Overview for Safe Drinking Water

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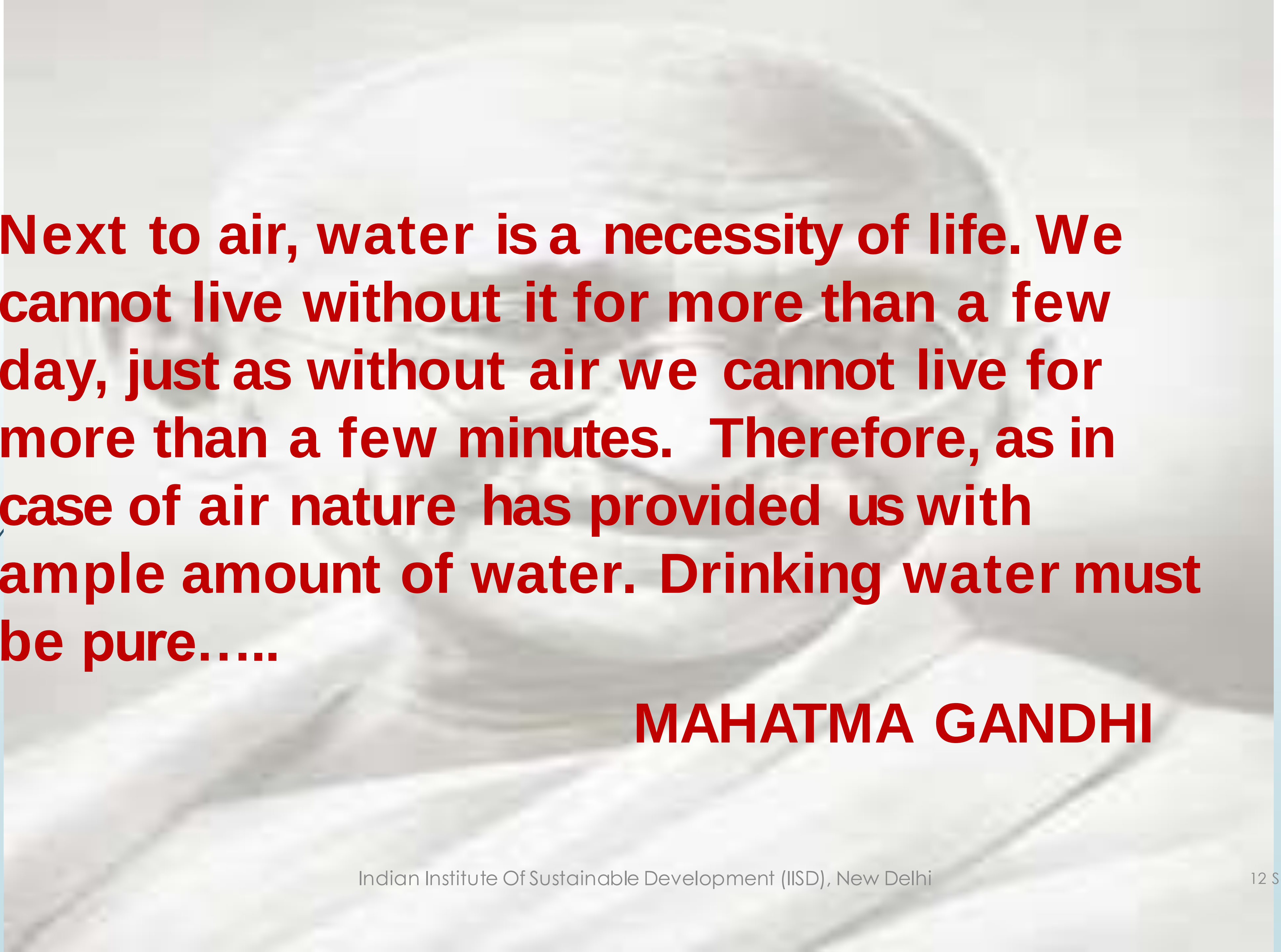


Next to air, water is a necessity of life. We cannot live without it for more than a few day, just as without air we cannot live for more than a few minutes. Therefore, as in case of air nature has provided us with ample amount of water. Drinking water must be pure…..

MAHATMA GANDHI

Having safe drinking water is a human need and right for every man, woman and child

People need clean water to maintain their health and dignity

INTRODUCTION

1981: 34th WHA, Geneva

emphasis that safe drinking water is a basic element of "primary health" care which is a key to the attainment of "**health for all**".

1975: report by WHO in cooperation with World Bank
1230 million people were without safe water supplies.

1981:
United Nations declared
International Drinking Water Supply and Sanitation decade

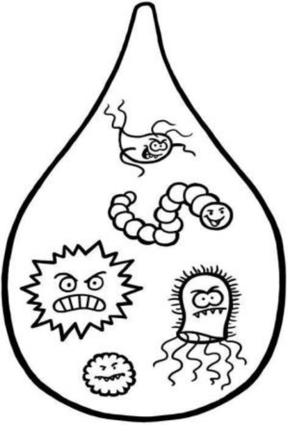
INTRODUCTION

VI Five-Year Plan of India(1980-85) had made a special provision for availability of safe Drinking water for the masses.

Therefore, the standard was prepared with the objective of assessing the quality of water resources, and to check the effectiveness of water treatment and supply by the concerned authorities.

- Routine surveillance of drinking water supplies must be carried out by the relevant authorities to understand the risk of specific pathogens and to define proper control procedures.
- Precautions/care should be taken to prevent contamination of drinking water from chlorine resistant parasites such as *Cryptosporidium species* and *giardia*.

SAFE WATER



- **Safe drinking water** does not have any significant risk to a person's health over their lifetime. Safe drinking water has microbiological, chemical and physical characteristics that meet World Health Organization (WHO) guidelines or national standards for drinking water quality.
- Free from pathogenic agents and harmful chemical substances and excessive amount of minerals which could produce undesirable physiological effects
- Safe water pleasant to taste, odour, colourless, and does not stain clothes and utensils, usable for domestic purposes.

WATER REQUIREMENT

(a) physiological

(b) domestic

3L	Drinking
5L	Cooking
7L	Washing utensils/ house
15L	Bathing
10L	Ablution/ toilets

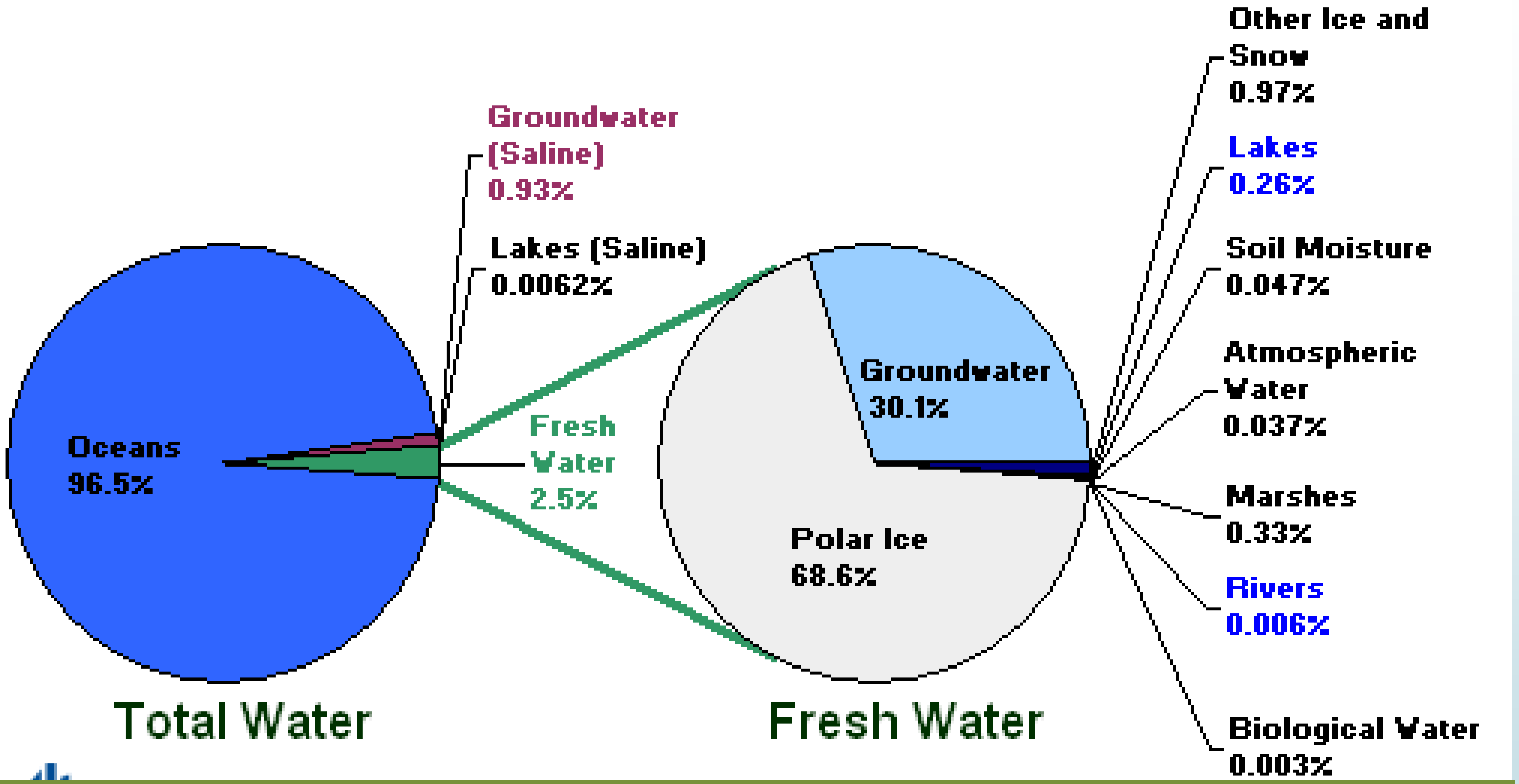
Rural

- ≥40Lpcd, source should be - 1.6 Km and <100 m elevation difference in hilly area
- 1 hand pump/250 persons+ 30L additional water in DDP(desert developmant programme) for cattle

Urban

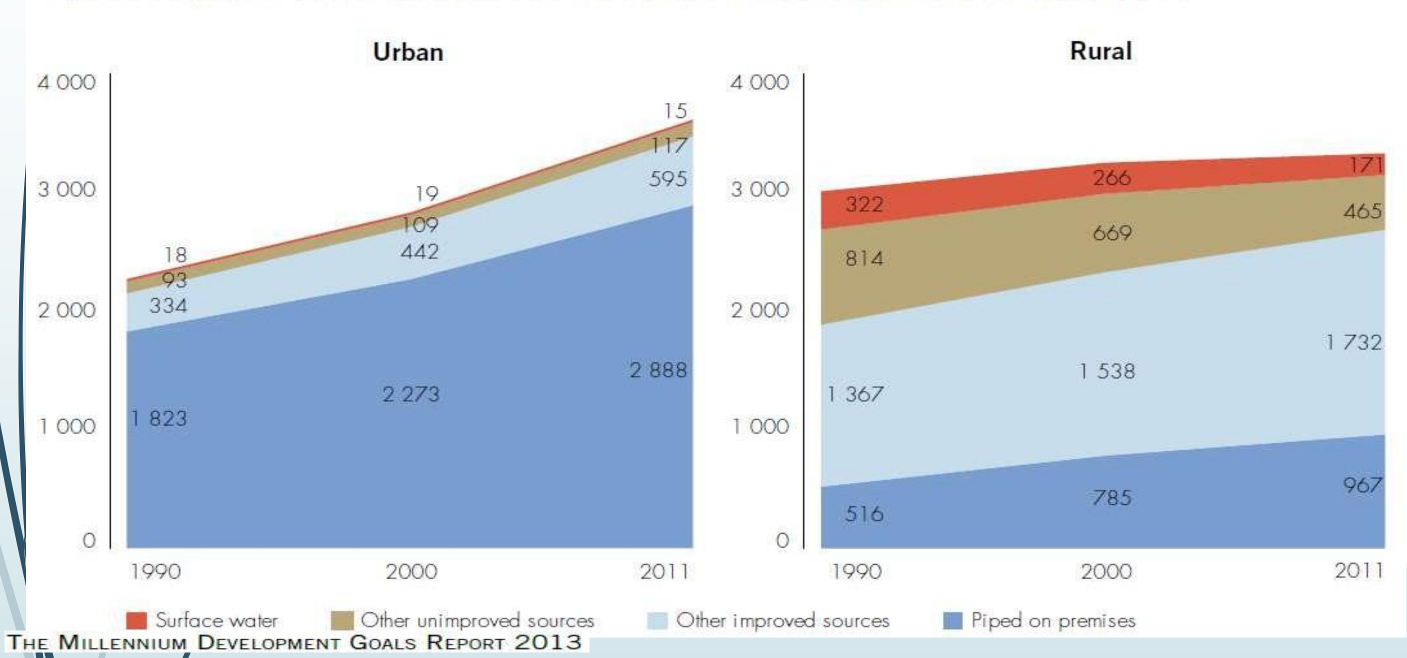
- piped supply without sewerage – 70 Lpcd
- piped supply with sewerage – 135Lpcd
- metropolitan – 150 Lpcd
- public stand post- 40Lpcd

Distribution of Global Water



India with 16% of the world's population has only 4% of the fresh water resources

Current water situation in India


Population with access to drinking water, urban and rural areas, 1990, 2000 and 2011 (Millions)

The Millennium Development Goals Report 2013

Source	Percentage of population
Piped drinking water	39-42% Rural 28% Urban 71%
Handpumps	39-42% Rural 47.3% Urban 20.8%
Wells	19%
Surface water	3%

Water-stressed condition: per capita availability of less than 1700 (m3) per year

Water scarcity condition: per capita availability below 1000 (m3) per year

Per capita availability of fresh water in India

1816 m3 2001 census

1545 m3 2011 census

833 m3 in 2025

899 m3 in 2050

12 Sep' 2020

Current water situation in India

In many rural areas, women still have to walk a distance of about 2.5 kms to reach the source of water.

On an average, a rural woman walks more than 14000 km a year just to fetch water. Water source being open dug well, the quality of water is poor; dirty, saline and has turbidity.

History of Water Treatment

From the earliest recorded history, since people have been gathering together into civilizations, the need for safe public water supplies has been paramount to survival. Ancient civilizations gathere around “clean” sources of water. Water treatment originally focused on aesthetic properties of drinking water.

- As early as 4000 B.C., ancient Sanskrit and Greek writings documented ways to improve the taste and odor of drinking water. Methods like **filtering through charcoal and exposure to sunlight, boiling and straining** in order to eliminate cloudiness were suggested.
- As early as 1500 B.C., Egyptians used the **chemical alum to remove suspended particles by coagulation**. Early Egyptian paintings that date from the 13th and 15th centuries B.C. depict devices that clarify water.
- In the fifth century B.C. Hippocrates, the Father of Medicine, invented the **Hippocrates Sleeve, a cloth bag to filter rainwater**.
- Between 343 B.C. and 225 A.D., Roman engineers created **aqueducts** that delivered 130 million gal daily. The first public water supply systems were born in Rome, Greece, Carthage and Egypt at the end of the 3rd century B.C.
- Several sources indicate that little progress in public water or water treatment took place between 500 and 1600 A.D.

In 1804, John Gibb built the **first public water facility in Paisley**, Scotland that supplied the entire town. Within three years, filtered water was piped directly to customers in Glasgow, Scotland.

- **Sand filtration** was being used regularly in Europe. Along with the proliferation of public water came the realization that diseases like typhoid, dysentery and cholera could be spread by pathogens in the public water supply.
- Antonie van Leeuwenhoek is credited with **the first observations of microorganisms** in water in 1676. Unfortunately, the connection between these microorganisms and waterborne diseases was not made until 1855. In that year, epidemiologist Dr. John Snow found that cholera was a waterborne disease after he linked an outbreak to a sewage-contaminated public well.
- In the late 1800s, scientists like Louis Pasteur, Robert Koch and Joseph Lister were demonstrating the manner by which microscopic organisms could transmit disease through media like water.
- By the early 1900s, water treatment focused mainly on disease-causing microbes. **Turbidity** was linked not only to aesthetic problems, but also to pathogens.
- Most water systems used filtration, but **chlorine disinfection** soon became the primary weapon in the war against waterborne disease. Jersey City, N.J. is credited with the first use of chlorine as a primary disinfectant in 1908.5 **Ozone** was also being used in Europe at the time.

Traditional household water purification methods practised by rural communities in developing countries

These techniques are simple and can treat water to a minimum extent wherein visible impurities can be removed.

- Winnowing
- Through cloth
- Clay vessels
- Clarification and filtration through plant material
- Jempeng stone filter method
- Horizontal flow coarse media filter
- Upflow gravel filter
- Two-stage filter
- Upflow/downflow filter

Traditional water purification methods include boiling, filtration, sedimentation and solar radiation.

The main difference between conventional and household systems is the scale of the technologies used:

- **Centralized or community water treatment:** Water can be treated at a central location, in large volumes, and then supplied to households through a network of pipes.
- **Household water treatment and safe storage (HWTS)** Smaller volumes of water can also be treated at the point of use (POU), such as in institutions (e.g., schools, clinics, religious institutions), and in the home (the family members gather the water, and then treat and store it in their home).

World Health Organization (WHO)

WHO has been active in the development of international standards. The Regional Office for Europe of the WHO released a study on water distribution for drinking purposes in 1956.

"Standards of Drinking-Water Quality and Methods of Examination Applicable to European Countries."

- WHO published International Standards for Drinking-Water, 1st ed., in 1958 and European Standards for Drinking-Water in 1961.
- WHO published both a European standard and an international standard ??

"International *Standards for Drinking-Water proposed minimal standards, which are considered to be within reach of all countries throughout the world at the present time. In view of the different economic and technological capabilities of various countries there will be some areas in which higher standards than those proposed for the world as a whole will be attainable—and these areas should be encouraged to attain such higher standards. It is believed that Europe is such an area and that there is, therefore nothing illogical in setting higher standards in Europe than internationally."*

Drinking Water Quality Testing

- As water moves through the water cycle, it naturally picks up many things along its path. Water quality will naturally change from place to place, with the seasons, and with the kinds of rocks and soil which it moves through.

- Water can also be polluted by human activities, such as open defecation, inadequate wastewater management, dumping of garbage, poor agricultural practices (e.g., use of fertilizers or pesticides near water sources), and chemical spills at industrial sites.

- In developing countries, 75% of all industrial waste and up to 95% of sewage is discharged into surface waters without any treatment.

Water quality testing is a tool that can be used to help identify safe drinking water – whether at the source, within a piped distribution system, or within the home.

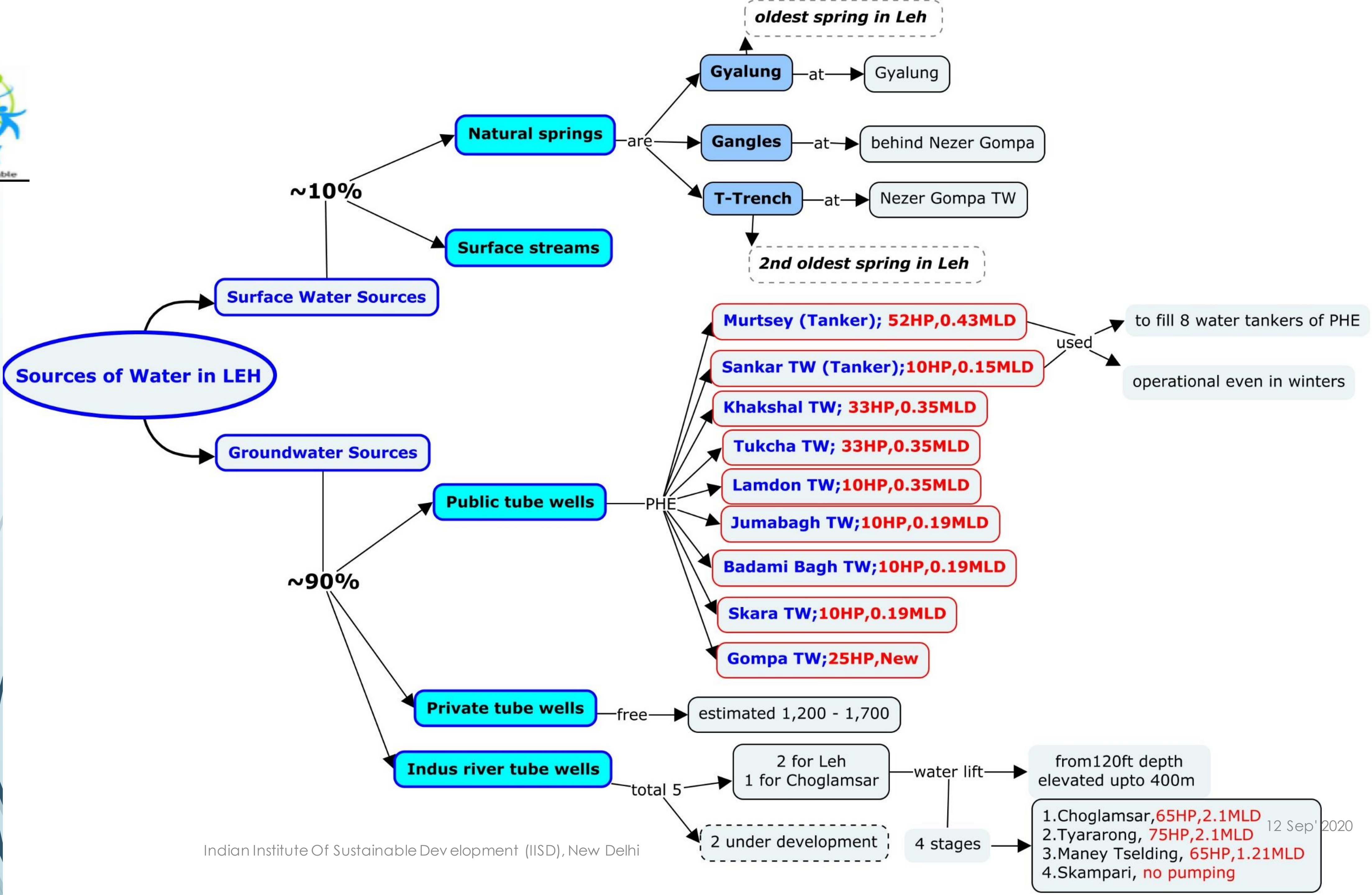
Water testing plays an important role in monitoring the correct operation of water supplies, verifying the safety of drinking water, investigating disease outbreaks, and validating processes and preventative measures.

Three sources that are used to collect drinking water are:

- **Groundwater –** Water that fills the spaces between rocks and soil making an aquifer. Groundwater depth and quality varies from place to place.
  - About half of the world's drinking water comes from the ground.

- **Surface water –** Water that is taken directly from a stream, river, lake, pond, spring or similar source.
  - Surface water quality is generally unsafe to drink without treatment.

- **Rainwater –** Water that is collected and stored using a roof top, ground surface or rock catchment.
  - The quality of rainwater collected from a roof surface is usually better than a ground surface or rock catchment.



Sources of Water in LEH

- **Surface Water Sources** ~10%
  - **Natural springs** are
    - **Gyalung** at Gyalung — *oldest spring in Leh*
    - **Gangles** at behind Nezer Gompa
    - **T-Trench** at Nezer Gompa TW — *2nd oldest spring in Leh*
  - **Surface streams**
- **Groundwater Sources** ~90%
  - **Public tube wells** PHE
    - **Murtsey (Tanker); 52HP,0.43MLD**
    - **Sankar TW (Tanker);10HP,0.15MLD**
      - used to fill 8 water tankers of PHE
      - used operational even in winters
    - **Khakshal TW; 33HP,0.35MLD**
    - **Tukcha TW; 33HP,0.35MLD**
    - **Lamdon TW;10HP,0.35MLD**
    - **Jumabagh TW;10HP,0.19MLD**
    - **Badami Bagh TW;10HP,0.19MLD**
    - **Skara TW;10HP,0.19MLD**
    - **Gompa TW;25HP,New**
  - **Private tube wells** free estimated 1,200 - 1,700
  - **Indus river tube wells** total 5
    - 2 for Leh
1 for Choglamsar — water lift from120ft depth elevated upto 400m
      - 4 stages
        1. Choglamsar, 65HP,2.1MLD
        2. Tyararong, 75HP,2.1MLD
        3. Maney Tselding, 65HP,1.21MLD
        4. Skampari, no pumping
    - 2 under development

Multi-barrier Approach to Safe Drinking Water

The best way to reduce the risk of drinking unsafe water is to use the multi-barrier approach

1. **Protect your source water**

2. **Sediment your water:** water removes larger particles and often more than 50% of pathogens

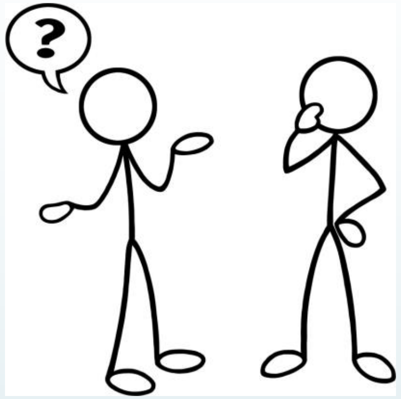
3. **Filter your water:** water removes smaller particles and often more than 90% of pathogens

4. **Disinfect your water:** deactivates or kills any remaining pathogens

5. **Store your water safely**

What is Drinking or Portable Water Quality Analysis ? How it is Done ?

- - How to identify Sampling Stations / Locations
- - How to Collect Drinking Water Samples ?
- - Explain the Sampling Procedure
- - How to store these Samples ?
- - How to analyze these Samples ?
- - Explain the Analysis Procedures ?



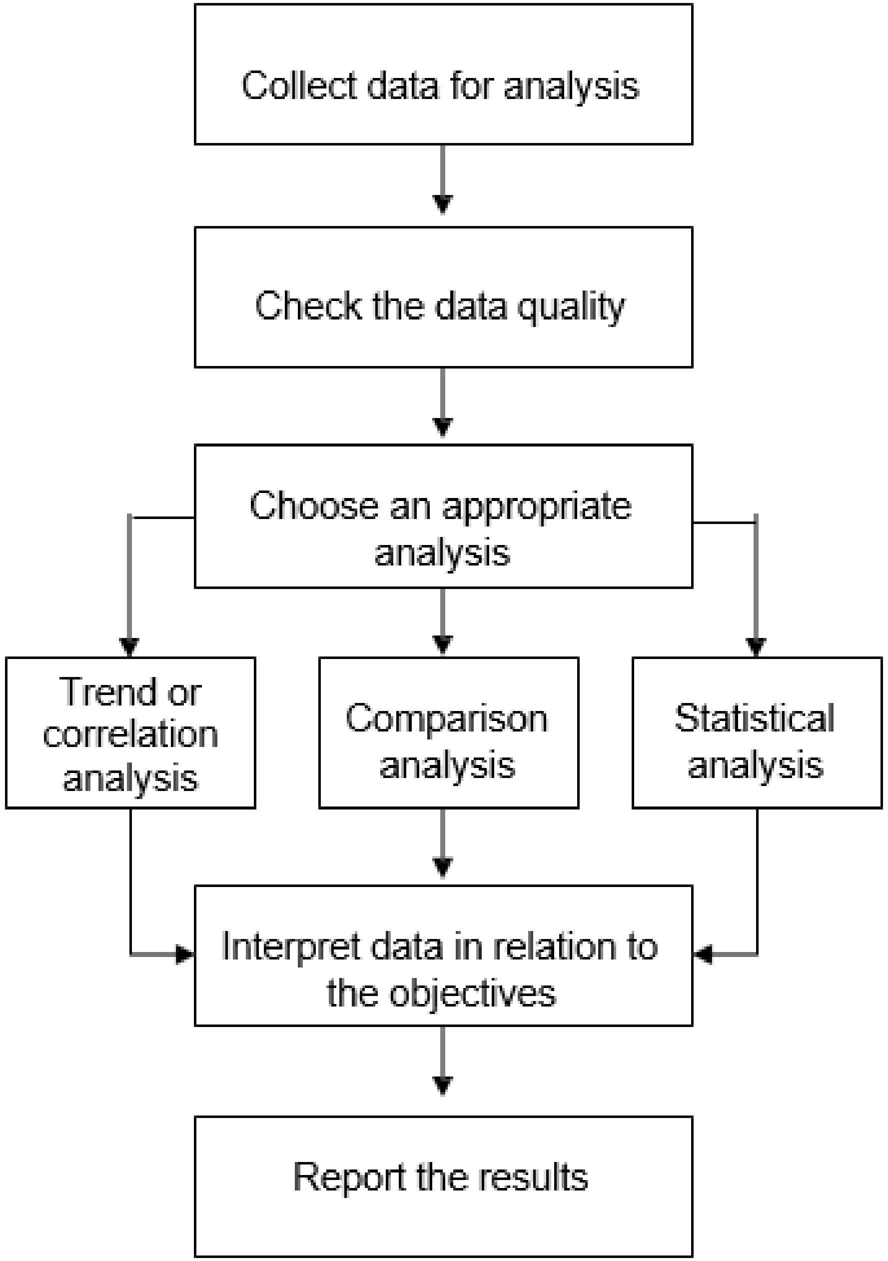
Types Of Parameters Of Drinking Water Quality Analysis

- What are the Physical Parameters ?
- What are the Chemical Parameters ?
- What are the Biological Parameters ?

Essential Drinking Water Quality Parameters in a City Water Supply System and their implications on basic Health of Citizens ?

Plan before you start doing water quality testing

1. Review the need – Why do you need to do water quality testing?
2. Develop your objectives – What are your objectives for testing the water quality?
3. Identify the test parameters – What water quality parameters are you going to test for?
4. Identify the test methods – How are you going to do the testing?
5. Design your sampling plan – How many water samples do you need? Where do you take them from?
6. Determine your key milestones – What achievements need to be reached in order to meet the final goal?
7. Identify your activities – What specific tasks need to be done?
8. Set out responsibilities – Who is going to do what?
9. Develop time and cost estimates – What are the time and costs to complete each activity?



Collect data for analysis

Check the data quality

Choose an appropriate analysis

Trend or correlation analysis

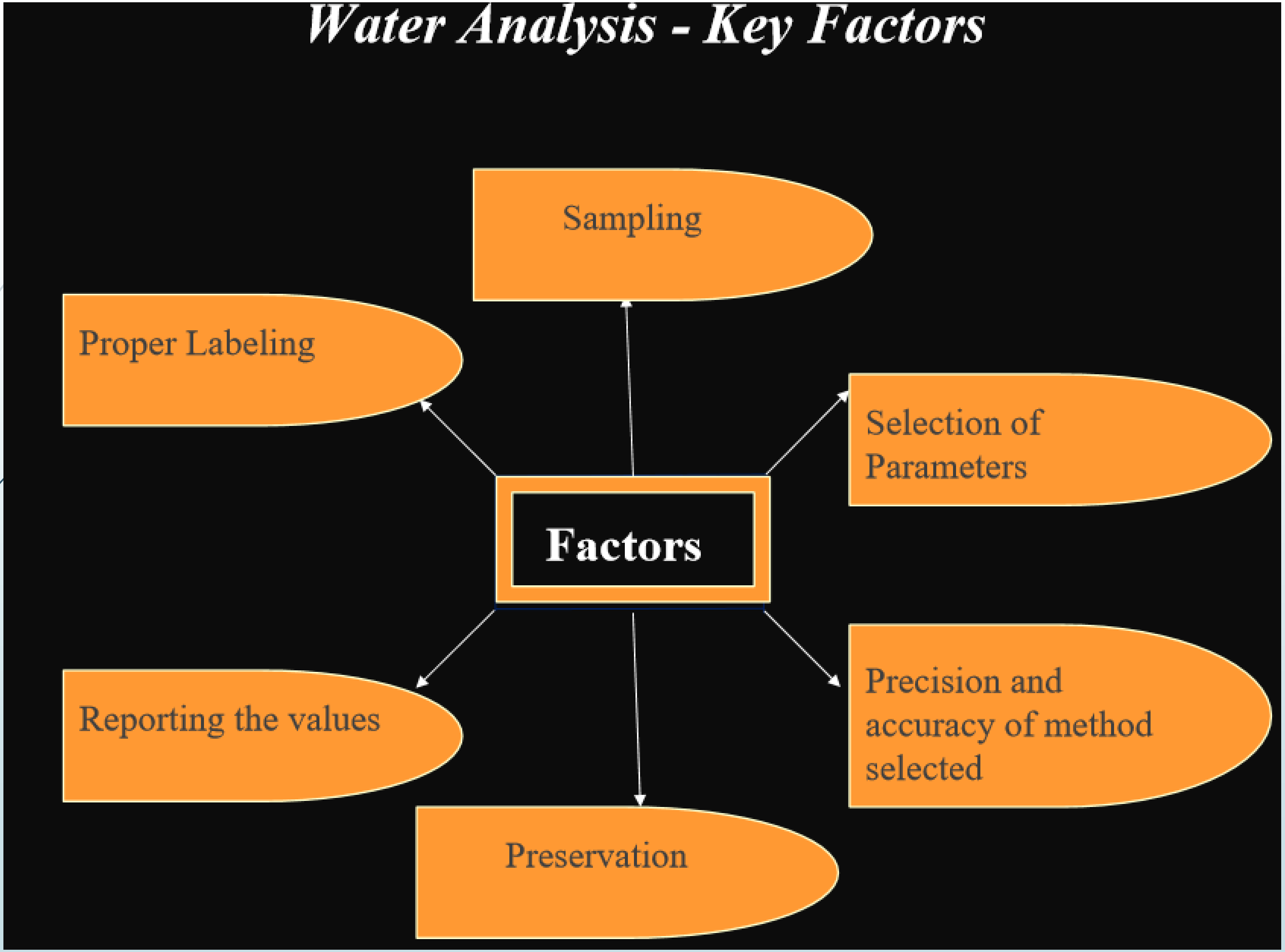
Comparison analysis

Statistical analysis

Interpret data in relation to the objectives

Report the results

- Enter the data in an appropriate table, spreadsheet or database.
- Address any unusual results. For example, if the number of *E. coli* is higher in the treated water compared to source water, it would be good to retake samples on different days and times.
- Data analysis methods should be selected in advance, and there should be enough data to analyze (see selecting sample size in Section 2: Planning).
- Results should be recorded in a simple format and easy for the audience to understand.
- Interpret the results so they are meaningful to the project objectives and situation in the local context. When generating results, keep in mind the quality control and reliability of the testing process.
- Develop conclusions and recommendations. Report the results.



Water Analysis - Key Factors

Factors

- Sampling
- Selection of Parameters
- Precision and accuracy of method selected
- Preservation
- Reporting the values
- Proper Labeling

Deciding What Locations to Sample

- ***Simple Random Sampling***

- ***Systematic Random Sampling***

households are selected at particular intervals. The interval can be calculated by dividing the total number of households who took part in the project by the number of households to be selected (sample size).

Eg. Your sample size is 100 households from a total population of 1,000 households

1,000/100 = 10 households

From a list of the 1,000 households, begin at a random household on the list, and select every 10th household to be sampled

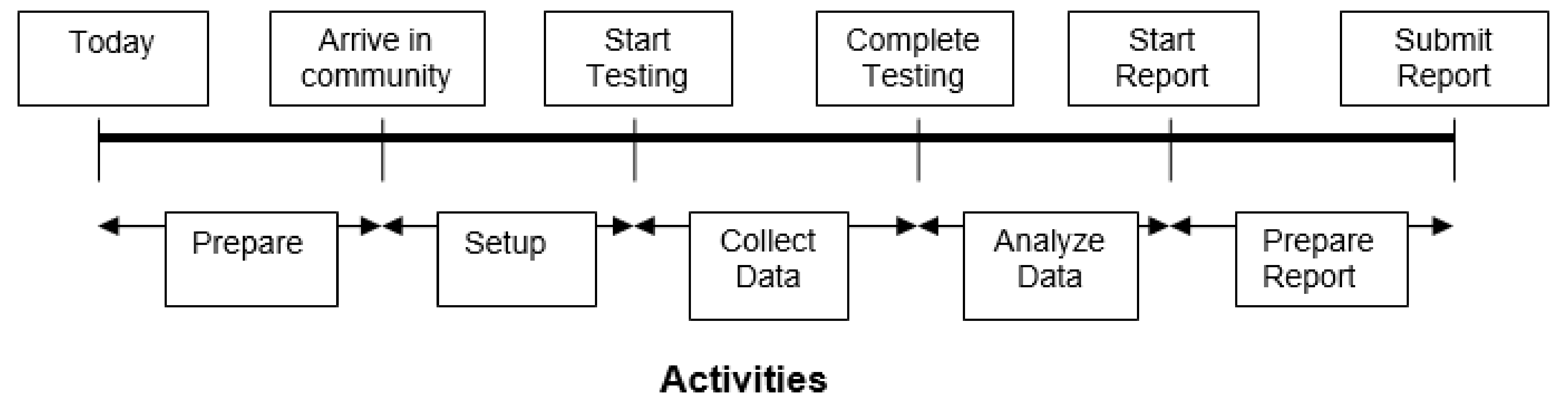
- ***Cluster Random Sampling***

good method to use for large projects. Samples taken from households of the same street or households within the same tribe are an example of cluster sampling.

- ***Convenience Sampling***

Many projects use convenience sampling instead of random sampling due to limited time and resources.

Determine Key Milestones



- ❖ Useful tool to help visualize the entire plan
- ❖ understand the steps necessary to complete the work
- ❖ focus on the specific activities required to complete each portion of the program.
- ❖ Generating the specific list of activities to achieve each milestone is the next step of the planning process.

Identify Activities

are specific tasks that need to be done to achieve a milestone.
Many activities will occur at the same time.
It is not always necessary to finish one activity before starting the next one.

Examples of some of these activities:

- **Acquire water testing equipment and supplies**
  - Identify local or international manufacturers of equipment and consumable items
  - Purchase all equipment and consumables
  - Develop an inventory checklist
  - Find a space where water quality testing will be conducted
  - Prepare testing procedures
  - Provide training to staff on how to use the equipment
  - Practice using the equipment to conduct water quality tests
- **Develop survey tools**
  - Determine sample sizes
  - Identify households or locations where water samples will be collected
  - Develop a household visit checklist and train staff on how to conduct themselves in households
  - Develop sanitary inspection forms and train staff on how to use them
- **Data management plan**
  - Determine what data will be recorded
  - Determine how data will be recorded
  - Create data collection forms
  - Determine process for compiling the data collected from different sources
  - Determine who will analyze the data and how the results will be reported

How to Collect Water Samples

- Collect water samples under normal, everyday conditions, in order to gain a representative sample. Proper procedures for collecting samples must also be observed.
- Technicians should be trained since the way samples are collected can influence the test results.
- Samples should be collected in a glass or plastic container with a screw cap that will maintain a tight seal, even after they have been sterilized many times. A reusable sample container is usually provided as part of portable field kits
- More water should be collected than needed (min. 250 mL), in case you make a mistake or if multiple tests are required.
- Label every sample container before filling the container. The sample label should have information about:
  - Sample location (e.g., household, source)
  - Sample description (e.g., inlet water, storage bucket water)
  - ID number
  - Date and time
  - Initials of the person collecting the sample
  - Other relevant information (e.g., project name, test to be performed)

Avoid contaminating the container and the water sample

The basic procedure for collecting a drinking water sample is as follows:

- Use sample containers only for water samples and never for storage of chemicals or other liquids.
- Use sample containers for microbiological testing only for that purpose.
- Use sterile sample containers for microbiological testing. Sample containers for chemical and physical testing need to be clean, but not sterile.
- Label the container before sampling.
- Wash and/or disinfect your hands before opening the sample container or wear disposable gloves
- Do not touch the inside of the sample container or cap with your fingers or any other object.
- Do not rinse the sample container since it is sterile.
- Keep the sample container cap in a clean place (not on the ground) to prevent contamination at any time that the sample container is open.

Cleaning and Sterilizing Sample Containers

- You can reuse glass or heat resistant plastic sample containers. To prepare the containers, they should be washed with soap and rinsed at least 3-5 times with distilled water/or clean chlorine-free water to remove any residue.

- After washing, sample containers for microbiological testing need to be sterilized. Sample containers for physical and chemical tests need to be clean, but not sterilized. However, often the same water sample is used for physical, chemical and microbiological testing, so then the container must be sterilized using one of the following methods:
  - Conventional oven: Heat at 180°C for 30 minutes (WHO, 2012)
  - Boiling: Boil for 10 minutes (CDC, 2010 and WHO, 2012)
  - Autoclave: Heat at 121°C for 20 minutes (WHO, 1997)
  - Pressure cooker: Heat for at least 30 minutes (WHO, 1997)

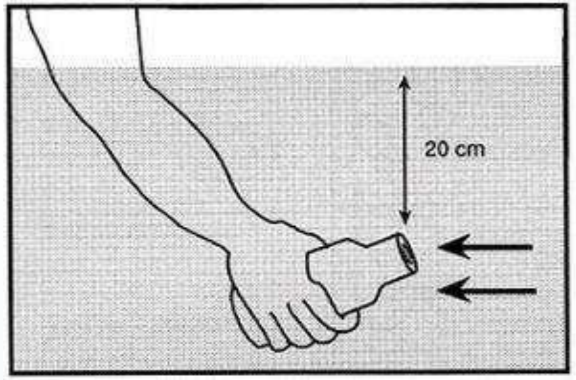
- Never use bleach, chlorine or disinfectants that may leave a residue without properly rinsing (with distilled water) or boiling the containers afterwards. The residue may affect the results by inhibiting or killing the bacteria you are trying to test for.

Sampling Surface Water

- For rivers or other moving water, obtain samples from a point where the water is well mixed and representative of the drinking water supply.
- Samples that are too near the bank, too far from the point of where the drinking water is taken, or at a depth above/below the point of where the drinking water is taken should not be taken.

- Surface water quality can also change depending on the time of day or season.
- It is important to sample at the same time of the day and record the weather conditions when you are taking your sample.

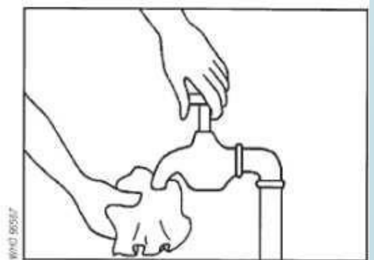
To sample a surface water source:

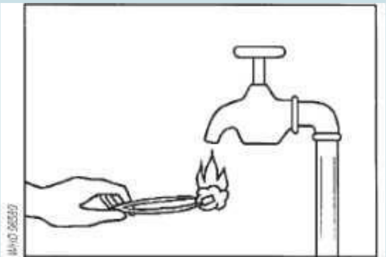


1. Carefully remove the cap from the container and put it facing up in a clean place. Take care to prevent dust from entering the container or anything else that may contaminate the sample.
2. Hold the sample container firmly and dip the open mouth of the container into the water.
3. Lower the container about 20 cm below the surface of the water and scoop up the water sample. This scooping action ensures that no external contamination enters the sample container.
   - In areas where the water is moving (e.g., rivers), the sample should be taken against the direction of the flow of water.
4. Lift the sample container carefully and place on a clean surface where it cannot be knocked over. If the container is completely full, pour out a little water to leave an air space in the container. This allows space for mixing the water sample before analysis. Put the cap back on the container.

Sampling a Tap

- Use a clean cloth to wipe the tap and to remove any dirt.
- Sterilize the inside and outside of the tap for 1 minute.
  - Sterilizing the tap will tell you the actual water quality. Not sterilizing the tap will tell you the water quality that people are drinking.
- Open the tap before sampling and allow water to flow at a moderate rate for 2-3 minutes to clear out any deposits in the pipes.
- Hold the sample container under the water flow to fill it. Leave an air space in the container. This allows space for mixing the water sample before analysis. Put the cap back on the container.





How to Transport Water Samples

- The time between sampling and testing should be kept to a minimum. For physical and chemical testing, the samples should be stored in a cool (4°C) and dark place to preserve the water quality. Residual chlorine, pH and turbidity should be tested immediately after sampling as they will change during storage and transport (WHO, 1997).

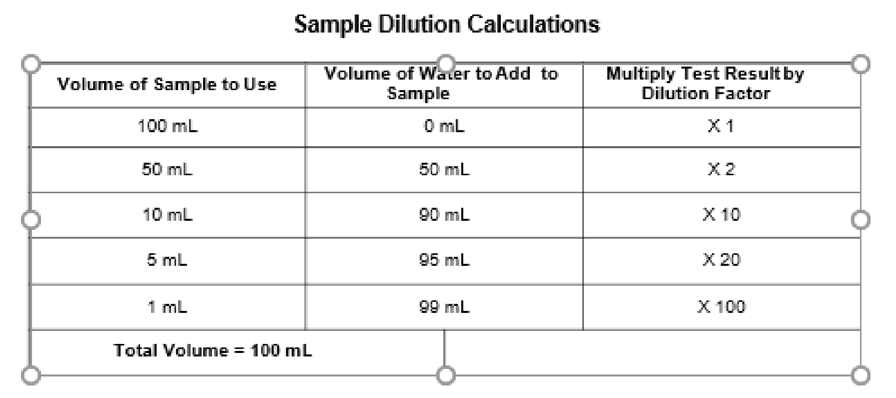
- Bacteria do not generally survive well in water due to a variety of factors. The number of bacteria within a water sample rapidly die off 24 hours after it has been collected. Temperature can also affect die off within the water sample, with higher temperatures leading to greater die offs.

- Samples for microbiological testing should be collected and placed on ice or ice packs in an insulated container (e.g., ice chest, cooler box) if they cannot be tested immediately; preferably held at <10°C during transit. If ice is not available, the transportation time must not take longer than 2 hours. Samples should be tested the same day or refrigerated overnight if necessary. If the time between collection and testing is more than 6 hours, the final report should include information on the conditions and duration of sample transport. Any samples older than 24 hours (from collection to testing) should not be tested (WHO, 1997).

How to Dilute a Water Sample

- Take a small sample volume with a sterile pipette/ sterile syringes .
- Working with small sample volumes can reduce the accuracy of results. As well, you need to be very careful on how you handle the sample.
- For physical and chemical testing, distilled water can be used for dilutions.
- For microbiological testing, sterile water must be used for dilutions. Use either stock phosphate buffer solution or boiled water (e.g., clean rainwater, bottled water, or spring water). Do not use chlorinated water to dilute your samples since the chlorine residual will kill the microorganisms you are trying to test for. As well, do not use distilled water since it is harmful for the microorganisms.

- You may have to dilute your water samples in the following situations:
  - Microbiological testing – there are too many bacteria which makes it difficult to count, or the turbidity is too high and it clogs the filter paper
  - Physical testing – turbidity is too high (out of range on the turbidimeter)
  - Chemical testing – chemical concentration is too high (out of range of the test methods)
  - Diluting your sample will reduce the concentration of the parameter – making it easier to measure and obtain more accurate results.



Sample Dilution Calculations

Volume of Sample to Use	Volume of Water to Add to Sample	Multiply Test Result by Dilution Factor
100 mL	0 mL	X 1
50 mL	50 mL	X 2
10 mL	90 mL	X 10
5 mL	95 mL	X 20
1 mL	99 mL	X 100
Total Volume = 100 mL		

How many households or water locations to sample

The sample size that you select will depend on:

- Resources for water quality testing and analyzing data
- The total number of sampling points involved
- The logistics in reaching the sampling points, especially those in rural, remote areas
- How much data is needed to make a good decision
- Your best judgment

The World Health Organization (WHO) divides the sources of chemicals into the following five groups

Sources of Chemical Contamination

Source of Chemicals	Examples	Common Chemicals
Naturally occurring	Rocks and soils	Arsenic, chromium, fluoride, iron, manganese, sodium, sulfate, uranium
Agricultural activities	Manure, fertilizer, intensive animal practices, pesticides	Ammonia, nitrate, nitrite
Industrial sources and human dwellings	Mining, manufacturing and processing industries, sewage solid waste, urban runoff, fuel leakages	Nitrate, ammonia, cadmium, cyanide, copper, lead, nickel, mercury
Water treatment	Water treatment chemicals, piping materials	Aluminium, chlorine, iodine, silver
Pesticides used in water for public health	Larvicides used to control insect vectors of disease	Organophosphorus compounds (e.g., chlorpyrifos, diazinon, malathion) and carbamates (e.g., aldicarb, carbaryl, carbofuran, oxamyl)

(Adapted from WHO, 2011)

The WHO Guidelines do not include some chemicals such as iron, calcium, sodium, magnesium and zinc. This is because these chemicals pose no health risk at the levels generally found in drinking water.

The WHO Guidelines are determined based on the tolerable daily intake (TDI) of a chemical. The TDI is an estimate of the amount of a chemical in food and drinking water, expressed on a body weight basis (milligram or microgram per kilogram of body weight), that can be ingested over a lifetime without significant health risk, and with a margin of safety (WHO, 2011).

Domestic Standards

- 1914: The U.S. Public Health Service established the first standards for bacteriological quality of drinking water.
  - ✓ A maximum level of two coliforms per 100 milliliters was set as a standard.
- 1962: standard was expanded to include 28 substances including manganese, iron, sulfate, chloride, fluoride, nitrate and dissolved solids.
- 1974: drinking water standards were put under the authority of the recently established U.S. Environmental Protection Agency (EPA) with the passage of the Safe Drinking Water Act.
- 1986 &1996: bill was amended again

There are two categories of drinking water standards in the U.S.:

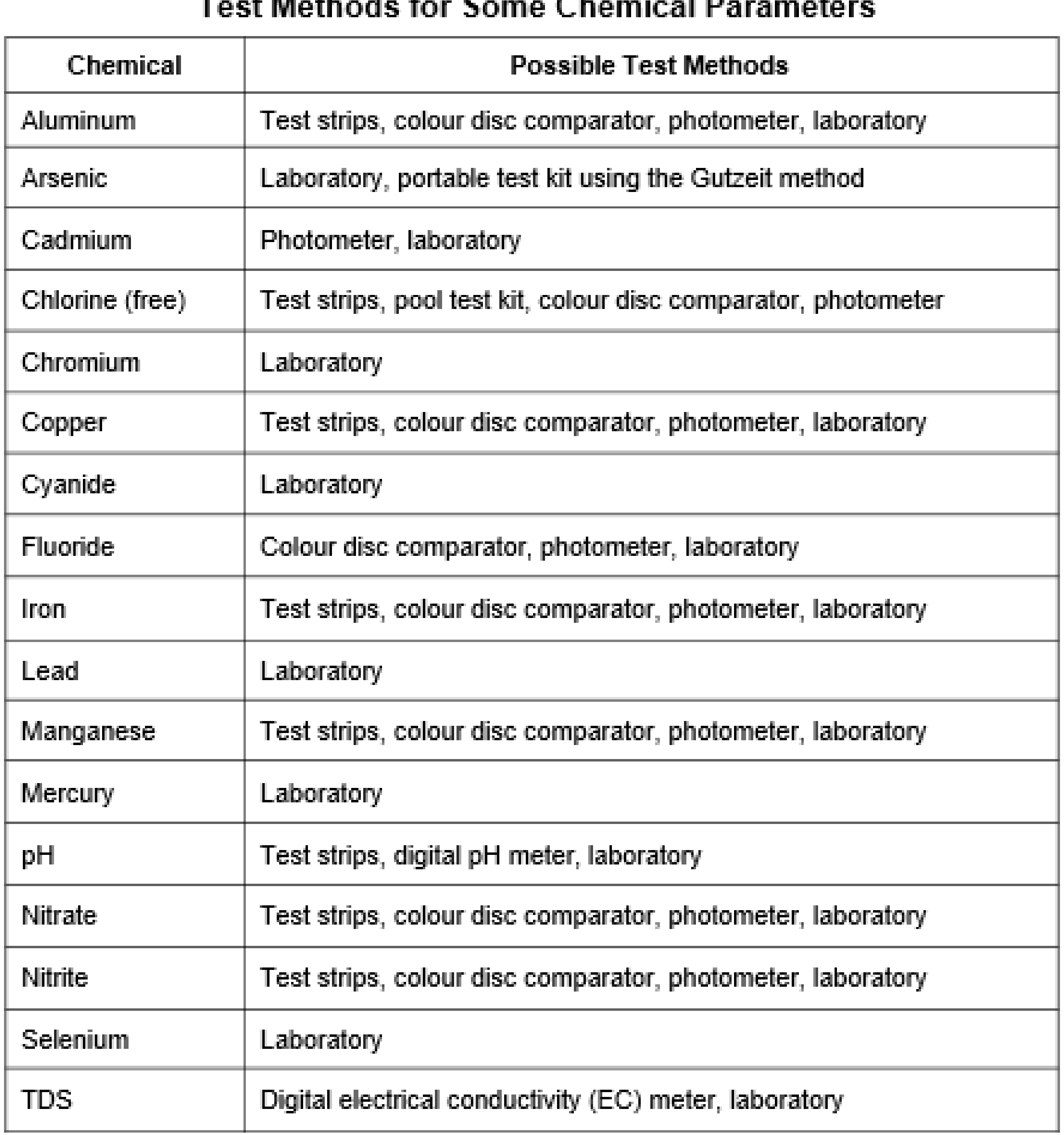
- the National Primary Drinking Water Regulations
- National Secondary Drinking Water Regulations.

Test Methods: Laboratory and field testing are the two main test methods used by government and nongovernmental organizations (NGOs).

There are several factors to be taken into consideration when choosing an appropriate test method for different chemical parameters, including:

- Available resources
- Required level of accuracy and precision
- Technical skills of staff
- Geographical location
- Objective of the results

NGOs tend to use portable kits for their chemical testing, whereas governmental institutes, research centres and universities generally prefer to use laboratory testing which can provide more accurate results



Test Methods for Some Chemical Parameters

Chemical	Possible Test Methods
Aluminum	Test strips, colour disc comparator, photometer, laboratory
Arsenic	Laboratory, portable test kit using the Gutzeit method
Cadmium	Photometer, laboratory
Chlorine (free)	Test strips, pool test kit, colour disc comparator, photometer
Chromium	Laboratory
Copper	Test strips, colour disc comparator, photometer, laboratory
Cyanide	Laboratory
Fluoride	Colour disc comparator, photometer, laboratory
Iron	Test strips, colour disc comparator, photometer, laboratory
Lead	Laboratory
Manganese	Test strips, colour disc comparator, photometer, laboratory
Mercury	Laboratory
pH	Test strips, digital pH meter, laboratory
Nitrate	Test strips, colour disc comparator, photometer, laboratory
Nitrite	Test strips, colour disc comparator, photometer, laboratory
Selenium	Laboratory
TDS	Digital electrical conductivity (EC) meter, laboratory

- ***Colorimetric Method***

Chemical reagents are added to the water sample which react with the particular chemical parameter of interest. The product that is formed absorbs light at a particular wavelength. The water sample is then analyzed in a colorimeter or spectrophotometer and compared to known standards.

- ***Electrode methods***

Ion-selective electrodes can measure the concentration of certain ions in the water sample. pH is easily measured with an electrode and meter.

- ***Chromatography***

Samples are passed through a column containing a specific packing or coating that selectively retains certain types of chemicals. Different compounds pass through the column at different speeds, depending on their affinity to the packing or coating. A detector at the exit of the column quantifies the concentration of the chemical. There are many types of chromatography: ion chromatography, liquid chromatography and gas chromatography.

- ***Atomic Absorption Spectrometer (AAS)***

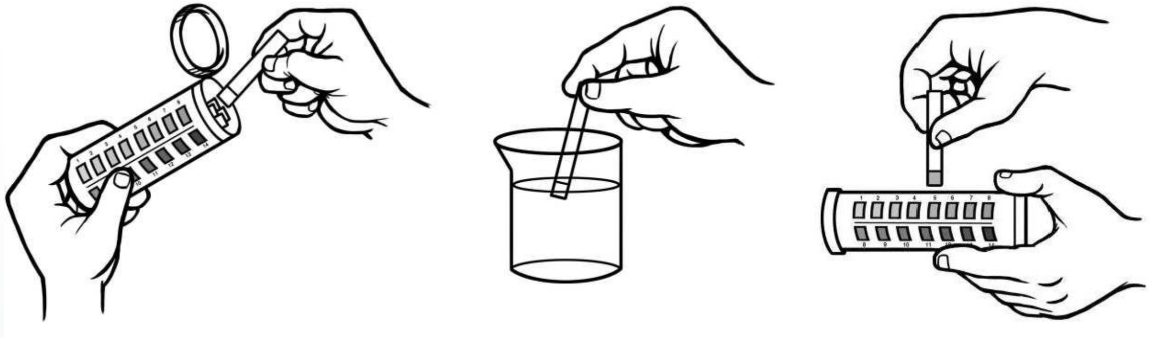
AAS is used to analyze the presence of metals. Samples are heated either in a flame or electrically in a graphite furnace, and the concentration is determined by the metal atom's absorption of light at a particular wavelength.

- ***Inductively Coupled Plasma (ICP)***

ICP is also used to analyze the presence of metals. Samples are broken down to the atomic level and metals are detected either through atomic emission spectroscopy or mass spectroscopy.

Colorimetric and electrode methods can be implemented in basic laboratories with relative ease. Chromatography and AAS are considerably more expensive and complex, and are more appropriate for central or reference laboratories. ICP methods are very costly and difficult, and are uncommon in developing countries (UNICEF, 2008).

Portable Test Methods



Popular portable test methods

- ❑ Test strips
- ❑ Colour disk comparators
- ❑ Colorimeters
- ❑ Photometers
- ❑ Digital meters

Check the validity of the test method before using

Test (Reagent) Strips: 2 Important things to keep in mind:

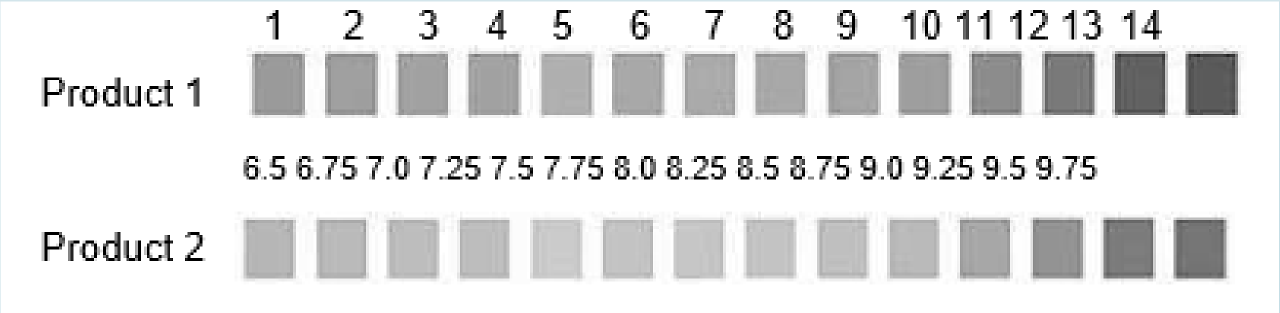
- Different products require different **activation methods**, such as:
  - Dipping the strip in the sample
  - Swishing the strip back and forth in the sample
  - Holding the reagent area in a stream of the sample
- Different test strips require different **read times** that is needed before comparing the strip to the colour chart.

Using the wrong activation method or reading your results too early or late for that test strip may lead to incorrect results

Understanding the limits and concentration ranges of chemical parameters

For example,

- a company produces test strips for measuring pH. Two products are available. One with a range between pH 1 to pH 14 and another with a range of pH 6.5 to pH 10.0.
- As drinking water usually lies between pH 6.5 and pH 8.5, the second test strip is more suited to our work and provides better precision and accuracy.



Digital instruments

Colorimeter and Photometer

- use a light source to measure the chemical concentration in a water sample.
- more accurate and repeatable results
- can read a large variety of chemicals in a water sample
- wider numerical range within each parameter
- more expensive
- need a power source
- require training to ensure they are being used properly

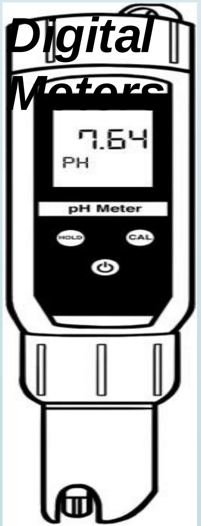
- ***Digital Meters***

Some portable test kits include various digital meters

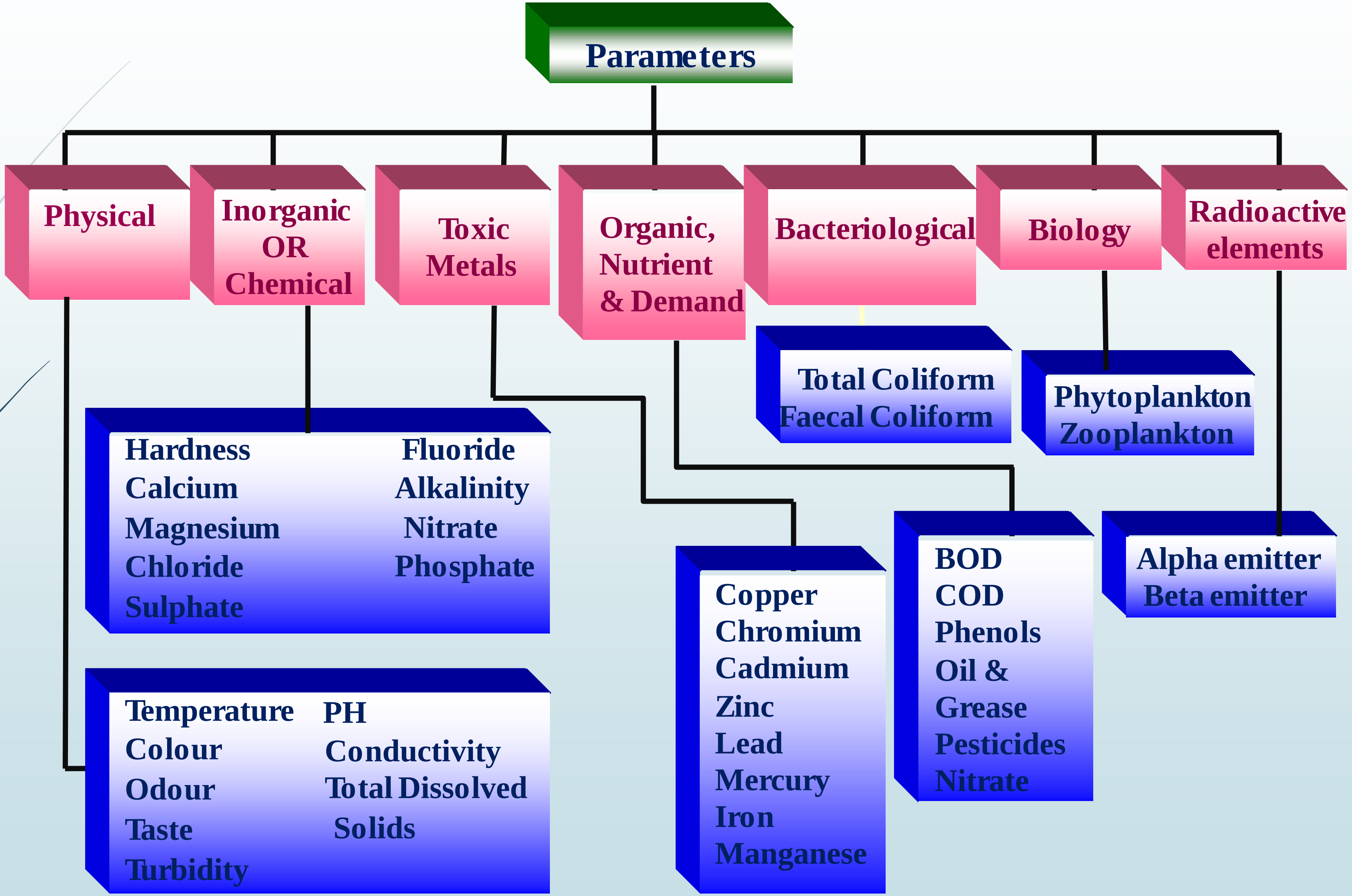
- measure parameters like pH & EC
- relatively easy to use
- provide more accurate measurements than other methods
- need to calibrate the meters and
- replace batteries as required
- fragility of electronic equipment.

Colorimeter and Photometer

Digital Meters



Water Quality Assessment : Potable & Industrial Uses



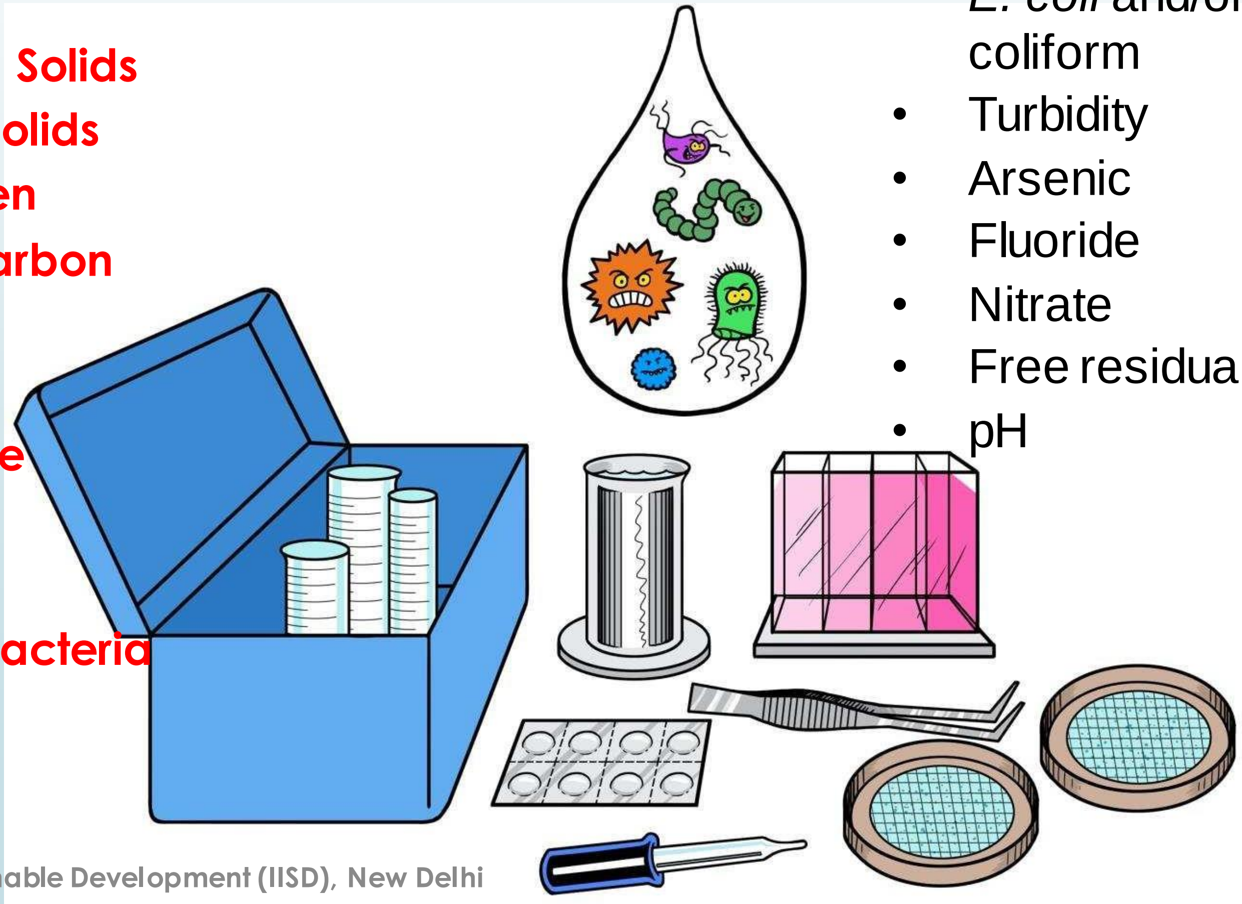
- **Parameters**
  - Physical
    - Temperature
    - Colour
    - Odour
    - Taste
    - Turbidity
    - PH
    - Conductivity
    - Total Dissolved Solids
  - Inorganic OR Chemical
    - Hardness
    - Calcium
    - Magnesium
    - Chloride
    - Sulphate
    - Fluoride
    - Alkalinity
    - Nitrate
    - Phosphate
  - Toxic Metals
    - Copper
    - Chromium
    - Cadmium
    - Zinc
    - Lead
    - Mercury
    - Iron
    - Manganese
  - Organic, Nutrient & Demand
    - BOD
    - COD
    - Phenols
    - Oil & Grease
    - Pesticides
    - Nitrate
  - Bacteriological
    - Total Coliform
    - Faecal Coliform
  - Biology
    - Phytoplankton
    - Zooplankton
  - Radioactive elements
    - Alpha emitter
    - Beta emitter

Drinking water quality parameters

- **Temperature**
- **Specific Conductance**
- **pH**
- **Turbidity**
- **Total Suspended Solids**
- **Total Dissolved Solids**
- **Dissolved Oxygen**
- **Total Organic Carbon**
- **Hardness**
- **Alkalinity**
- **Nitrate and Nitrite**
- **Ammonia**
- **Phosphate**
- **Fecal Coliform Bacteria**

The priority water quality parameters to test for are

- *E. coli* and/or thermotolerant coliform
- Turbidity
- Arsenic
- Fluoride
- Nitrate
- Hardness
- Free residual chlorine
- pH



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Physical testing

- Common physical tests of water include temperature, solids concentration and turbidity.
- Most physical parameters can be simply observed, like **taste, smell and colour**

Chemical testing

- It is not possible to test water for all of the chemicals that could cause health problems, nor is it necessary.
- Most chemicals are rarely present, and many result from human contamination of a small area, only affecting a few water sources.

Microbiological testing

- Testing for microbiological contamination is usually the priority in most drinking water projects
- Primary concern is infectious diarrheal disease transmitted by people drinking water contaminated with faeces.
- Pathogens in water – bacteria, viruses, protozoa and helminths – can cause a wide range of health problems

3 potential chemicals cause serious health problems and occur over widespread areas.

- **Arsenic and fluoride**, which can occur naturally, and
- **Nitrate**, which is commonly used in fertilizer for agriculture.

Chemical parameters that commonly cause water to be rejected for aesthetic purposes

- Metals (**mainly iron and manganese**)
- **total dissolved solids** (salinity)

When water is disinfected with chlorine, monitor the drinking water quality for

- **pH and free residual chlorine** (FRC) as indicators of appropriate and effective treatment.

Chemicals that are known to be present locally, **copper or lead** from industrial pollution.

WATER QUALITY STANDARD

Indian Standard

Drinking Water - Specification

IS 10500 : 2012(Second Revision)

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Indian Institute Of Sustainable Development (IISD), New Delhi

IS 10500 : 2012 Indian Standard (Second Revision)

It prescribes the requirements and the methods of sampling and test for drinking water. The revision assistance has been derived from the following:

1. EU Directives relating to the quality of water intended for human consumption (80/778/EEC) and Council Directive 98/83/EC.
2. USEPA standard — National Primary Drinking Water Standard. EPA 816-F-02-013 dated July, 2002.
3. WHO Guidelines for Drinking Water Quality. 3rd Edition Vol. 1 Recommendations, 2008.
4. Manual on Water Supply and Treatment, third edition — revised and updated May 1999, Ministry of Urban Development, New Delhi.

Coloured water is not acceptable for drinking (Aesthetic as well as toxicity reasons)
Industrial wastewater require colour removal before discharge into water courses

The term colour means true colour that is the colour of water from which turbidity has been removed. True colour of water is due to dissolved material

Apparent colour is due to suspended matter as well as due to substances on solution removed by filtration

Colour, Hazen Units	
IS 10500-2012	Desirable : 5 Hz. , Permissible : 15 Hz.
Risks or effects	Visible tint, acceptance decreases
Sources	Tannins, Iron, Copper, Manganese Natural deposits
Treatment	Filtration, Distillation, Reverse osmosis, Ozonisation

Unit for Measurement of colour

- Unit for colour measurement is based on platinum cobalt scale

Methods for Colour Measurement Visual

Comparison Method

- Colour of the sample is determined by visual comparison with known concentration of coloured colutions prepared by diluting stock platinum cobalt solution
- Or properly calibrated glass coloured disk is used for comparison
- This method is useful for potable water and water in which colour is due to naturally occuring materials
- This method is not applicable to most highly coloured industrial wastewater

Spectrophotometric Method

- This method is applicable to potable and waste both domestic and industrial
- In this method light absorbed or transmitted is measured at dominant wavelength of a particular hue of sample

  Spectrophotometer should have an effective operating range from 400 to 700 nm before measurement remove turbidity either by filtration or by centrifuging
- Colour hues for dominant wavelengths ranges are

Odour	
IS 10500-2012	Unobjectionable
Risks or effects	Rotten egg, Musty, Chemical
Sources	Chlorine, Hydrogen sulphide, Organic matter, Septic contamination, Methane gas
Treatment	Activated carbon, Air stripping, oxidation, Filtration

Temperature

- Respiration of organisms is temperature-related;
- respiration rates can increase by 10% or more per 1° C temperature rise.
- increased temperature not only reduces oxygen availability, but also increases oxygen demand, which can add to physiological stress of organisms

Turbidity is generally the most important physical parameter to measure, since high levels of turbidity are usually associated with high levels of microbiological contamination. As well, high levels of turbidity can reduce the effectiveness of some water treatment technologies.

Turbidity	
IS 10500-2012	Desirable: 1NTU, Permissible : 5NTU
Risks or effects	Interfere with Disinfection
Sources	Due to particulate matter
Treatment	Activated carbon, Air stripping, oxidation, Filtration

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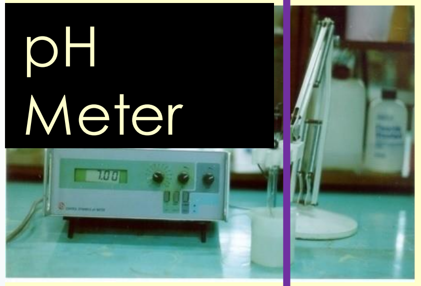
pH	
IS 10500-2012	Desirable :6.5 – 8.5, Permissible:6.5 – 8.5
Risks or effects	Low pH - corrosion, metallic taste High pH – bitter/soda taste, deposits
Sources	Natural
Treatment	Increase pH by soda ash Decrease pH with white vinegar / citric acid



pH
Hydrogen Ion
Exponent
6.5 - 8.5

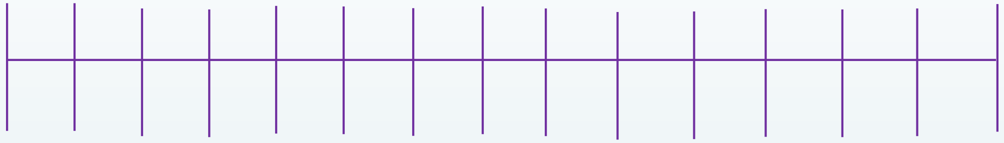
Definition

- **pH** = - $\log_{10} [H^+] = \log_{10} 1/[H^+]$ OR $[H^+] = 10^{-pH}$

  This method has advantage because all states of acidity and alkalinity of solutions with respect to hydrogen and hyroxide ions can be expressed by a series of positive numbers between 0 to 14

[H^+] (10^o) 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} 10^{-12} 10^{-13} 10^{-14}

pH 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14



pOH 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

[OH^-]10^{-14} 10^{-13} 10^{-12} $10^{-11}$$10^{-10}$ 10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{-0}

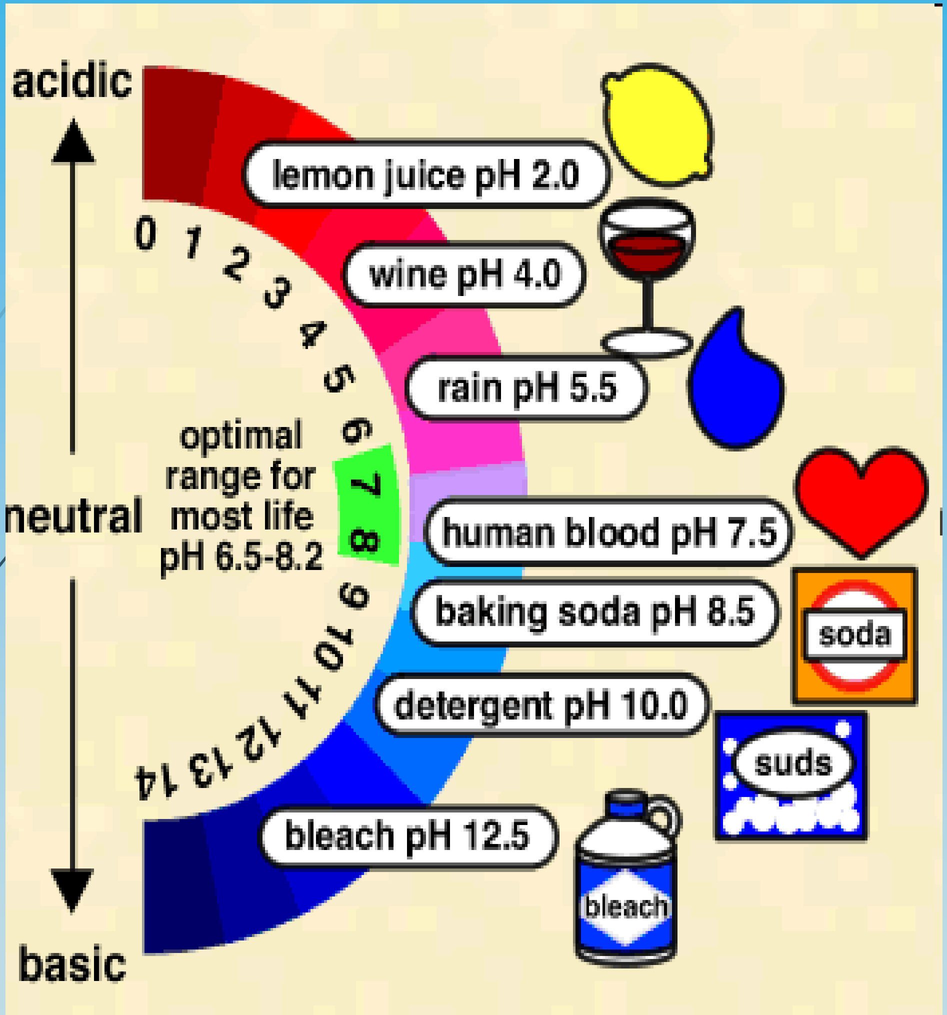
Significance

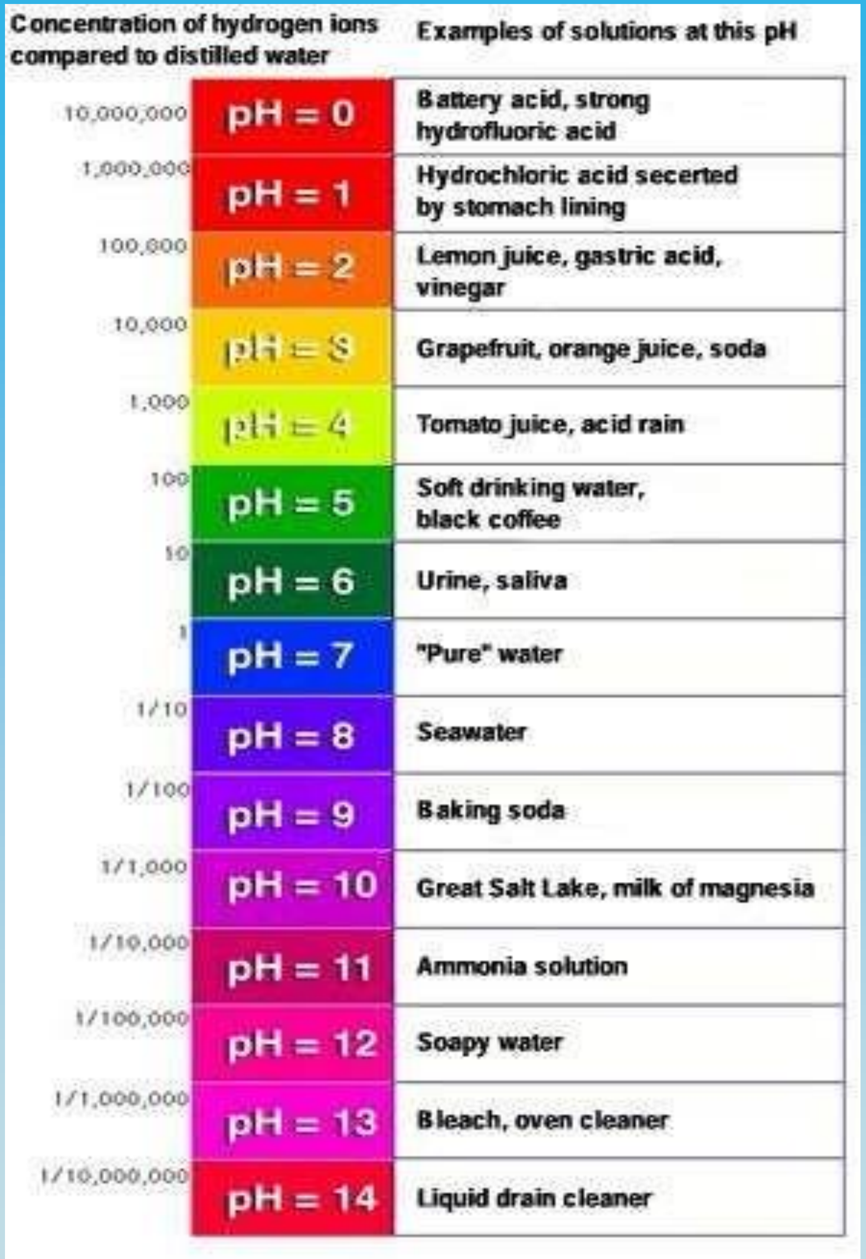
- Chemical reactions depend on pH
- Water Supply and Waste Water Treatment
- Water Softening ,Precipitation., Coagulation, Disinfection, Corrosion Control,Alkalinity and CO_2 Measurement and fluoride activity

Measurement

- Electrometric method - Using pH meter and electrodes
- e.m.f. produced in glass electrode system varies linearly with pH
- pH meter is calibrated potentiometrically with electrode system using standard buffers having assigned values so that pH = - $\log_{10} [H^+]$

pH depends on the presence of phosphates, silicates, borates, fluorides and some other salts in dissociated form





Concentration of hydrogen ions compared to distilled water		Examples of solutions at this pH
10,000,000	pH = 0	Battery acid, strong hydrofluoric acid
1,000,000	pH = 1	Hydrochloric acid secerted by stomach lining
100,000	pH = 2	Lemon juice, gastric acid, vinegar
10,000	pH = 3	Grapefruit, orange juice, soda
1,000	pH = 4	Tomato juice, acid rain
100	pH = 5	Soft drinking water, black coffee
10	pH = 6	Urine, saliva
1	pH = 7	"Pure" water
1/10	pH = 8	Seawater
1/100	pH = 9	Baking soda
1/1,000	pH = 10	Great Salt Lake, milk of magnesia
1/10,000	pH = 11	Ammonia solution
1/100,000	pH = 12	Soapy water
1/1,000,000	pH = 13	Bleach, oven cleaner
1/10,000,000	pH = 14	Liquid drain cleaner

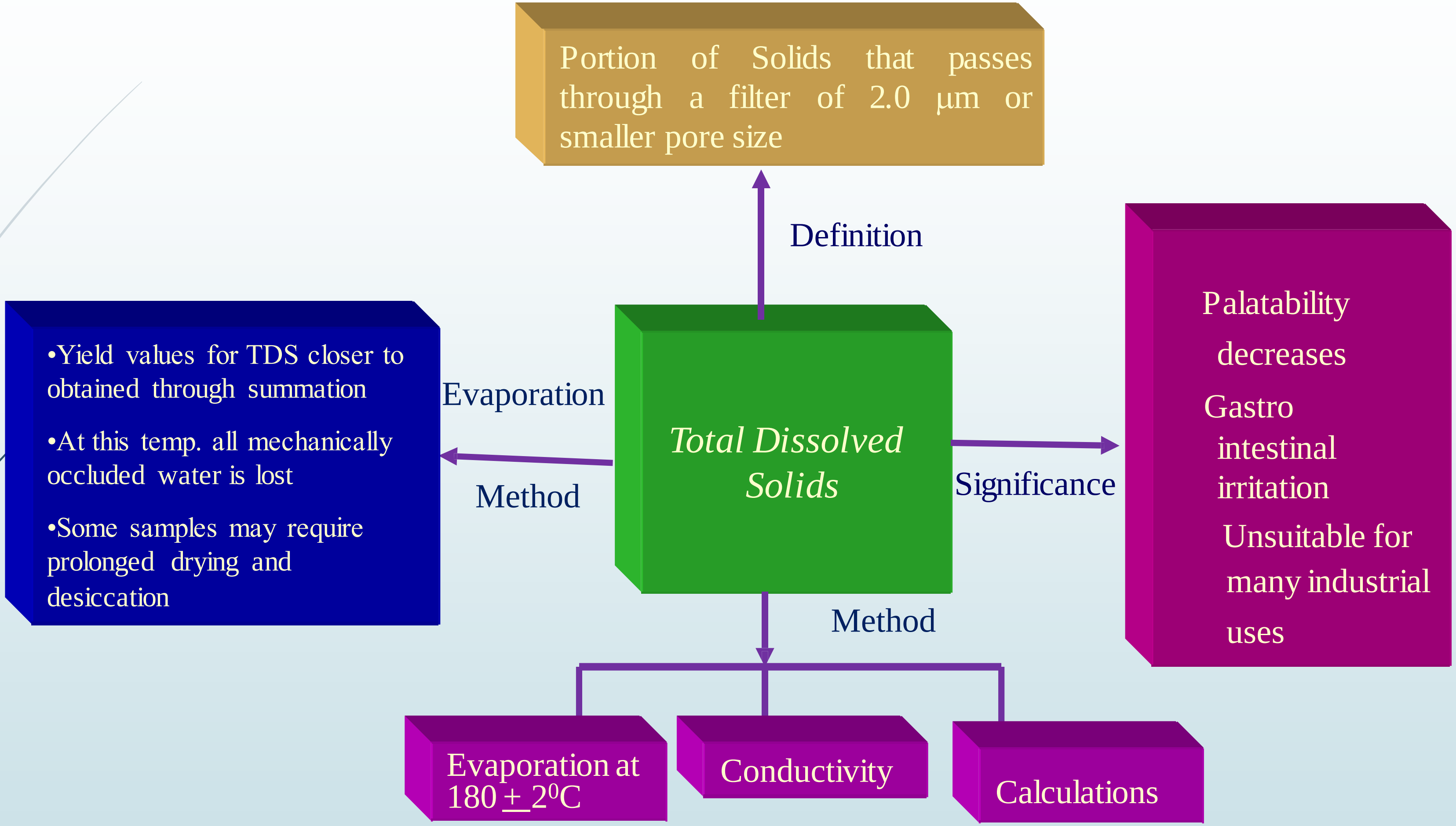
Clean rainwater has pH about 5.7 coz of dissolved CO2
After reaching surface of earth, rainwater acquires alkalinity

High TDS results in undesirable taste which could be salty, bitter, or metallic as well as it is less thirst quenching.

Water with higher TDS is considered by some health advocates to have a poorer cleansing effect in the body than water with a low level of TDS. This is because water with low dissolved solids has a greater capacity of absorption than water with higher solids.

Total Dissolved Solids (TDS)	
IS 10500-2012	Desirable : 500 mg/l , Permissible : 2000 mg/l
Risks or effects	Hardness, scaly deposits, sediment, cloudy colored water, staining, salty or bitter taste, corrosion of pipes and fittings
Sources	Livestock waste, septic system Landfills, nature of soil Hazardous waste landfills Dissolved minerals, iron and manganese
Treatment	Reverse Osmosis, Distillation, deionization by ion exchange

Total dissolved salt concentrations is the primary indicator of the total mineral content in water and are related to problems such as excessive hardness



Portion of Solids that passes through a filter of 2.0 µm or smaller pore size

Definition

Total Dissolved Solids

Evaporation

Method

- Yield values for TDS closer to obtained through summation
- At this temp. all mechanically occluded water is lost
- Some samples may require prolonged drying and desiccation

Significance

Palatability decreases

Gastro intestinal irritation

Unsuitable for many industrial uses

Method

Evaporation at $180 \pm 2^{0}C$

Conductivity

Calculations

For seawater TDS(mg/l) = 0.5 x SC in US/cm
For groundwater TDS(mg/l) = 0.55 to .7 x SC in US/cm

TDS = sum of cations + sum of anions +Si
TDS = 0.6 (alkalinity) + Na+ K+ Ca+ Mg+Cl+SO4+ SiO3

TDS and salinity

- indicate dissolved salts
- Include humic acids, tannin and pyrogens
- Is removed by PPT, ion exchange, RO
- Major contributors carbonate, bicarbonate, Cl, SO4, PO4, NO3 salts
- Taste problems arise due to certain metals like Fe, Cu, Mn, Zn

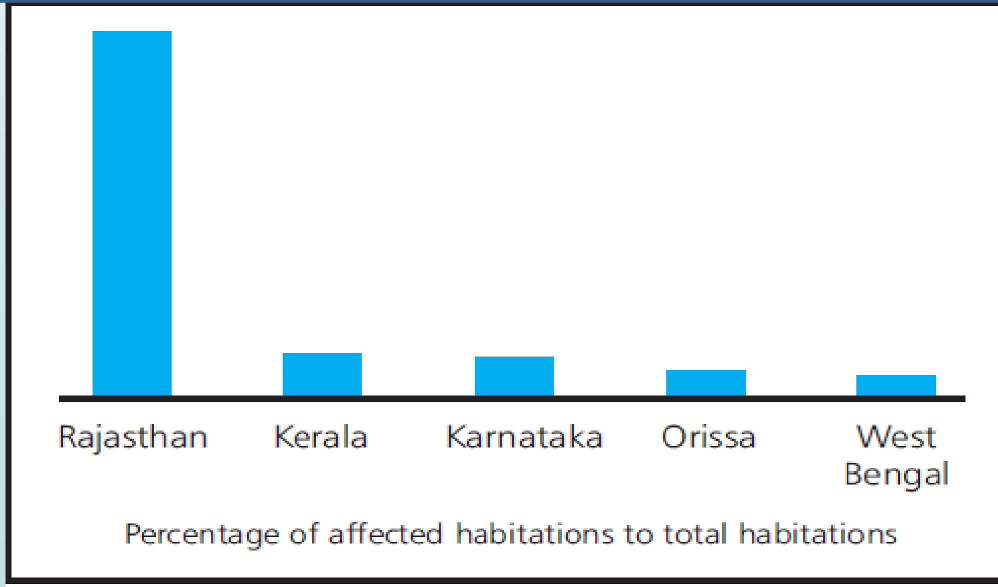
1000-3000 slightly saline

3000-10000 moderately saline

10000-35000 very saline

>35000 briny

Top Five Salinity Affected States



Source: Data from DDWS (2011)

Hardness is measure of **polyvalent** cations (ions with a charge greater than +1) in water.

Hardness generally represents the concentration of Ca2+ and Mg2+ ions, because these are the most common polyvalent cations.

Other ions, such as Fe2+ and Mn2+ may also contribute to the hardness of water, but are generally present in much lower concentrations.

Hardness	
IS 10500-2012	Desirable :200 mg/l , Permissible : 600 mg/l
Risks or effects	Scale in utensils and hot water system, soap scums
Sources	Dissolved calcium and magnesium from soil and aquifer minerals containing limestone or dolomite
Treatment	Water Softener Ion Exchanger , Reverse Osmosis

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- Hardness is generally expressed in units of mg/l or ppm of $CaCO_3$.
- It can also be expressed in "grains per gallon" (gpg); one gpg equals approximately 17 mg/L.
- Hardness can also be calculated from measurements of calcium and magnesium using the following formula:

$$\text{Hardness, mg equivalent/L } CaCO_3 = ([Ca, mg/l]*2.497) + ([Mg, mg/l]*4.116)$$

- When hardness equals alkalinity, the only cations present in significant concentrations in the water are calcium and magnesium.: carbonate or temporary hardness
- When hardness is greater than alkalinity, the waters may contain considerable amounts of other cations: noncarbonate or permanent hardness

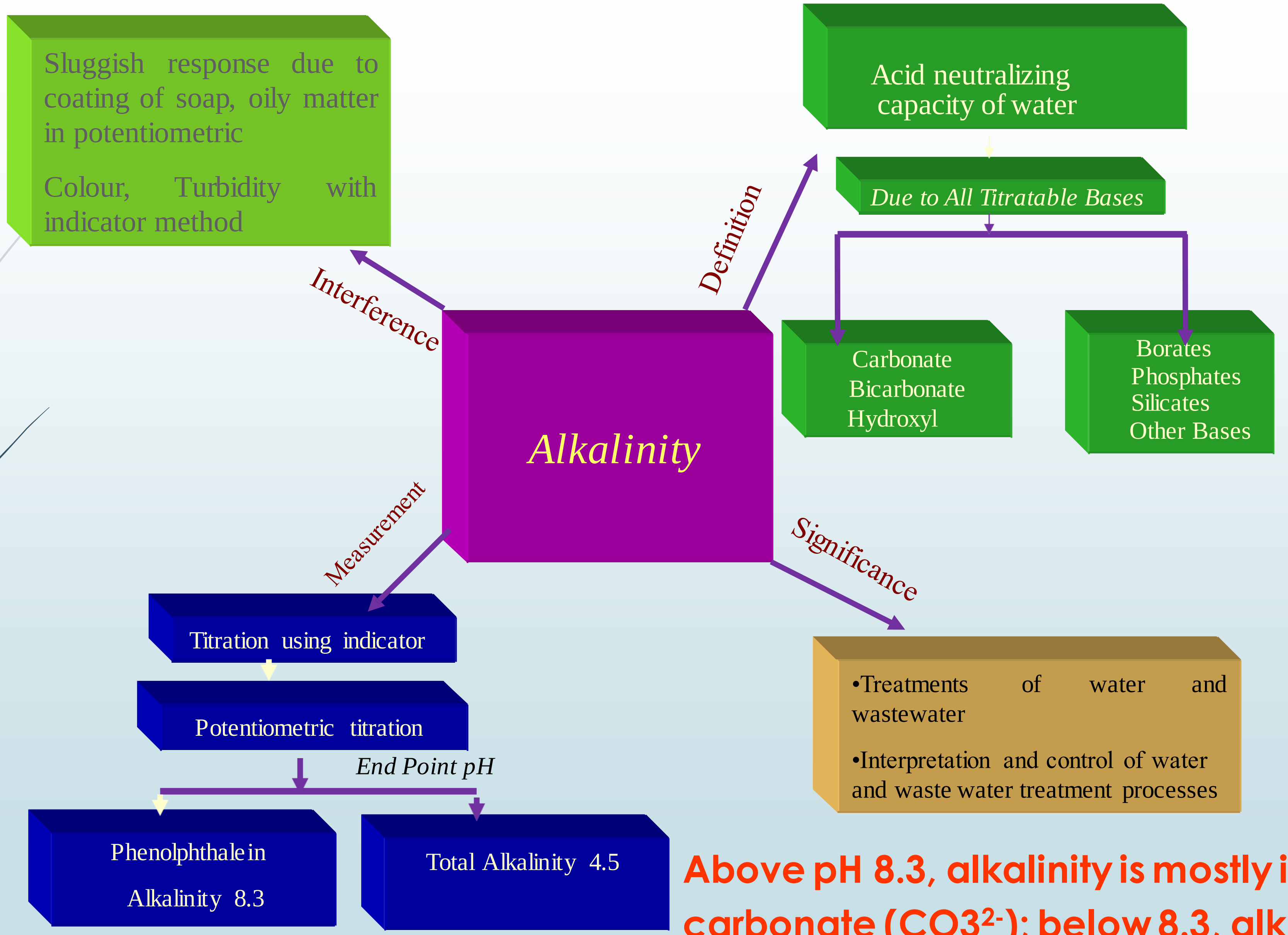
	pH
Soft water	5.3-7.4
Hard water	7.6-8.8
Sea water	8.2-9.2
Water affected by acidic pollutants	2.2- 4.8
pH of water in eqbm with atm	5.6

Assessment	mg/l (CaCO3)
Soft water	0-50
Moderately soft	50-100
Slightly hard	100-150
Moderately hard	150-200
Hard	200-300
Very hard	>300

Waters with high hardness values are referred to as "hard," while those with low hardness values are "soft".

- Because alkalinity varies greatly due to differences in geology, there aren't general standards for alkalinity.
- Levels of 20-200 mg/L are typical of fresh water. A total alkalinity level of 100-200 mg/L will stabilize the pH level in a stream. Levels below 10 mg/L indicate that the system is poorly buffered, and is very susceptible to changes in pH from natural and human-caused sources.

Alkalinity	
IS 10500-2012	Desirable : 200 mg/l , Permissible : 600 mg/lit
Risks or effects	Low Alkalinity (i.e. high acidity) causes deterioration of plumbing and increases the chance for many heavy metals in water are present in pipes, solder or plumbing fixtures.
Sources	Pipes, landfills Hazardous waste landfills
Treatment	Neutralizing agent



Alkalinity

Definition

Acid neutralizing capacity of water

Due to All Titratable Bases

Carbonate
Bicarbonate
Hydroxyl

Borates
Phosphates
Silicates
Other Bases

Interference

Sluggish response due to coating of soap, oily matter in potentiometric

Colour, Turbidity with indicator method

Measurement

Titration using indicator

Potentiometric titration

End Point pH

Phenolphthalein Alkalinity 8.3

Total Alkalinity 4.5

Significance

- Treatments of water and wastewater
- Interpretation and control of water and waste water treatment processes

Above pH 8.3, alkalinity is mostly in the form of carbonate ($CO3^{2-}$); below 8.3, alkalinity is present mostly as bicarbonate (HCO3-).

Alkalinity

- Alkalinity of water is a measure of its capacity to neutralize acids.
- Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater.
- Is due primarily to salts of weak acids, although weak or strong bases may contribute
- Bicarbonates ($HCO3-$), alongwith carbonates ($CO3^{2-}$ and occasionally hydroxides, borates, silicates, phosphates, ammonium, sulfides, and organic ligands.

$$CO_3 + CaCO3 + H2O = Ca(HCO3)2$$

$$HCO3^- + H^+ = CO2 + H2O$$

$$CO_3^{2-} + H^+ = HCO3-$$

$$OH^- + H^+ = H2O$$

- Alkalinity (mol/l)=$[HCO3^-]+2[CO3^{2-}]+[OH^-]+[H^+]$
- Alkalinity (meq/l)=$[HCO3^-]+[CO3^{2-}]+[OH^-]+[H^+]$

- For nearly neutral water (pH 6-8) the conc of H+ and OH^- are insignificant

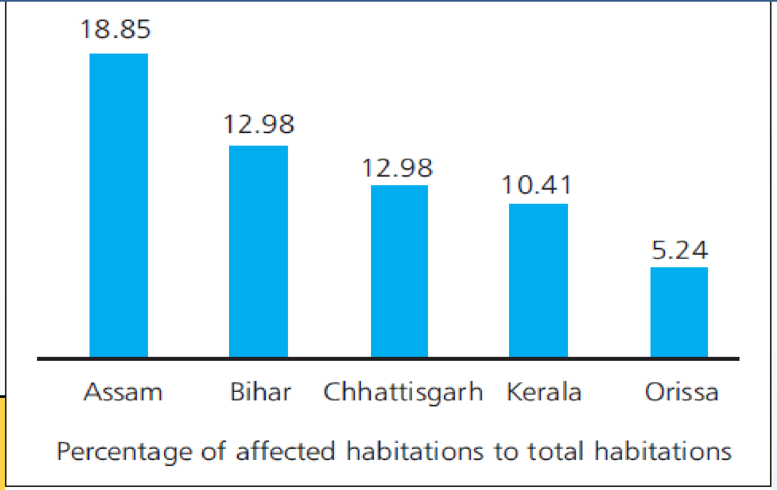
Alkalinity (meq/l)=$[HCO3^-]+[CO3^{2-}]$

- Hardness has some similarities to alkalinity
- As with alkalinity, hardness is usually expressed as an equivalent conc of $CaCO_3$.
- Hardness is a property of cations (Ca^{2+}, Mg^{2+}) while alkalinity is a property of anions (HCO_3^-, CO_3^{2-})

Softening

- Lime soda process
  - Quick line (CaO) or hydrated lime($Ca(OH)_2$)is added. pH raised to 10.3, solb bicarb ions to insolb carb ions which then ppt out
  - $Ca(HCO_3)_2 + Ca(OH)_2 = 2\ CaCO_3\downarrow + 2H_2O$
  - $Mg(HCO_3)_2 + 2Ca(OH)_2 = 2\ CaCO_3 + Mg(OH)_2\downarrow + 2H_2O$
- Ion-exchange process
  - Resin zeolite removes Ca^{2+} and Mg^{2+} replaces them with Na ions
  - $Ca(HCO_3)_2 + Na_2R = CaR + 2\ NaHCO_3$

Top five Iron Affected States



Source: Data from DDWS (2011)

Iron	
IS 10500-2012	Desirable : 0.3 mg/l , Permissible : 0.3 mg/l
Risks or effects	Brackish color, rusty sediment, bitter or metallic taste, brown-green stains, iron bacteria, discolored beverages
Sources	Leaching of cast iron pipes in water distribution systems Natural
Treatment	Oxidizing Filter , Green-sand Mechanical Filter

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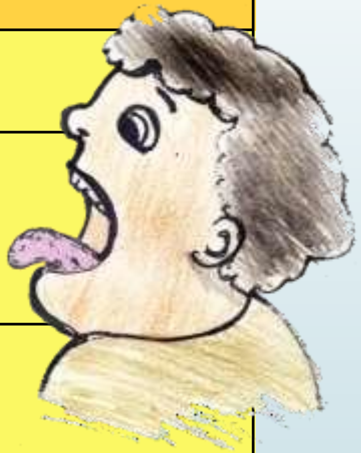
Manganese	
IS 10500-2012	Desirable : 0.1 mg/l , Permissible : 0.3 mg/l
Risks or effects	Brownish color, black stains on laundry and fixtures at .2 mg/l, bitter taste, altered taste of water-mixed beverages
Sources	Landfills Deposits in rock and soil
Treatment	Ion Exchange , Chlorination, Oxidizing Filter , Green-sand Mechanical Filter



Methods for Detection of Iron and Manganese in Water

- Atomic Absorption spectrophotometer (AAS)
- Inductively Coupled Plasma (ICP)
- Colorimetric method In colorimetric method iron is detected at wavelength 510 nm and manganese is detected at 525 nm.

1.Iron:-Phenanthroline method

2.Manganese:-

    - Persulphate method
    - Periodate method

Determination of Metals

Inductively Coupled Plasma-Atomic Emission Spectrometer

Spectorphotometric Method Principle: Sulfate ions are precipitated as $BaSO_4$ in acidic media (HCl) with Barium Chloride. The absorption of light by this precipitated suspension is measured by spectrophotometer at 420 nm or scattering of light by Nephelometer

Calculation

mg / L SO_4 =mg SO_4 x 1000 ml sample

Sulphate	
IS 10500-2012	Desirable : 200 mg/l, Permissible : 400 mg/l
Risks or effects	Bitter, medicinal taste, scaly deposits, corrosion, laxative effects, "rotten-egg" odour from hydrogen sulphide gas formation
Sources	Animal sewage, septic system, sewage By-product of coal mining, industrial waste Natural deposits or salt
Sulphate Treatment	Ion Exchange , Distillation , Reverse Osmosis

Sources

- Fertilizers and manure
- Decayed vegetable
- Animal feedlots
- Municipal wastewater and sludge disposal to land
- Industrial discharges
- Leachates from refuse dumps
- Septic systems and
- N-fixation from atmosphere by bacteria and lightning

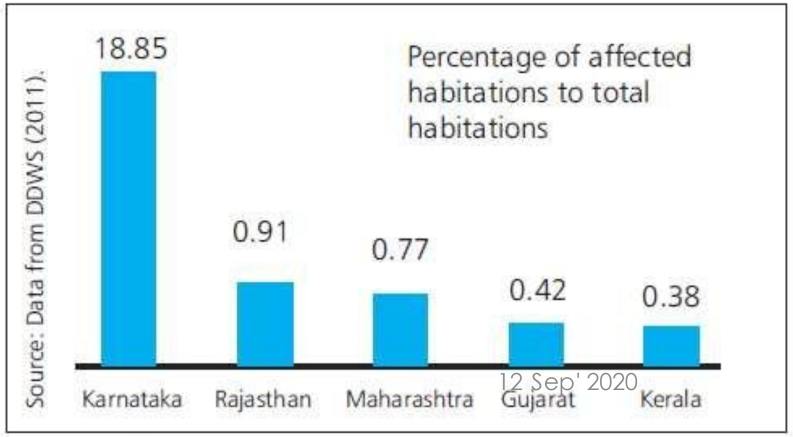
The results reported for nitrates can be confusing because they may be reported as nitrogen (N) or nitrate-nitrogen or as nitrate (NO3).

The following are the maximum levels for each:

- **Nitrogen (N) or nitrate-nitrogen (NO3-N) should not be higher than 10mg/L.**
- **Nitrate (NO3) should not be higher than 45mg/L.**

Nitrate	
IS 10500-2012	Desirable : 45 mg/l, Permissible : 45 mg/lit
Risks or effects	Methemoglobinemia or blue baby disease in infants
Sources	Livestock facilities, septic systems, manure lagoons, Household waste water, Fertilizers, Natural Deposits,
Treatment	Ion Exchange, Distillation, Reverse Osmosis

Top Five Nitrate affected States



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Source: Data from DDWS (2011)

Methods for Nitrate Estimation

A) Ultraviolet Spectrophotometric Method

- Useful for uncontaminated natural waters and potable water supplies that have low organic content
- Follows Beer's law upto 11 mg/L as N
- Interferences
  - Dissolved Organic Matter
  - Surfactants
  - Nitrite and Hexavalent Chromium
- Procedure
  - Filter the sample
  - Add 1 ml of 1N HCl per 50 ml of sample
  - Read absorbance or tranmittance at 220 nm and 275 nm
  - Set 0 absorbance or 100% tranmittance with distilled water

B) Nitrate Electrode Method

- Useful for Nitrate concentration range of 0.14 to 1400 mg/L NO_3-N
- Interferences
  - Chloride and bicabonate with weight ratios to NO_3-N >10 or >5 respectively
  - NO_2, CN, Sulphide, Br, I, Chlorite and Chlorate

Cl

Presence in Natural Waters

- Dissolution of salt deposits
- Discharges of effluents
- Oil well operations
- Sewage discharges
- Irrigation drainage
- Sea water intrusion in coastal areas

Chloride	
IS 10500-2012	Desirable : 250 mg/l , Permissible : 1000 mg/l
Risks or effects	High blood pressure, salty taste, corroded pipes, fixtures and appliances, blackening and pitting of stainless steel
Sources	Fertilizers Industrial wastes Minerals, seawater
Treatment	Reverse Osmosis , Distillation, Activated Carbon

Chloride

Methodology : An Argentometric Method

- Principle

  Chloride is determined in a natural or slightly alkaline solution by titration with standard silver nitrate, using potassium chromate as an indicator. Silver chloride is quantitatively precipitated before red silver chromate is formed.

$$\text{Chloride mg/L} = \frac{(A-B) \times N \times 35.45 \times 1000}{\text{ml sample}}$$

Where A = ml $AgNO_3$ required for sample

B = ml $AgNO_3$ required for blank

N = Normality of $AgNO_3$ used

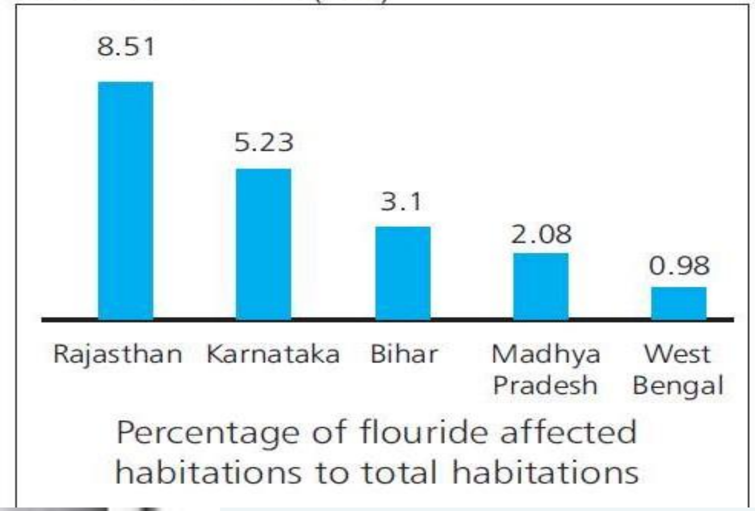
Fluoride

IS 10500-2012	Desirable : 1.0 mg/l, Permissible : 1.5 mg/l
Risks or effects	Brownish discoloration of teeth, bone damage
Sources	Industrial waste Geological
Treatment	Activated Alumina, Distillation, Reverse Osmosis, Ion Exchange

Fluorosis

Top Five Fluoride affected states

Source: Data from DDWS (2011)



Dental fluorosis **Skeletal fluorosis**

Concentration < 0.8 mg/L results in dental Carries

Essential to maintain F^- concentration between 0.8 mg/L to 1.0 mg/L in drinking water

Fluoride

Methods

Colorimetric SPADNS Method

Principle: Under acidic conditions fluorides (HF) react with zirconium SPADNS solution and the lake (colour of SPADNS reagent) gets bleached due to formation of ZrF_6 . Since bleaching is a function of fluoride ions, it is directly proportional to the concentration of fluoride. It obeys Beers law in a reverse manner.

Ion Selective Electrode Method

Principle: The fluoride sensitive electrode is of the solid state type, consisting of a lanthanum fluoride crystal; in use it forms a cell in combination with a reference electrode, normally the calomel electrode. The crystal contacts the sample solution at one face and an internal reference solution at the other. A potential is established by the presence of fluoride ions across the crystal which is measured by a device called ion meter or by any modern pH meter having an expanded millivolt scale.

Calculate mg F^- / L present in the sample using standard curve

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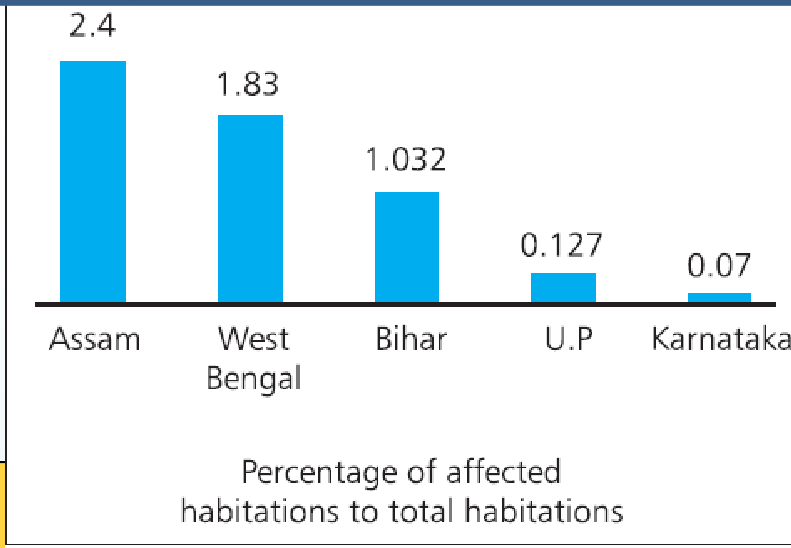
Top five Arsenic affected States

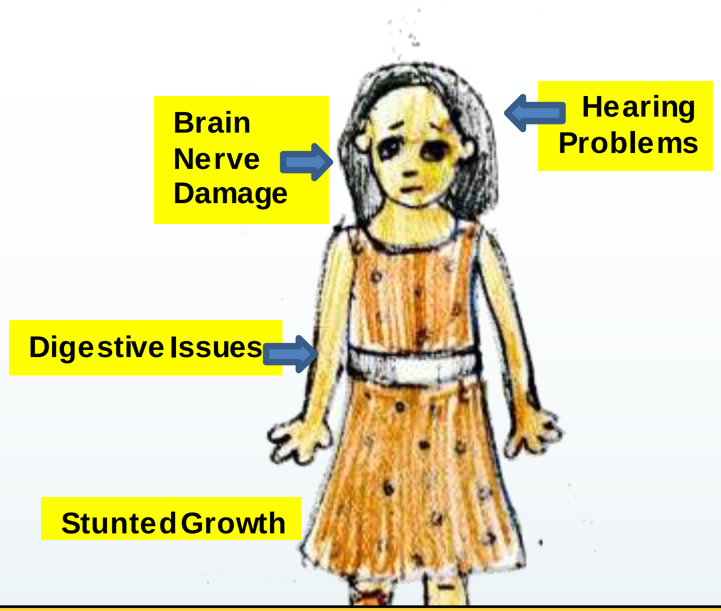


Source: Data from DDWS, April 2011

Arsenic	
IS:10500-2012	Desirable: 0.01 mg/l Permissible: 0.05mg/l
Risks or effects	Weight loss; Depression; Lack of energy; Skin and nervous system toxicity
Sources	Previously used in pesticides (orchards) Improper waste disposal or product storage of glass or electronics, Mining Rocks
Treatment	Activated Alumina Filtration, Reverse Osmosis, Distillation, Chemical Precipitation, Ion exchange, lime softening

Chromium	
IS 10500-2012	Desirable : 0.05 mg/l, Permissible : 0.05 mg/l
Risks or effects	Skin irritation, skin and nasal ulcers, lung tumors, gastrointestinal effects, damage to the nervous system and circulatory system, accumulates in the spleen, bones, kidney and liver
Sources	Septic systems Industrial discharge, mining sites Geological
Treatment	Ion Exchange, Reverse Osmosis, Distillation

Copper	
IS 10500-2012	Desirable : 0.05 mg/l, Permissible : 1.5 mg/l
Risks or effects	Anemia, digestive disturbances, liver and kidney damage, gastrointestinal irritations, bitter or metallic taste; Blue-green stains on plumbing fixtures
Sources	Leaching from copper water pipes and tubing, algae treatment Industrial and mining waste, wood preservatives Natural deposits
Treatment	Ion Exchange, Reverse Osmosis, Distillation



Lead	
IS 10500-2012	Desirable : 0.01 mg/l, Permissible : 0.01 mg/l
Risks or effects	Reduces mental capacity (mental retardation), interference with kidney and neurological functions, hearing loss, blood disorders, hypertension, death at high levels
Sources	Paint, diesel fuel combustion Pipes and solder, discarded batteries, paint, leaded gasoline Natural deposits
Treatment	Ion Exchange, Activated Carbon , Reverse Osmosis, Distillation

mercury
80
Hg
200.59

Mercury	
IS 10500-2012	Desirable : 0.001 mg/l, Permissible : 0.001 mg/l
Risks or effects	Loss of vision and hearing, intellectual deterioration, kidney and nervous system disorders, death at high levels
Sources	Fungicides Batteries, fungicides Mining, electrical equipment, plant, paper and vinyl chloride Natural deposits
Treatment	Reverse Osmosis, Distillation

Zinc	
IS 10500-2012	Desirable :5 mg/l, Permissible : 15 mg/l
Risks or effects	Metallic taste
Sources	Leaching of galvanized pipes and fittings, paints, dyes Natural deposits
Treatment	Ion Exchange Water Softeners, Reverse Osmosis, Distillation

Total Coliform Bacteria and E.coliform Bacteria	
IS 10500-2012	E.Coliform or Thermotolerant Bacteria Nil / 100ml(Drinking Water, Water entering distribution System, Distribution System) Total coliform bacteria Nil / 100ml(Drinking Water, Water entering distribution System, Distribution SystemIn case of large supplies, where sufficient samples are examined, must not be present in 95% of any samples taken throughout 12mths period.)
Risks or effects	Gastrointestinal illness
Sources	Livestock facilities, septic systems, manure lagoons Household waste water Naturally occurring
Treatment	Chlorination , Ultraviolet, Distillation, Iodination

Bacteriological Analysis

Bacteria

Single cell microscopic organisms lacking chlorophyll Coliform group

Contamination

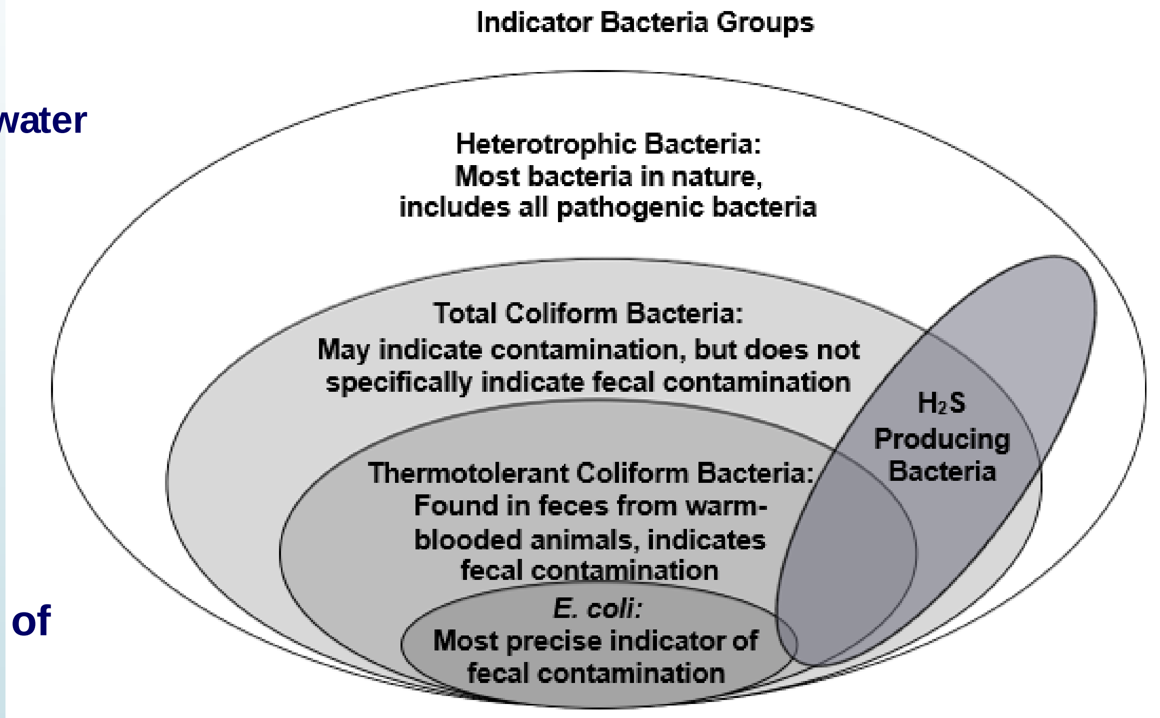
- Insanitary condition of surrounding area
- Unhygienic practices
- Discharge/seepage of sewage and domestic wastewater

Need

- Impact on water quality
- Potability for human consumption
- To prevent water-borne diseases
- To assess the quality of raw and treated water
- Specially to detect Faecal Contamination

Bacteriological analysis : mainly includes estimation of

- Total coliforms
- Faecal coliforms


Indicator Bacteria Groups

Heterotrophic Bacteria:
Most bacteria in nature,
includes all pathogenic bacteria

Total Coliform Bacteria:
May indicate contamination, but does not specifically indicate fecal contamination

Thermotolerant Coliform Bacteria:
Found in feces from warm-blooded animals, indicates fecal contamination

E. coli:
Most precise indicator of fecal contamination

H_2S
Producing
Bacteria

There are several factors to be taken into consideration when choosing an appropriate microbiological test method, including:

- Available resources
- Required level of accuracy and precision
- Technical skills of staff
- Geographical location
- Objective of the results

There are three main test methods to determine the presence of indicator bacteria in drinking water:

- Membrane filtration (MF)
- Presence/absence (P-A)
- Most probable number (MPN)

Traditionally, membrane filtration using international standard methods was recommended to test for indicator bacteria in drinking water. This method requires trained technicians, equipment and other supporting materials that were historically only available in a conventional laboratory. The relatively high cost of membrane filtration made it difficult, impractical or impossible to perform these tests in many parts of the world.

These constraints highlighted the great need for rapid, simple and inexpensive test methods. This need is especially great for small community and household water supplies that lack access to and cannot afford conventional laboratory testing. On-site testing using portable test kits and the development of alternative and simplified testing methods, such as P-A or MPN tests, have contributed to overcoming these constraints (WHO, 2002).

Methodology

Approved techniques generally used as per "Standard Methods for the examination of water and wastewater”

- Membrane Filter (MF)
- Multiple Tube Dilution (MTD)

MF-technique Principle

Biochemical reactions are used to detect the various groups of micro-organisms

MF-technique - Merits

- Results in 24 hours (MTD - 48 to 96 hours)
- Larger volume of samples can be tested (MTD - less volume)
- Results with greater precision (MTD - MPN)
- Require less laboratory space (MTD – More space)
- Easy processing (MTD – Tedious)
- Useful during normal and emergencies (MTD – Difficult in emergencies)

Limitations : Samples with more turbidity

H_2S Bacteria

- Hydrogen sulphide (H_2S) bacteria were reported in 1982 as a simple way to indicate faecal contamination in drinking water (Manja et al., 1982 cited in UNICEF, 2008). The authors noted that water containing coliform bacteria also consistently contained organisms that produced H_2S.

- The H_2S test does not specifically test for standard indicator bacteria, such as *E. coli* or thermotolerant coliforms. Rather, a large number of bacteria can produce H_2S (e.g., *Citrobacter, Enterobacter, Salmonella, Clostridium perfringens*). Most of these bacteria come from faeces.

- However, faecal bacteria are the not only bacteria that produce H_2S. Sulphate-reducing bacteria (which do not come from faeces) and water that has naturally high sulfide levels (this is particularly true in groundwater) will also make the H_2S test turn positive.

- Therefore, you should be cautious when using H_2S as an indicator of water quality since there are possible sources other than fecal contamination that can give a positive result (WHO, 2002).

Leh water samples studies

- Most of the water samples were found within the desirable or permissible limit as prescribed by BIS standards
- 2018, Dutta et al: Iron concentration was above the desirable level in all the collected samples. The iron concentration was in range 0.56 to 0.58mg/L. Iron concentrations have exceeded the desirable limit of 0.3mg/L.
    - high concentration of Mg may be responsible for hardness of water. Bharti et al, 2017, hardness contributing ion was calcium
- 2015, Dolma et al: groundwater quality in the study area in general are well within the permissible limits and hence suitable for domestic purposes.
- 2019, LeDEG-Borda report:
    - Study by TUM summer 2017: almost 90% of the samples had traces of E.coli and nitrates
    - Study by CDD, Bengaluru Jan 2019: Murtsey tube well: above permissible limits: turbidity, nitrates, total hardness and fluoride
    - Cold winter is an unfavourable environment for E.Coli bacteria to multiply. Also less tourism in winters means pollutants seeping in ground will be very low. Many locals switch to dry toilets in winter as it uses no water. Wastewater and faecal discharge would be highest during summer tourist season.

THANK YOU

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Making India Sustainable

Indian Institute Of Sustainable Development (IISD), New Delhi

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