs to be disposed safely.

4.5 Examination of water/analysis of water:

The following types of examination are carried out for water:

- Physical examination
- Chemical examination
- Bacteriological examination

4.5.1 Physical examination:

This examination is done to determine the physical characteristics of water.

- **Temperature:**

Temperature affects several parameters as surface tension, viscosity, density, etc. The desirable temperature is 10 to 15.6^{0}C. The temperature above 25^{0}C is considered objectionable and the temperature above 35^{0}C is considered to be unsuitable for water supply. The temperature of the water is measured by the thermometer.

Determination of temperature:

- 200ml water is taken in a beaker.
- The thermometer is dipped in a beaker with water.
- Reading is taken after two minutes.

- **Color:**

The color is measured by the ability of the solution to absorb light. Dissolved organic material imparts color in the water. The color is expressed in units of platinum cobalt scale. The permissible color unit is 5 for drinking water but up to 15 units is considered. The color is measured by means of tintometer or colour meter.

Determination of color:

- The instrument is kept with the red switch towards us.
- The lid of the instrument is opened.
- Colour measurement disc with colour units either in ^{o}Hazen or platinum-cobalt scale is inserted.
- The empty glass tube is inserted into the left-hand slot and the tube with the water sample is inserted in the right-hand slot.
- The lid of the instrument is closed.
- The instrument is then switched on.
- Looking through the eye piece the standard color disc is rotated until the color on the disc matches with the color or water.
- The reading is then taken carefully.

- **Turbidity:**

Turbidity is defined as the measure of the resistance of the passage of light through it. The units of turbidity are Nephelometric Turbidity Unit (NTU), Jackson Turbidity Unit (JTU), Formazyn Turbidity Unit (FTU). The standard unit of turbidity is obtained by one mg of Fuller's Earth in the form of finely divided silica in one liter of distilled water. Permissible turbidity is 5NTU but turbidity up to 10 NTU is tolerated.

Determination of Turbidity:

- The instrument is turned on.
- The instrument is left for 10 minutes for stabilization.
- 25ml of the sample is poured into the sample cell.
- 10 NTU standard cell is selected and is put into the sample holder.
- Scale reading is then adjusted to 100.
- The standard cell is removed and the sample cell is introduced.
- The reading is then taken.

4.5.2 Chemical Examination:

The chemical examination is done to determine the chemical characteristics of the water sample.

- **pH:**

pH is defined as the negative logarithm of H^+ concentration. The pH of drinking water should be between 6.5 and 8.5.

Determination of pH:

- Function control to 'Batt Test' is turned on and the voltage is maintained.
- The electrode is connected to the meter and is immersed in the buffer solution of known pH.
- The function 'pH' is switched on.
- The function 'pH' is turned off and the electrode is removed from the buffer solution.
- The electrode is well rinsed and is immersed in the water sample and the 'pH' function is switched on.
- The reading is recorded.
- Solids:

Solids are classified as total solids, dissolved solids and suspended solids. 1000mg/l total dissolved solids is acceptable in water supply scheme.

Determination of total solids:

- The weight of the clean and dry crucible is measured. Let it be A mg.
- A known volume of water, let it be W ml is taken in the crucible.
- The water is evaporated to dryness.
- The crucible is then kept in the oven at 103^{o}C for half an hour and cooled in the dessicator with Calcium Carbonate for 10 minutes.
- The weight of the crucible is then measured again. Let it be B mg.
- The total solid is calculated in mg/l as Total solids (mg/l) = (B-A)*1000/W.

Determination of suspended solids:

- Whatman filter No. 44 is kept in a funnel and a known volume of the water sample is filtered through the filter paper.
- The weight of the clean and dry crucible is measured. Let it be A mg.
- A known volume of filtered water, let it be W ml is taken in the crucible.
- The crucible is then kept in the oven at 103^{o}C for half an hour and cooled in the dessicator with Calcium Carbonate for 10 minutes.
- The weight of the crucible is then measured again. Let it be B mg.
- The suspended solid is calculated in mg/l as suspended solids (mg/l) = (B-A)*1000/W.

4.5.3 Bacteriological Examination:

The bacteriological examination is carried out to determine the presence of microorganisms in the water sample. The concentration of indicator organisms E-coli are tested to determine the presence of pathogens. The two methods are:

- Multiple tube fermentation technique.
- Membrane filter fermentation technique.

Multiple tube fermentation technique:

Durham tubes are used for the determination of the coliform group of bacteria. The method is performed in three tests as:

- Presumptive test
- Confirmed test
- Completed test

Presumptive test:

The sample is take in Durham tubes containing lactose broth in multiples of ten as 0.1 ml, 1 ml,10 ml and so on. The tubes are then incubated at a temperature of 37^{o}C for 24 hours. After that, the presence of gas is checked in the tube. The presence of gases indicates the presence of coliform group and the test is said to be positive. The absence of gas means the test is negative. If all the tube contains gas i.e. result is positive from all the tubes confirmed test is carried out else the incubation at 37^{o}C is carried out for other 24 hours. The observation of gas is done again and the sample showing positive tests are taken for confirmed test and the sample showing negative tests are discarded.

Confirmed test:

A small portion of the incubated material from the tubes showing positive test in the presumptive test is transferred to the other fermentation tube containing brilliant lactose broth. The tubes are then incubated at a temperature of 37^{o}C for 24 hours. After that, the presence of gas is checked in the tube. The presence of gases indicates the presence of coliform group and the test is said to be positive. The absence of gas means the test is negative. If all the tube contains gas i.e. result is positive from all the tubes completed test is carried out else the incubation at 37^{o}C is carried out for other 24 hours. The observation of gas is done again and the sample showing positive tests are taken for completed test and the sample showing negative tests are discarded.

Completed test:

A small portion of the incubated material from the tubes showing positive test in the confirmed test is marked as streaks in the plates containing Endo or Eosin methylene blue agar. The plates are then incubated at the temperature of 37^{o}C for 24 hours. Colonies of the coliform group will be formed after the incubation period. The discrete isolated colonies of the coliform group are

transferred to the fermentation tube containing lactose broth. The tubes are then incubated at a temperature of 37^{o}C for 24 hours. After that, the presence of gas is checked in the tube. The presence of gases indicates the presence of coliform group and the test is said to be positive. The absence of gas means the test is negative.

Most Probable Number (MPN)

Most Probable Number (MPN) is defined as that bacterial density which is most likely to be present in the water.

MPN/100ml = Number of positive tubes * 100 / (ml in negative tubes * ml in all tubes)$^{1/2}$

Membrane filter fermentation technique:

Membrane filter fermentation technique is the most recent method for detecting coliform group. Sterile membrane filter having porosity 80% with microscopic pores of 5-10 micron capable of retaining bacteria is taken and is fitted with a funnel. About 20 ml of the water sample is filtered through the funnel with the vacuum pump. The membrane filter is taken out from the funnel and is put in the plate containing M-Endo medium as a nutrient which inhabits the growth of bacteria other than the coliform group. The plate is then incubated at a temperature of 37^{o}C for 20 hours. If the bacteria of the coliform group were present, they become visible colonies at this period of time. The number of visible colonies was counted with the help of the microscope. Coliform colonies / 100 ml is then calculated as:

Coliform colonies / 100 ml = (Number of coliform colonies counted*100)/(ml of water sample taken).

4.6 Water quality standard for drinking purposes:

Water quality guideline for domestic consumption

S.No.	Characteristics	Highest Desirable level	Maximum Permissible level
1	Total solids (mg/l)	500	1500
2	Total dissolved solid	500	1000
3	Color (°H)	5	50
4	pH	7-8.5	6.5-9.2
5	Temperature (°C)	4.4-10	<26, (>35 unfit)
6	Taste and odor	Unobjectionable	-
7	Turbidity (NTU)	5	10
8	Chloride (mg/l)	-	250
9	Residual free chlorine (mg/l)	-	0.2
10	Iron (mg/l)	0.3	1.0
11	Manganese (mg/l)	0.05	0.1
12	Copper (mg/l)	0.05	1.0
13	Zinc (mg/l)	3.0	15
14	Calcium (mg/l)	75	200
15	Magnesium (mg/l)	30	150
16	Sulphate (mg/l)	200	400
17	Total hardness (as $CaCO_3$) (mg/l)	100	500
18	Phenol (mg/l)	0.001	0.002
19	Nitrite (as NO_2) (mg/l)	-	<10
20	Nitrate (as NO_3) (mg/l)	10	45
21	Fluoride (mg/l)	0.5	1-1.5
22	Arsenic (mg/l)	-	0.01
23	Aluminum(mg/l)	-	0.2
24	Cadmium (mg/l)	-	0.003
25	Chromium (mg/l)	-	0.05
26	Cyanide (mg/l)	-	0.01
27	Lead (mg/l)	-	0.1
28	Mercury (mg/l)	-	0.001
29	Selenium (mg/l)	-	0.01
30	Bacteria in 100ml	-	-
31	DDT,(ppb)	-	2
32	Ammonia(mg/l)	-	1.5
33	Sodium (mg/l)	-	200
34	H_2S(mg/l)	-	0.05
35	E. coli in 100ml	-	-
36	Coliform in 100ml	-	10

Water quality standard for drinking purposes

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