NPTEL ONLINE CERTIFICATION COURSES

Course Name: Introduction to Environmental Engineering and Science – Fundamentals and Sustainability Concepts

Faculty Name: Dr. Brajesh Kumar Dubey

Department : Civil engineering

Topic Water Quantity and Quality

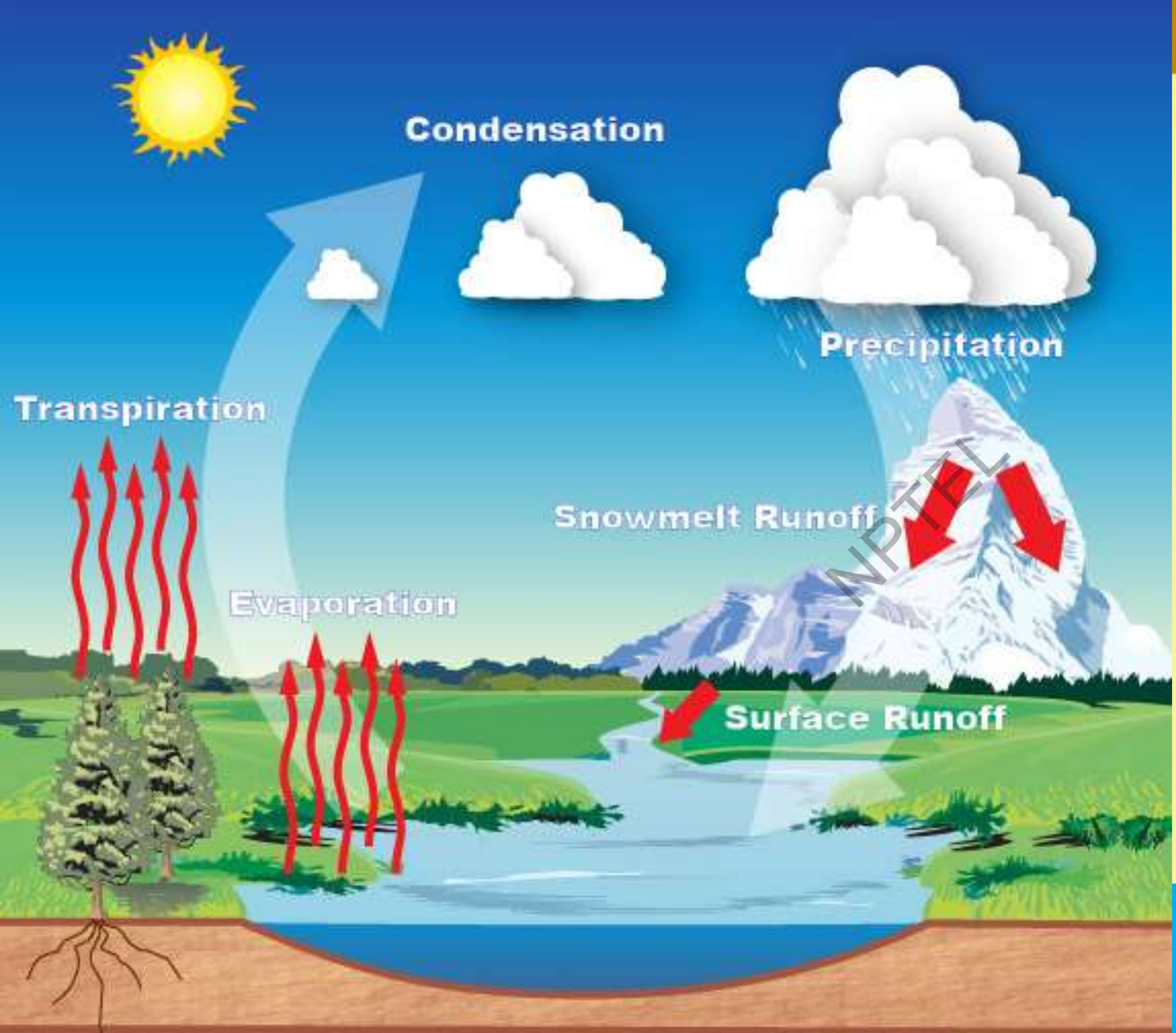
Lecture 31: Water quantity

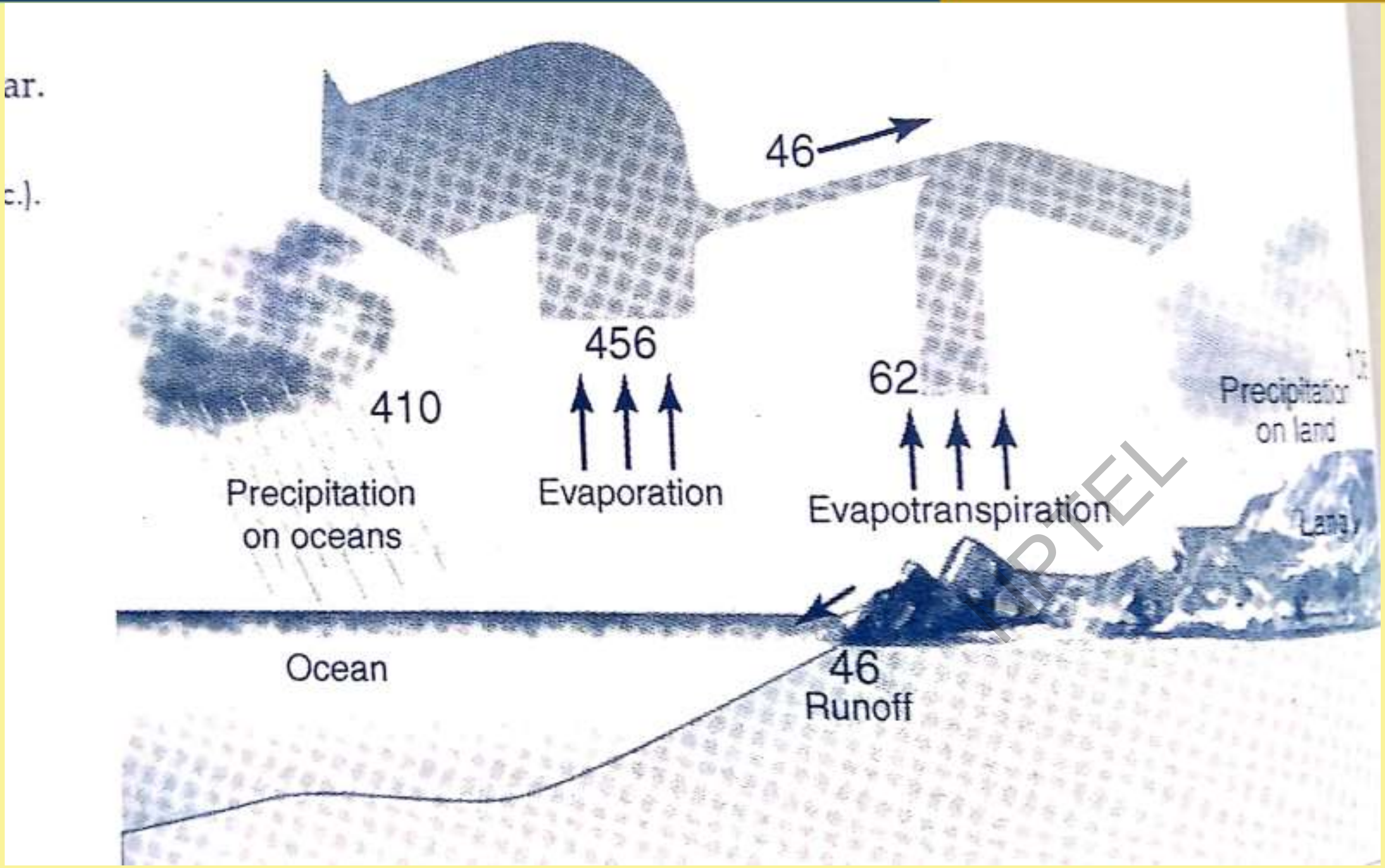
CONCEPTS COVERED

Concepts to be Covered

- ❑ Water quantity
- ❑ Water quality

Hydrologic cycle





The Hydrologic Cycle Units of water transfer are 10^{12} m^3/year.

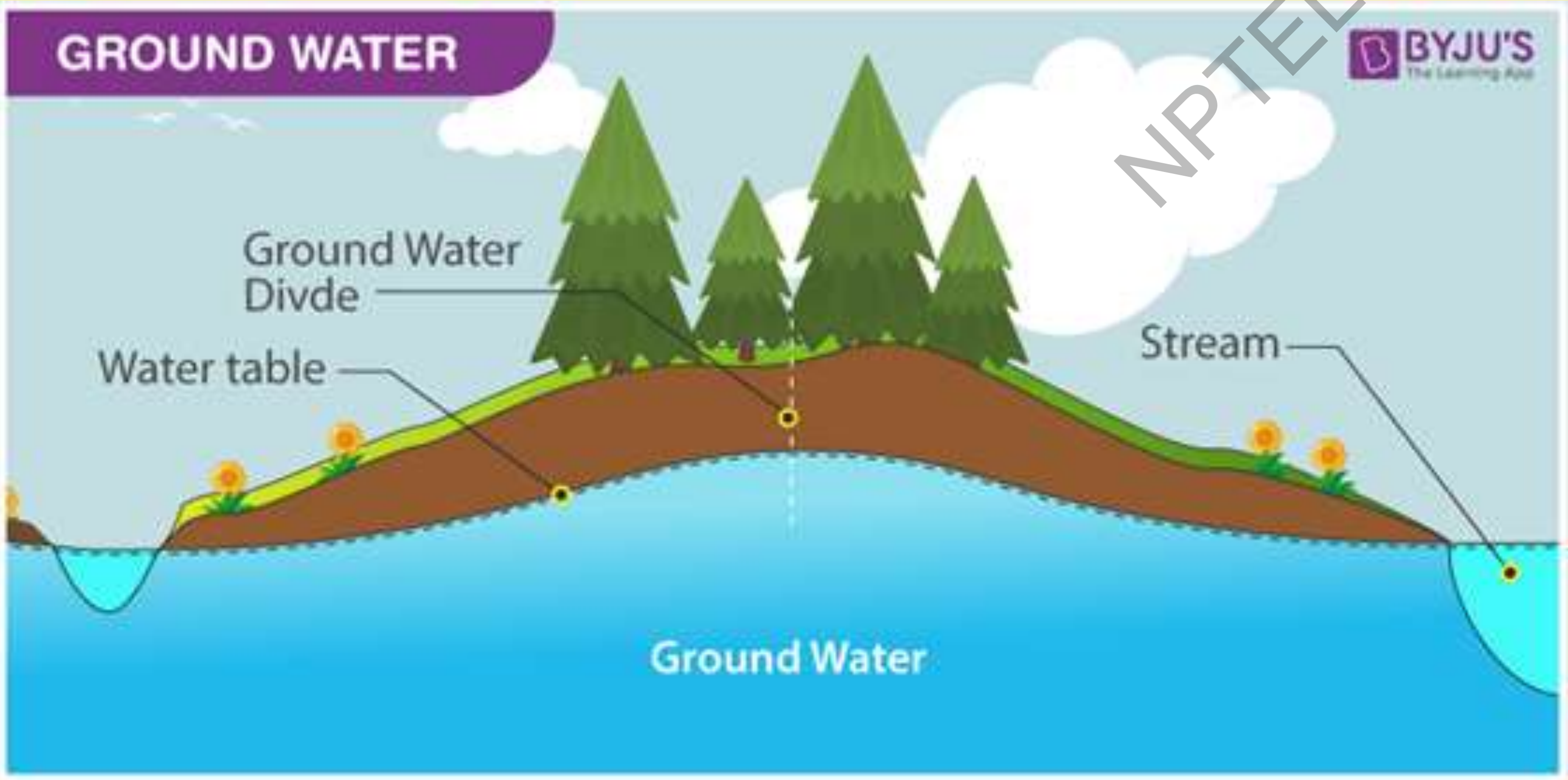
Sources of water

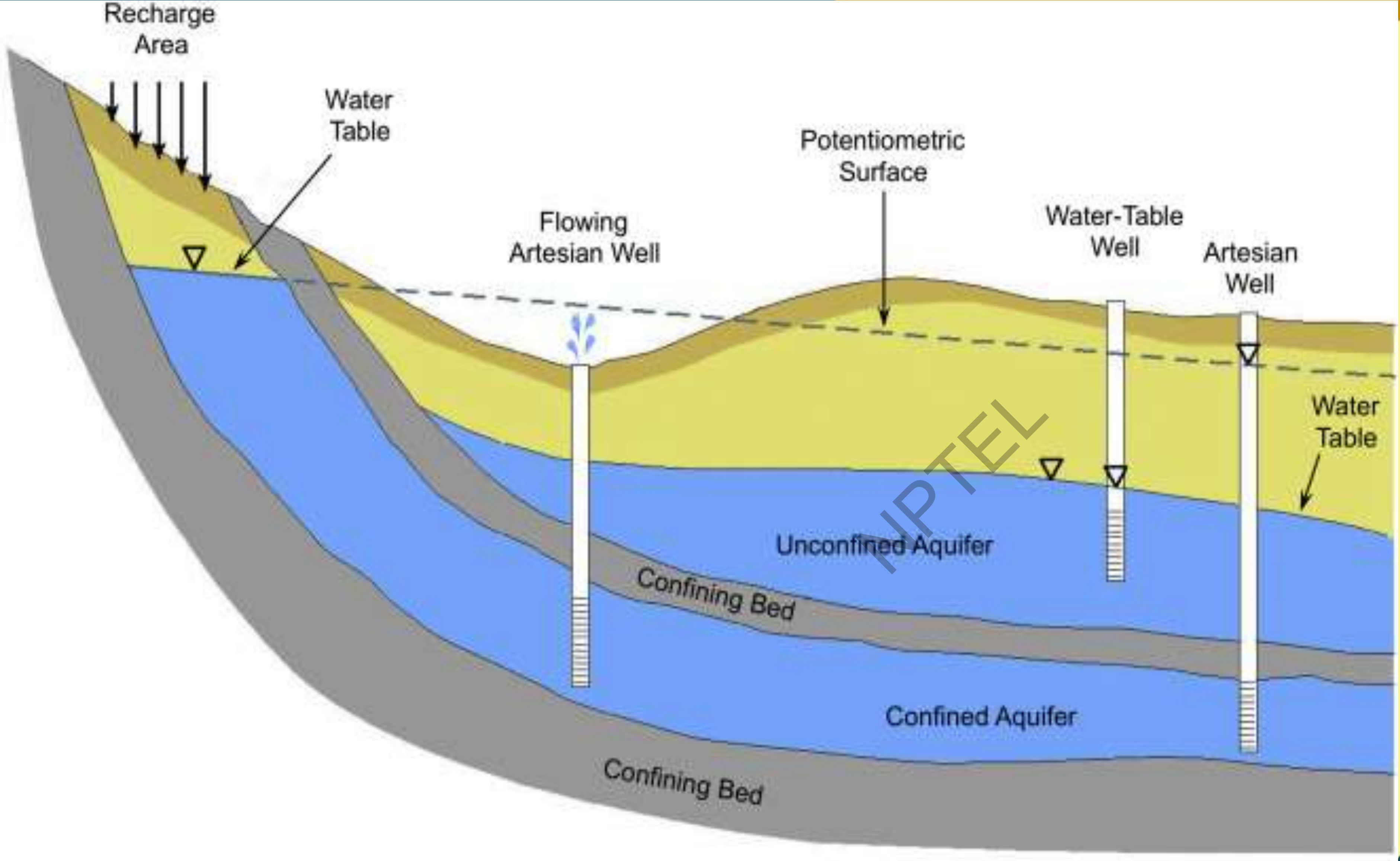
Groundwater

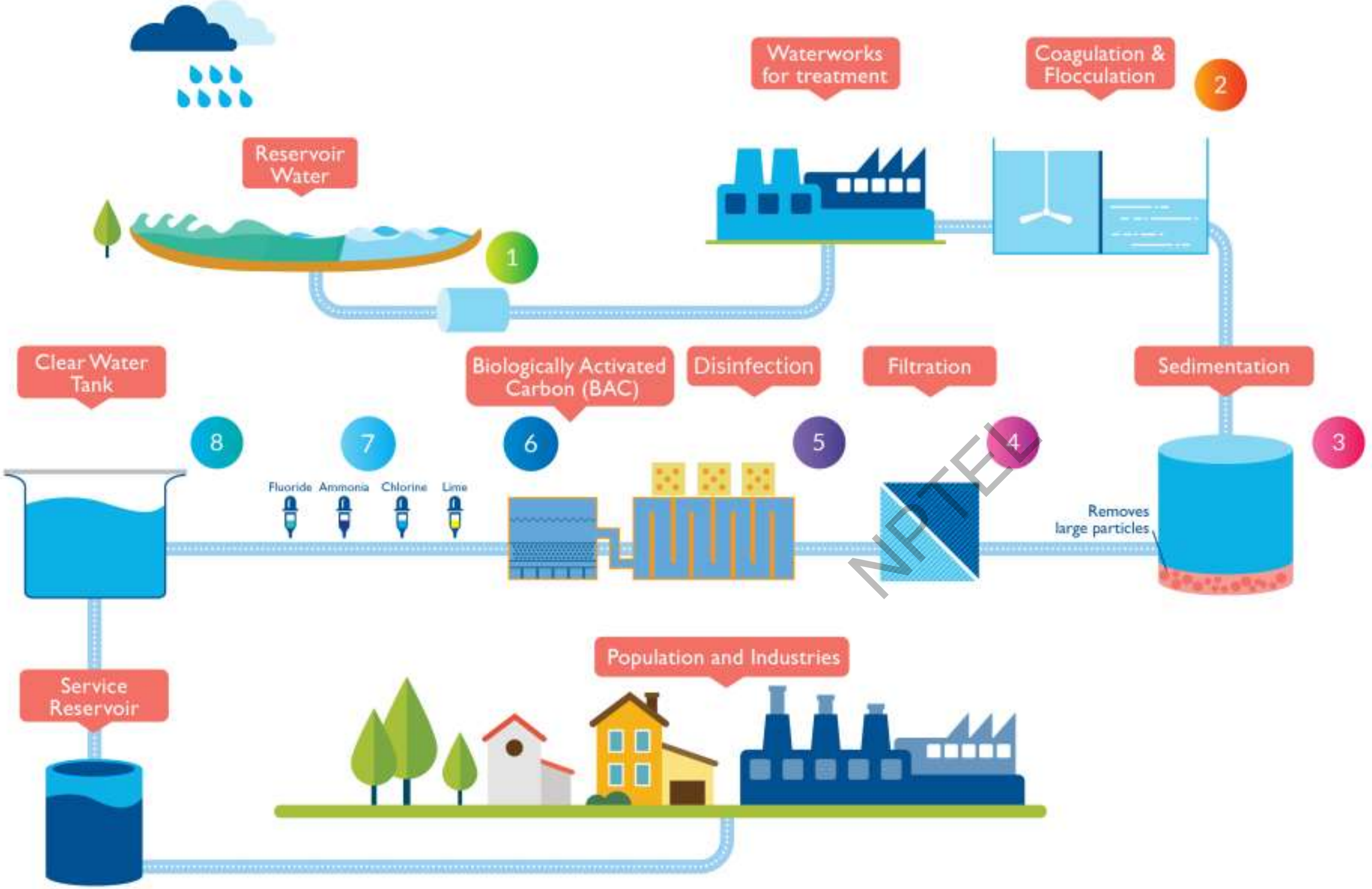
Groundwater is located underground in large aquifers and must be pumped out of the ground after drilling a deep well.

Surface water

Surface water is found in lakes, rivers and streams and is drawn into the public water supply by an intake.




Recharge Area
Water Table
Potentiometric Surface
Flowing Artesian Well
Water-Table Well
Artesian Well
Water Table
Unconfined Aquifer
Confining Bed
Confined Aquifer
Confining Bed


Reservoir Water
1
Waterworks for treatment
Coagulation & Flocculation
2
Sedimentation
3
Removes large particles
Filtration
4
Disinfection
5
Biologically Activated Carbon (BAC)
6
7
Fluoride
Ammonia
Chlorine
Lime
8
Clear Water Tank
Service Reservoir
Population and Industries

Essential Elements

(1) Intake and reservoir

(2) Water treatment plant

(3) Elevated tanks and stand pipes

(4) Valves

(5) Hydrants

(6) Distribution systems

(7) Service

Sources of water

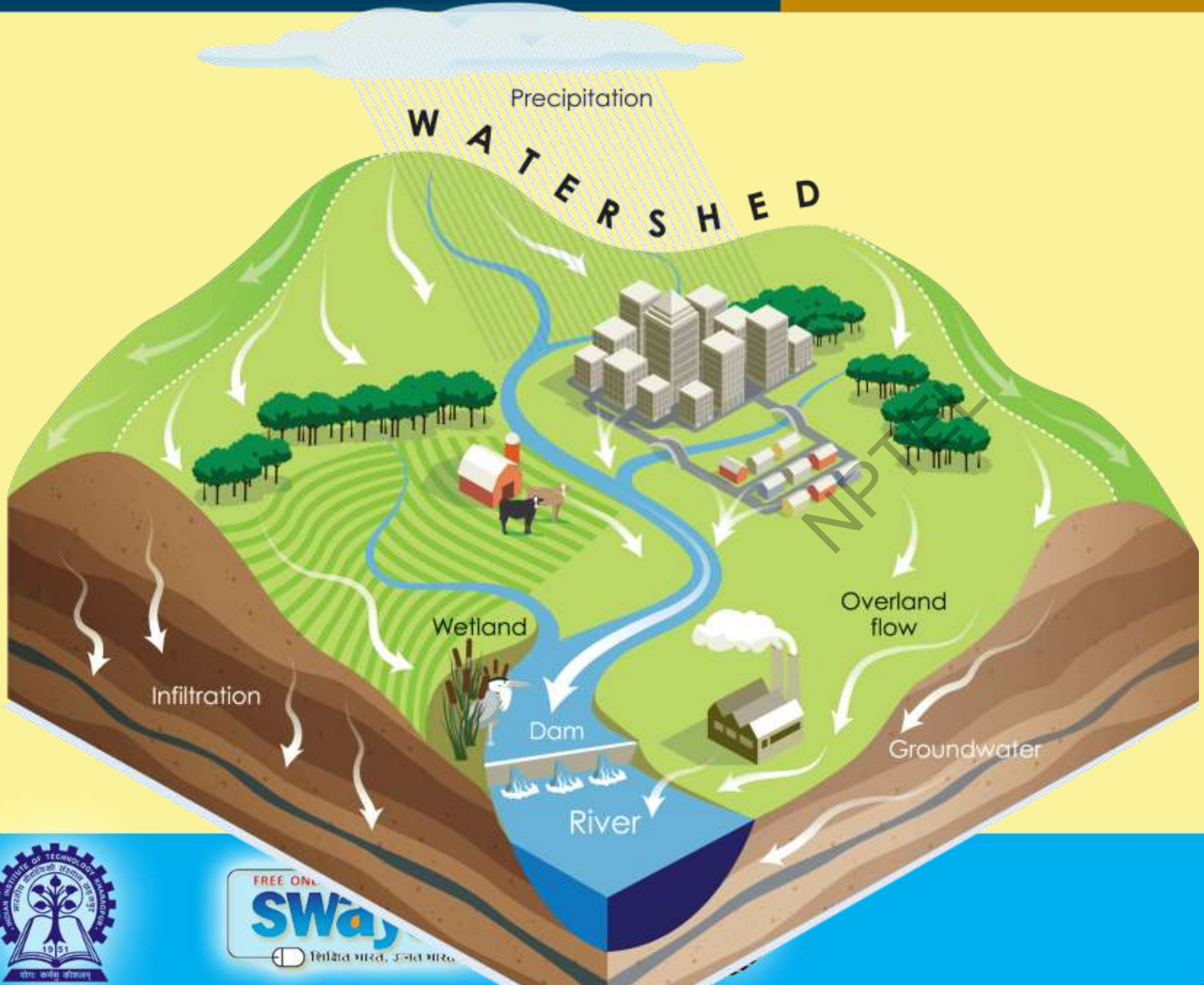
Surface water

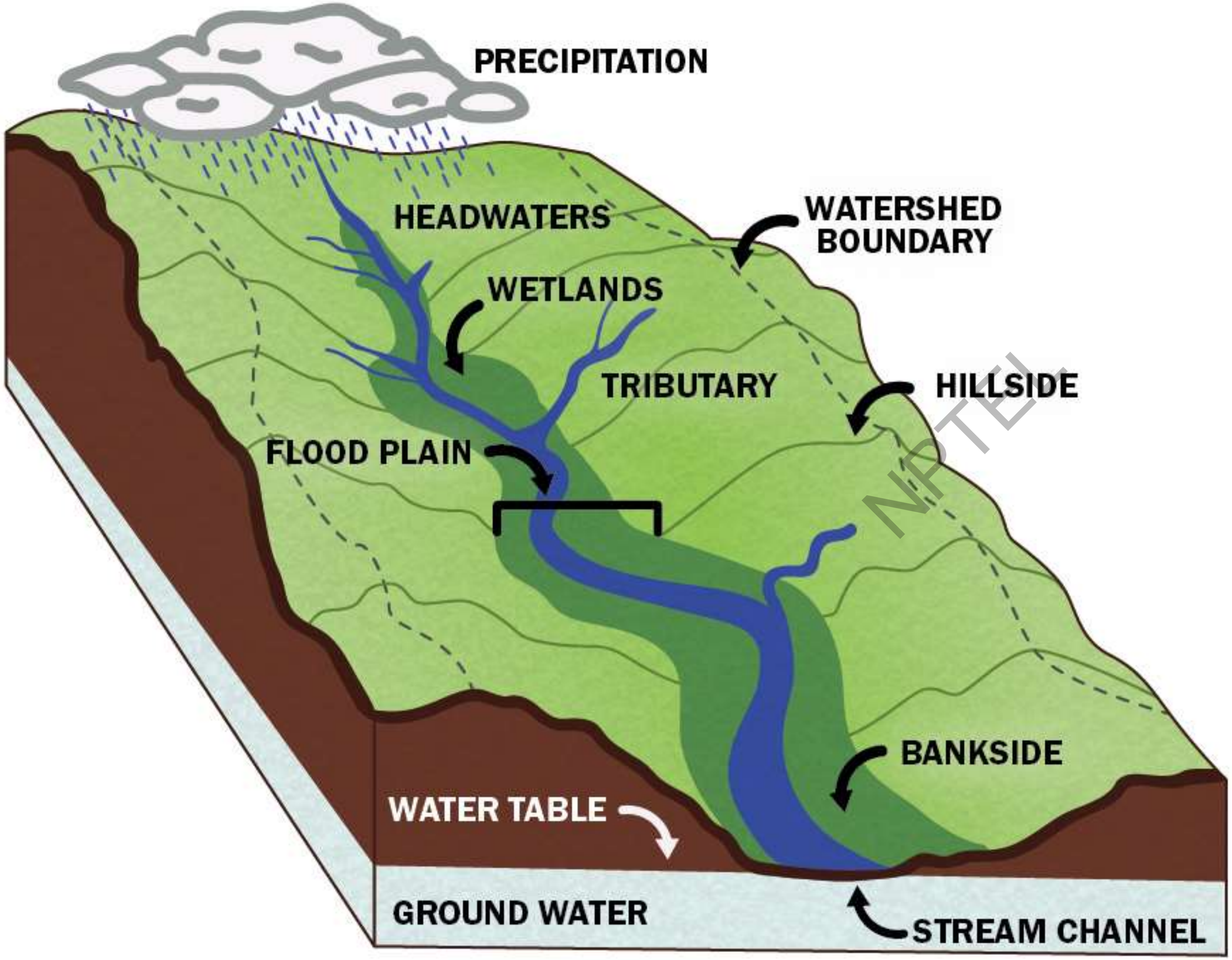
Surface water is found in lakes, rivers and streams and is drawn into the public water supply by an intake.

Watersheds

A Watershed is an area of land where all of the water that is under it, or drains off of it collects into the same place (e.g. The River).

Most of the watersheds in Idaho are part of the Columbia River Basin Watershed, which drains into the Pacific Ocean!


Precipitation
WATERSHED
Wetland
Overland flow
Infiltration
Dam
Groundwater
River


PRECIPITATION
HEADWATERS
WATERSHED
BOUNDARY
WETLANDS
TRIBUTARY
HILLSIDE
FLOOD PLAIN
BANKSIDE
WATER TABLE
GROUND WATER
STREAM CHANNEL

Estimating surface runoff from land use

Storm water quantity can be estimated by rational method as below:

Storm water quantity, **$Q = C.I.A / 360$**

Where, Q = Quantity of storm water, m^3 /sec

C = Coefficient of runoff

I = Intensity of rainfall (mm/hour) for the duration equal to time of concentration, and

A = Drainage area in hectares

Estimating surface runoff from land use

Type of Cover	Coefficient of runoff
Business areas	0.70 – 0.90
Apartment areas	0.50 – 0.70
Single family area	0.30 – 0.50
Parks, Playgrounds, Lawns	0.10 – 0.25
Paved Streets	0.80 –0.90
Water tight roofs	0.70 – 0.95

Estimating surface runoff from land use

The catchment area is of 300 hectares. Calculate the runoff coefficient and quantity of storm water runoff, if intensity of rainfall is 30 mm/h. The surface cover in the catchment can be classified as given below:

Type of cover	Coefficient of runoff	Percentage
Roofs	0.90	15
Pavements and yards	0.80	15
Lawns and gardens	0.15	25
Roads	0.40	20
Open ground	0.10	15
Single family dwelling	0.50	10

Estimation of storm water discharge

Overall runoff coefficient

C = [A1.C1 + A2.C2 + ….+ An.Cn] / [A1 + A2 + …+ An]

$$= \frac{0.15 \times 0.90 + 0.15 \times 0.80 + 0.25 \times 0.15 + 0.20 \times 0.4 + 0.15 \times 0.1 + 0.10 \times 0.5}{0.15 + 0.15 + 0.25 + 0.20 + 0.15 + 0.10}$$

= 0.44

Therefore quantity of storm water, Q = C.I.A/360

= 0.44 x 30 x 300/360

= 11 m^3/sec

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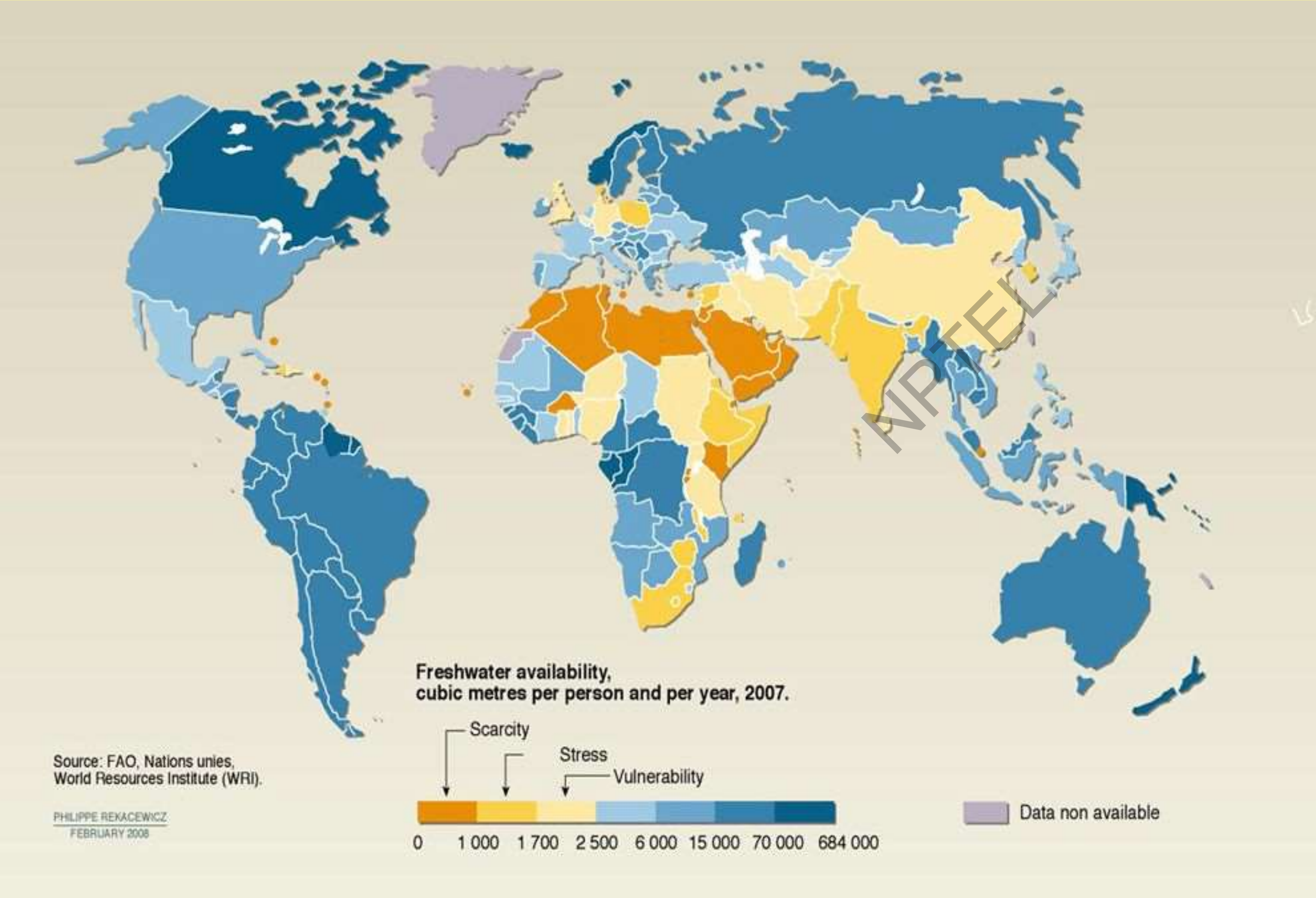
Topic Water Quantity and Quality

Lecture 32: Water Availability & Usage

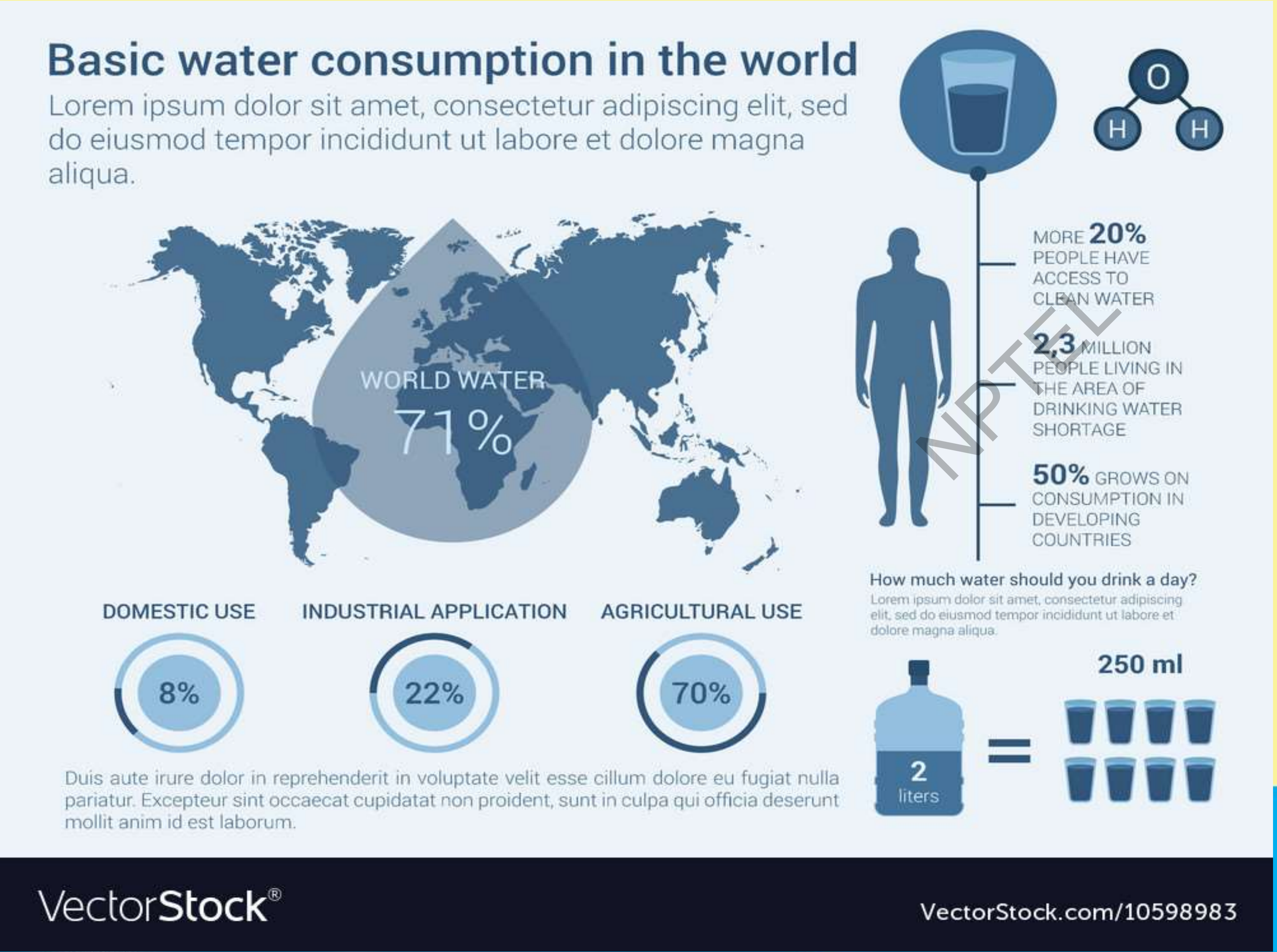
Water availability



Water availability

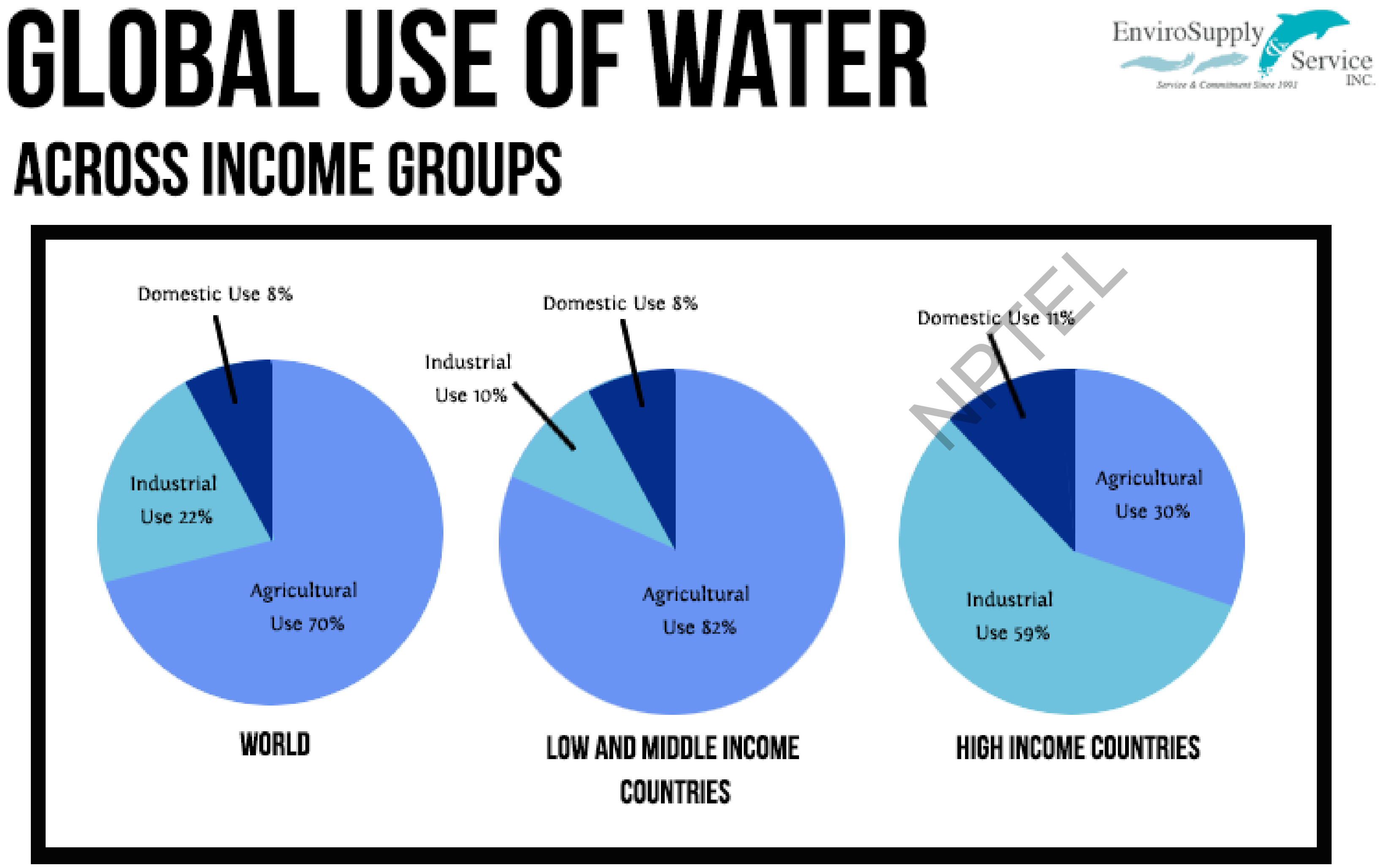
Percent of World's Total Freshwater in Different Locations Total amount of freshwater on earth is approximately 3.5×10^7 km^3	
Location	**Percent of World's Freshwater**
Glaciers and permanent snow cover	68.7
Groundwater	30.1
Lakes	0.26
Soil moisture	0.05
Atmosphere	0.04
Marshes and swamps	0.03
Biological Water	0.003
Rivers	0.006

Water usage



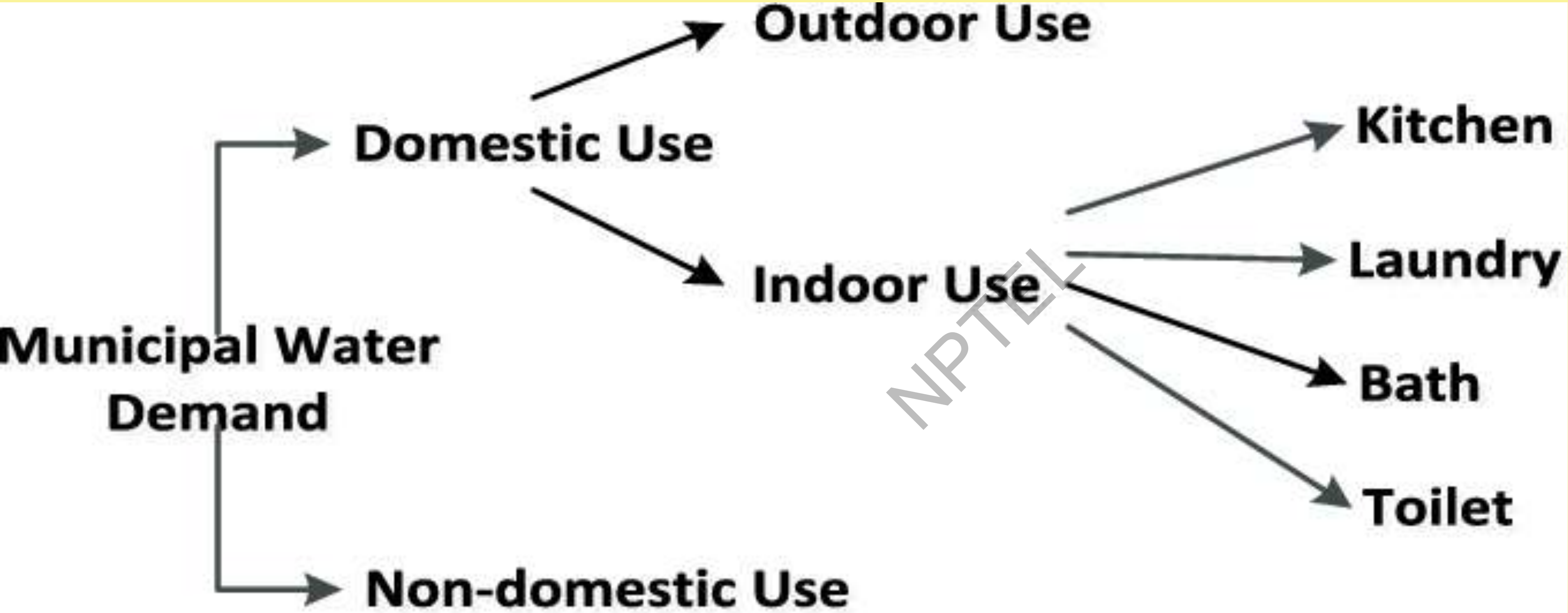
Basic water consumption in the world
Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.
O
H
H
WORLD WATER
71%
MORE 20% PEOPLE HAVE ACCESS TO CLEAN WATER
2,3 MILLION PEOPLE LIVING IN THE AREA OF DRINKING WATER SHORTAGE
50% GROWS ON CONSUMPTION IN DEVELOPING COUNTRIES
How much water should you drink a day?
Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.
DOMESTIC USE
8%
INDUSTRIAL APPLICATION
22%
AGRICULTURAL USE
70%
2 liters
=
250 ml
Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.
VectorStock®
VectorStock.com/10598983

Water usage



GLOBAL USE OF WATER
ACROSS INCOME GROUPS
EnviroSupply & Service INC.
Domestic Use 8%
Industrial Use 22%
Agricultural Use 70%
WORLD
Domestic Use 8%
Industrial Use 10%
Agricultural Use 82%
LOW AND MIDDLE INCOME COUNTRIES
Domestic Use 11%
Agricultural Use 30%
Industrial Use 59%
HIGH INCOME COUNTRIES

Municipal water demand



Municipal water demand: Forecast

WATER DEMAND

Types of Water Demands

1. Domestic Water Demand
2. Industrial Water Demand
3. Institutional and Commercial Water Demand
4. Demand for Public Uses
5. Fire Demand
6. Wastes and Thefts act

Per Capita Demand

$$\text{PCD} = \frac{Total\ yearly\ water\ requirement\ of\ the\ city\ in\ litres}{365 \times Design\ population}$$

Factors affecting Per Capita Demand

(1) Size of the city

(2) Climate conditions

(3) Types of gentry and habits of people

(4) Industrial and commercial activities

(5) Quality of water supplies

(6) Pressure in the distribution systems

(7) Development of sewerage facilities

(8) System of supply

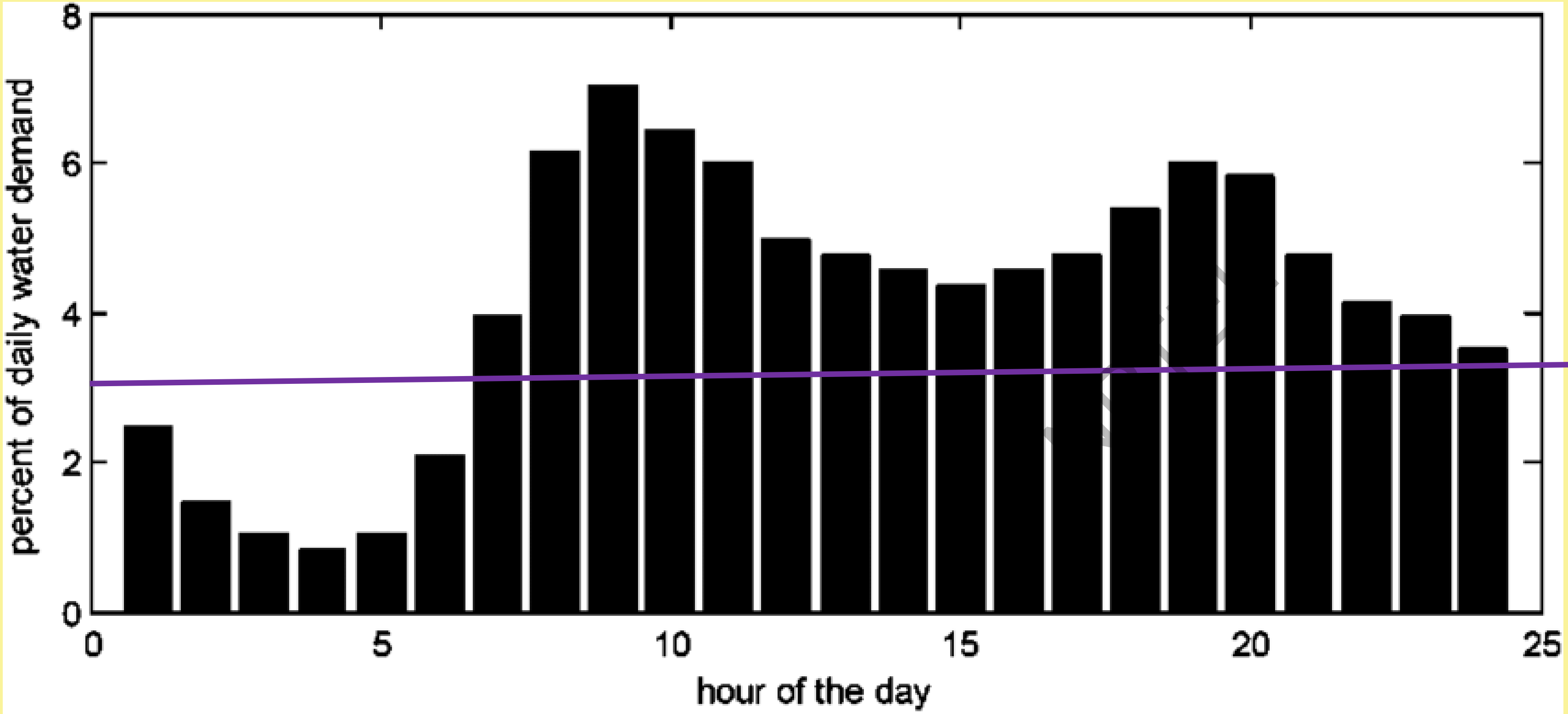
(9) Cost of water

(10) Policy of metering and method of charging

Factors affecting water demand

Factors	Water Requirement	
	More Water	**Lesser Water**
Climatic Condition		
Status and Habits of Residents		
Availability of Sewer		
Water Rate		
Type of Water Supply		

Variation in water demand



Average demand

Source:
https://www.researchgate.net/publication/276208691_Optimizing_Wellfield_Operation_in_a_Variable_Power_Price_Regime/figures?lo=1

Variation in water demand

Maximum daily demand = 1.8 × Average daily demand

Maximum hourly demand = 1.5 × 1.8 × Average daily demand
= 2.7 × Average daily demand

Total draft/demand

i. Maximum daily demand + Fire demand
ii. Maximum hourly demand

Fire demand

It is the amount of water required for fire fighting purposes.

The actual amount of water used in a year for fire is very small, but the rate of flow is large.

Fire demand

1. Kuichling's Formula

$$Q = 3182\sqrt{\frac{P}{1000}}$$

2. Buston's Formula

$$Q = 5663\sqrt{\frac{P}{1000}}$$

3. Freeman's Formula

$$Q = 1136\left(\frac{P}{5000} + 10\right)$$

4. National Board of Fire Underwriters formula

$$Q = 4637\sqrt{\frac{P}{1000}}\left(1 - 0.01\sqrt{\frac{P}{1000}}\right)$$

Q obtained is in liters/min
P is the population of a city

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Topic Water Quantity and Quality

Lecture 33: Population Forecasting

Population forecasting

Design of water supply and sanitation scheme is based on the projected population of a particular city, estimated for the design period. Any underestimated value will make system inadequate for the purpose intended; similarly overestimated value will make it costly. Changes in the population of the city over the years occur, and the system should be designed taking into account of the population at the end of the design period.

Population forecasting

Factors affecting changes in population are:

- Increase due to births
- Decrease due to deaths
- Increase/ decrease due to migration
- Increase due to annexation

The present and past population record for the city can be obtained from the census population records. After collecting these population figures, the population at the end of design period is predicted using various methods as suitable for that city considering the growth pattern followed by the city.

Population forecasting method

- Arithmetical Increase Method
- Geometrical Increase Method
- Incremental Increase Method
- Graphical Method
- Comparative Graphical Method
- Master Plan Method
- Logistic Curve Method

Arithmetical Increase Method

- This method is suitable for large and old city with considerable development.

If it is used for small, average or comparatively new cities, it will give lower population estimate than actual value.

In this method the average increase in population per decade is calculated from the past census reports.
This increase is added to the present population to find out the population of the next decade. Thus, it is assumed that the population is increasing at constant rate.

Arithmetical Increase Method

Hence, dP/dt = Constant i.e., rate of change of population with respect to time is constant.

Therefore, Population after n^{th} decade will be

$$P_n = P + n.C$$

Where, $\mathbf{P_n}$ is the population after ‘n’ decades and ‘P’ is present population.

Arithmetical Increase Method

Example:1

Predict the population for the year 2021, 2031, and 2041 from the following population data.

Year	**1961**	**1971**	**1981**	**1991**	**2001**	**2011**
Population	8,58,545	10,15,672	12,01,553	16,91,538	20,77,820	25,85,862

Year	Population	Increment
1961	8,58,545	
1971	10,15,672	157127
1981	12,01,553	185881
1991	16,91,538	489985
2001	20,77,820	386282
2011	25,85,862	508042

Average increment = 345463

Population forecast for year 2021 is,

P_{2021} = 2585862 + 345463 x 1 = 2931325

Similarly, P_{2031} = 2585862 + 345463 x 2 = 3276788

P_{2041} = 2585862 + 345463 x 3 = 3622251

Geometrical Increase Method

- In this method the percentage increase in population from decade to decade is assumed to remain constant.
- Geometric mean increase is used to find out the future increment in population.
- Since this method gives higher values and hence should be applied for a new industrial town at the beginning of development for only few decades.

The population at the end of n^{th} decade 'Pn' can be estimated as:

$$P_n = P\,(1 + I_G/100)^n$$

Where, I_G = geometric mean (%)

P = Present population

N = no. of decades

Geometrical Increase Method

Example:2

Considering data given in example 1 predict the population for the year 2021, 2031, and 2041 using geometrical progression method.

Year	Population	Increment	Geometrical increase Rate of growth
1961	8,58,545		
1971	10,15,672	157127	(157127/858545) = 0.18
1981	12,01,553	185881	(185881/1015672) = 0.18
1991	16,91,538	489985	(489985/1201553) = 0.40
2001	20,77,820	386282	(386282/1691538) = 0.23
2011	25,85,862	508042	(508042/2077820) = 0.24

Geometrical Increase Method

Geometric mean I_G = (0.18 x 0.18 x 0.40 x 0.23 x 0.24)1/5 = 0.235 i.e., 23.5%

Population in year 2021 is, P_{2021} = 2585862 x $(1+ 0.235)^1$ = 3193540

Similarly for year 2031 and 2041 can be calculated by,

$$P_{2031} = 2585862 \times (1+ 0.235)^2 = 3944021$$

$$P_{2041} = 2585862 \times (1+ 0.235)^3 = 4870866$$

Incremental Increase Method

This method is modification of arithmetical increase method and it is suitable for an average size town under normal condition where the growth rate is found to be in increasing order. While adopting this method the increase in increment is considered for calculating future population. The incremental increase is determined for each decade from the past population and the average value is added to the present population along with the average rate of increase.

Hence, population after n^{th} decade is **$P_n = P + n.X + \{n\,(n+1)/2\}.Y$**

Where, Pn = Population after nth decade

X = Average increase

Y = Incremental increase

Incremental Increase Method

Example: 3 Considering data given in example 1 predict the population for the year 2021, 2031, and 2041 using incremental increase method.

Year	Population	Increment	Incremental increase (Y)
1961	8,58,545		-
1971	10,15,672	157127	-
1981	12,01,553	185881	+28754
1991	16,91,538	489985	+304104
2001	20,77,820	386282	-103703
2011	25,85,862	508042	+121760
	Total	1727317	350915
	Average	345463	87729

Incremental Increase Method

Population in year 2021 is,

P_{2021} = 2585862 + (345463 x 1) + {(1 (1+1))/2} x 87729 = 3019054

For year 2031

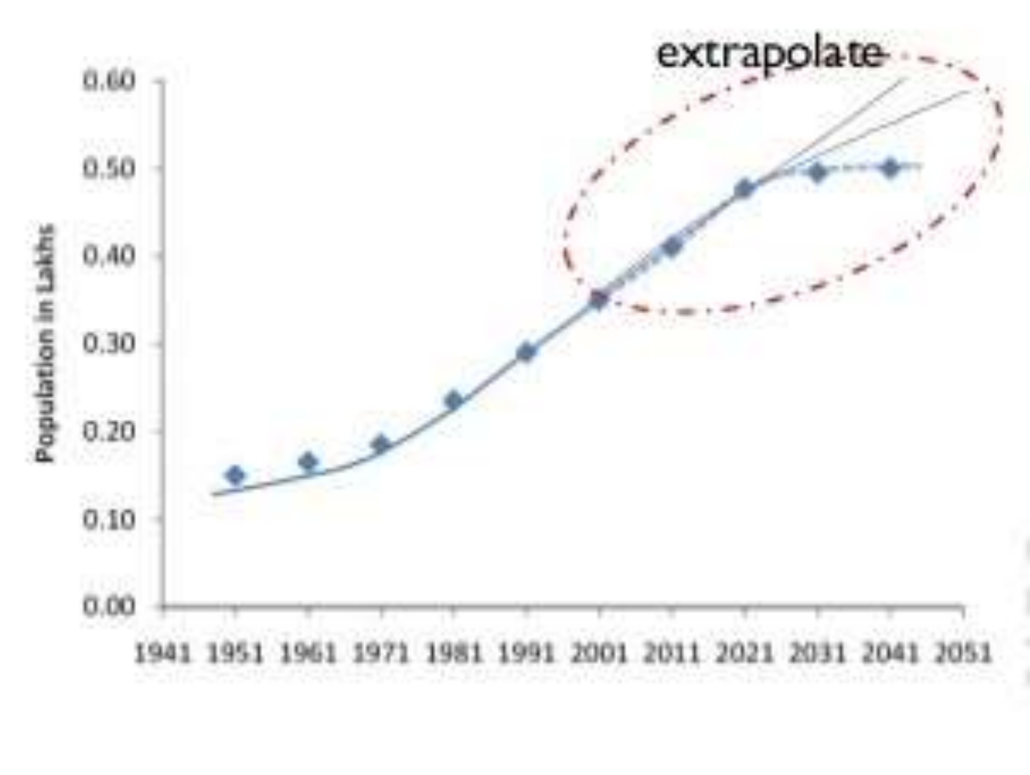
P_{2031} = 2585862 + (345463 x 2) + {(2 (2+1)/2)} x 87729 = 3539975

P_{2041} = 2585862 + (345463 x 3) + {(3 (3+1)/2)} x 87729 = 4148625

Graphical Method

In this method, the populations of last few decades are correctly plotted to a suitable scale on graph. The population curve is smoothly extended for getting future population.

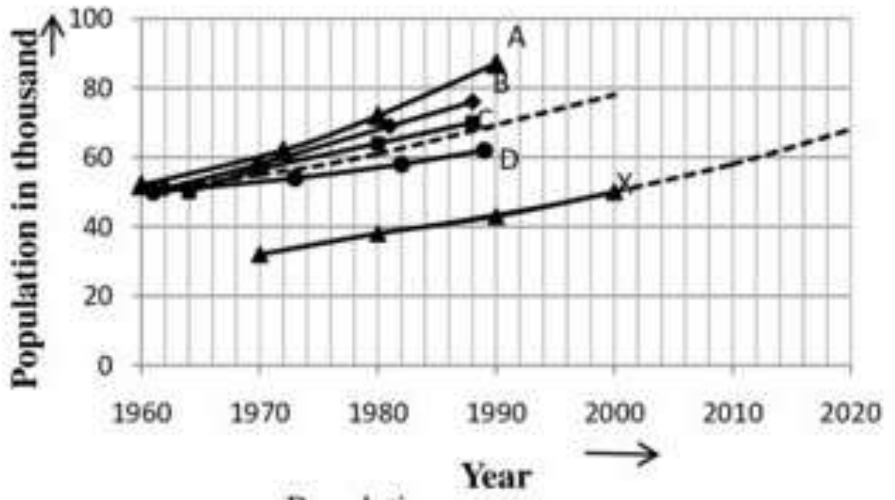
This extension should be done carefully and it requires proper experience and judgment.



The best way of applying this method is to extend the curve by comparing with population curve of some other similar cities having the similar growth condition.

Comparative Graphical Method

- In this method the census populations of cities already developed under similar conditions are plotted.
- The curve of past population of the city under consideration is plotted on the same graph.
- The curve is extended carefully by comparing with the population curve of some similar cities having the similar condition of growth.
- The advantage of this method is that the future population can be predicted from the present population even in the absence of some of the past census report.



Population curve

Master Plan Method

- The big and metropolitan cities are generally not developed in haphazard manner, but are planned and regulated by local bodies according to master plan.
- The master plan is prepared for next 25 to 30 years for the city.
- According to the master plan the city is divided into various zones such as residence, commerce and industry.
- The population densities are fixed for various zones in the master plan.
- From this population density total water demand and wastewater generation for that zone can be worked out. By this method it is very easy to access precisely the design population.

Logistic Curve Method

Equation of logistic curve is, P = $\frac{P_s}{1+m\ log_e^{-1}(nt)}$

where, P = population at any time t from the origin A

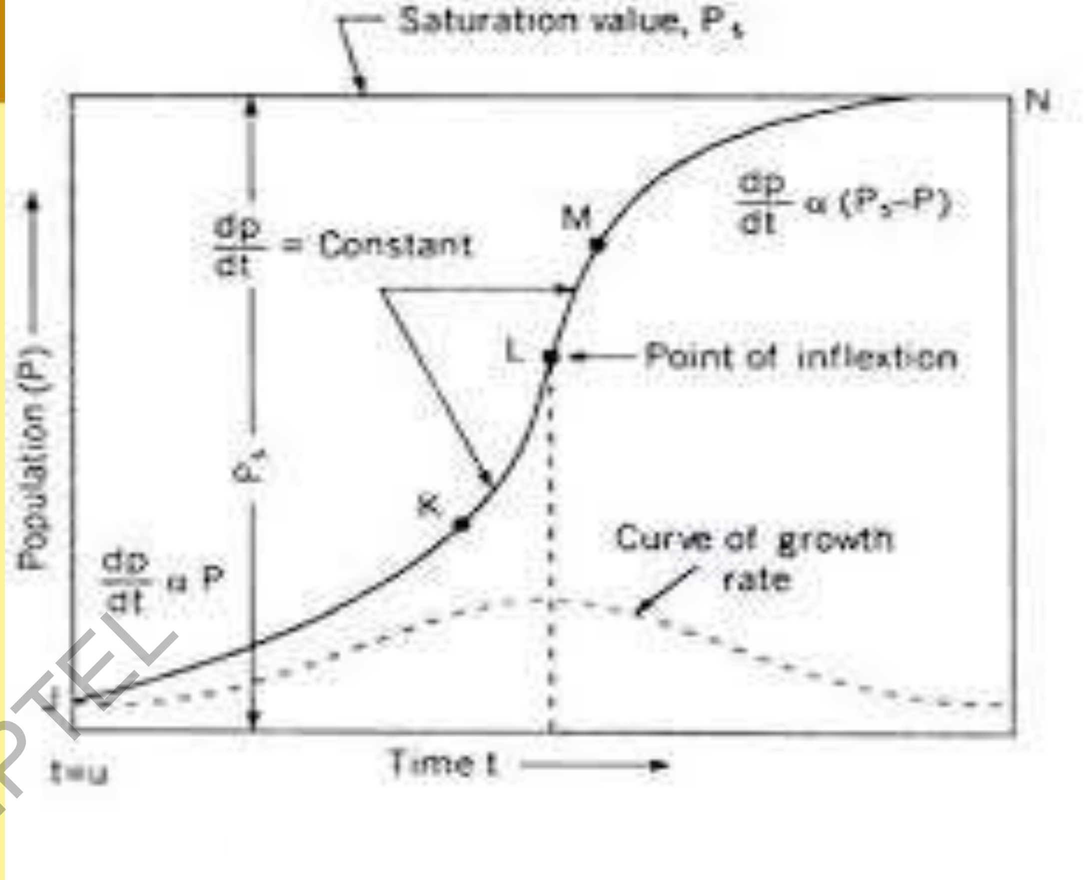
P_s = saturated population

m = $\frac{P_s P_o}{P_o}$ (a constant)

n = kp_s (another constant)

P_o = population at the start point of the curve.

k = constant



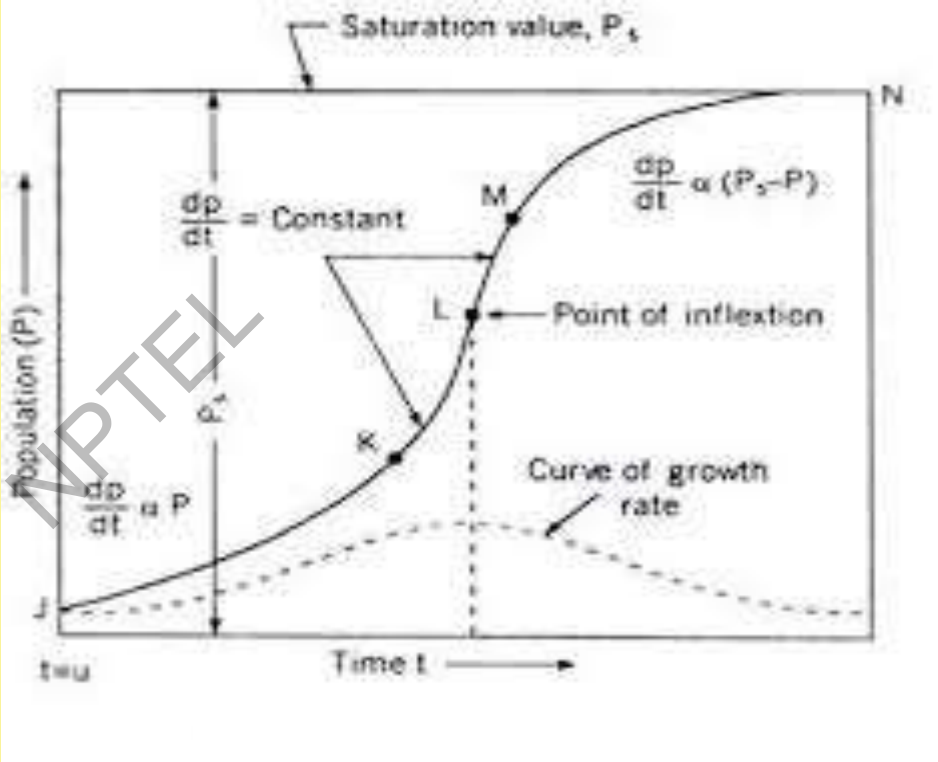
Logistic Curve Method

: if only three pairs of characteristic values P_0, P_1, P_2 at time t = t_0 =0, t1 and t_2 = $2t_1$ extending over the useful range of the census population are chosen, then

$$P_s = \frac{2P_0P_1P_2 - P_1^2(P_0+P_2)}{P_0P_2 - P_1^2},$$

$$m = \frac{P_s - P_o}{P_o},$$

$$n = \frac{1}{t_1} log_e \left[\frac{P_o(P_s-P_1)}{P_1(P_s-P_0)}\right] = \frac{2.3}{t_1} log_{10} \left[\frac{P_0(P_s-P_1)}{P_1(P_s-P_0)}\right]$$



Conveyance of Water

Water is generally conveyed by using pressure conduits (pipe). To design pressure conduits Darcy's Weisbach equation (or) Hazen Williams equation.

Weisbach equation, $h_f = \frac{fL\,V^2}{2gd} = \frac{fL\,Q^2}{12.1d^5}$

Hazen Williams equations,

$$V = 0.85C_h(R)^{0.63}\,(S)^{0.54}$$

To generate pressure to drive water from source to city or town it also require a pump. Capacity of pump require is found by following equation

$$BHP = \frac{\gamma_w QH}{0.746\eta_p\eta_m}$$

$\eta_p\eta_m$ = efficiency of pump & motor

A town with a population 1 lakh supplied water at a rate of 200 lpcd gets its supply from a source which is 8 km away from the town. Find the diameter of the conveying main (pipe) required if friction factor is 0.003. Elevation difference between the source and supply is 10 m.

Solution: Q = Population X per capita water supply

= 100000 X 200 l/day

= 0.231 m^3/sec

h_f = It is assumed as elevation difference between source and supply = 10 m

L = Distance between source and supply

$$h_f = \frac{flQ^2}{12.1d^5} = \frac{0.003 \times 8000 \times (0.231)^2}{12.1d^5} = 10$$

Diameter of the conveying main d = 0.4 m

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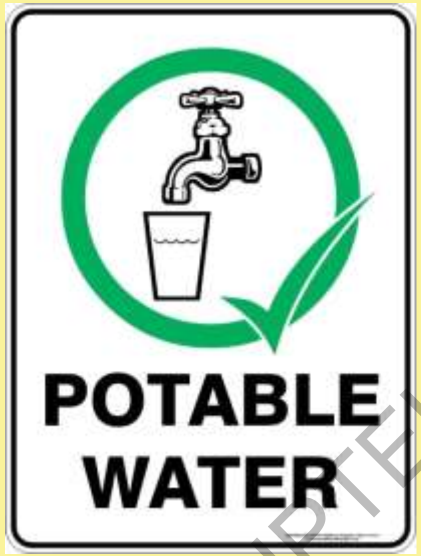
Topic Water Quantity and Quality

Lecture 34: Water quality

Water quality

Pure water



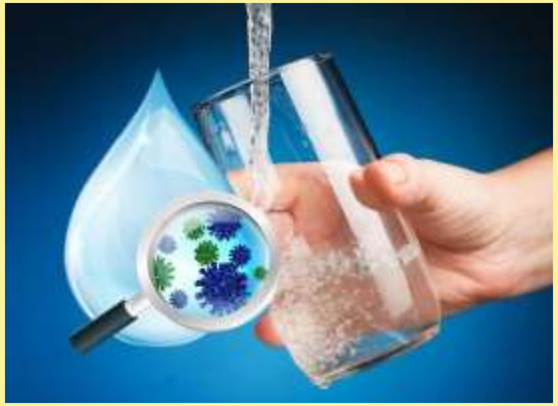
Potable water

Palatable water

Water quality

wholesome water

Polluted water



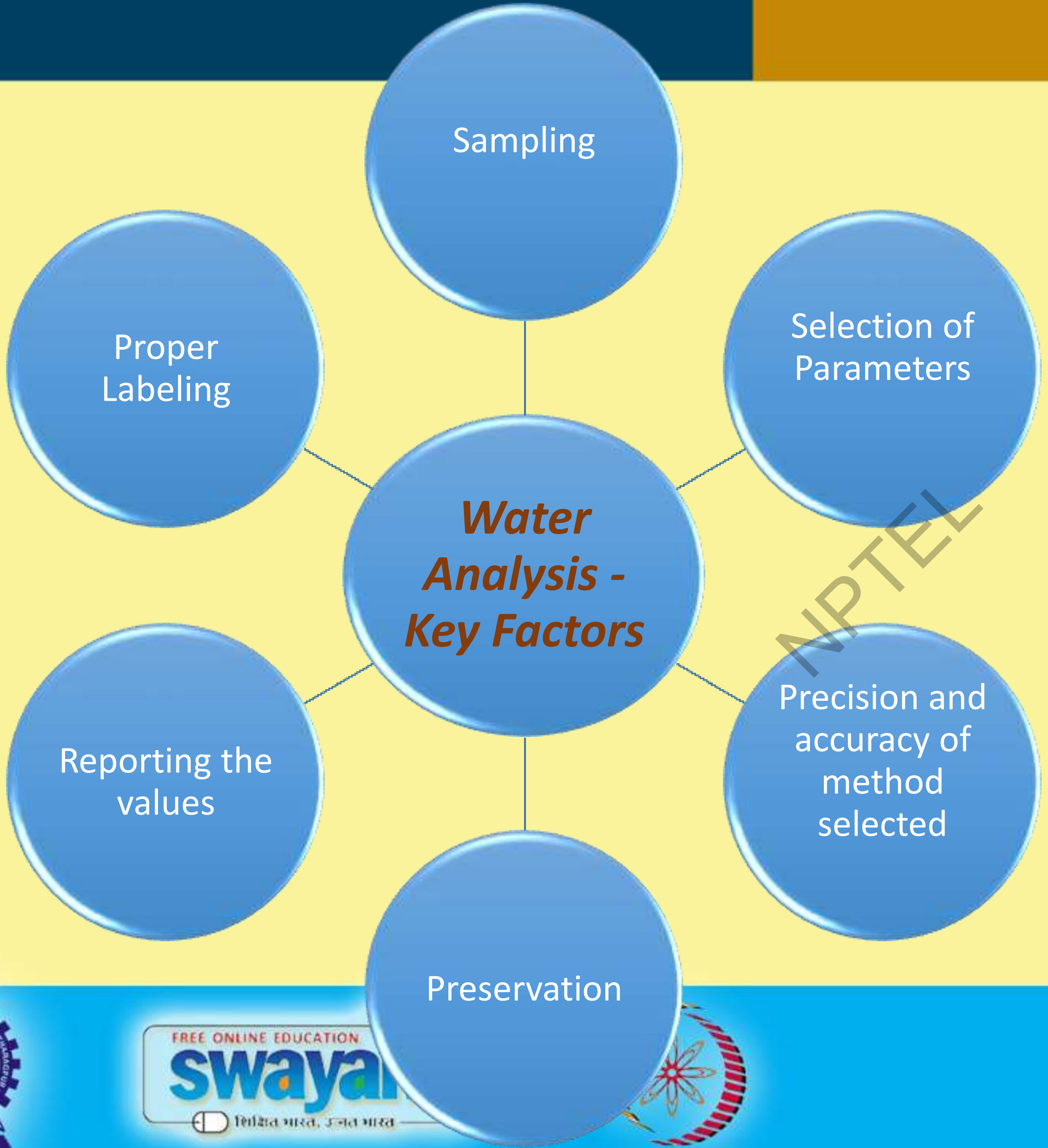
Contaminated water

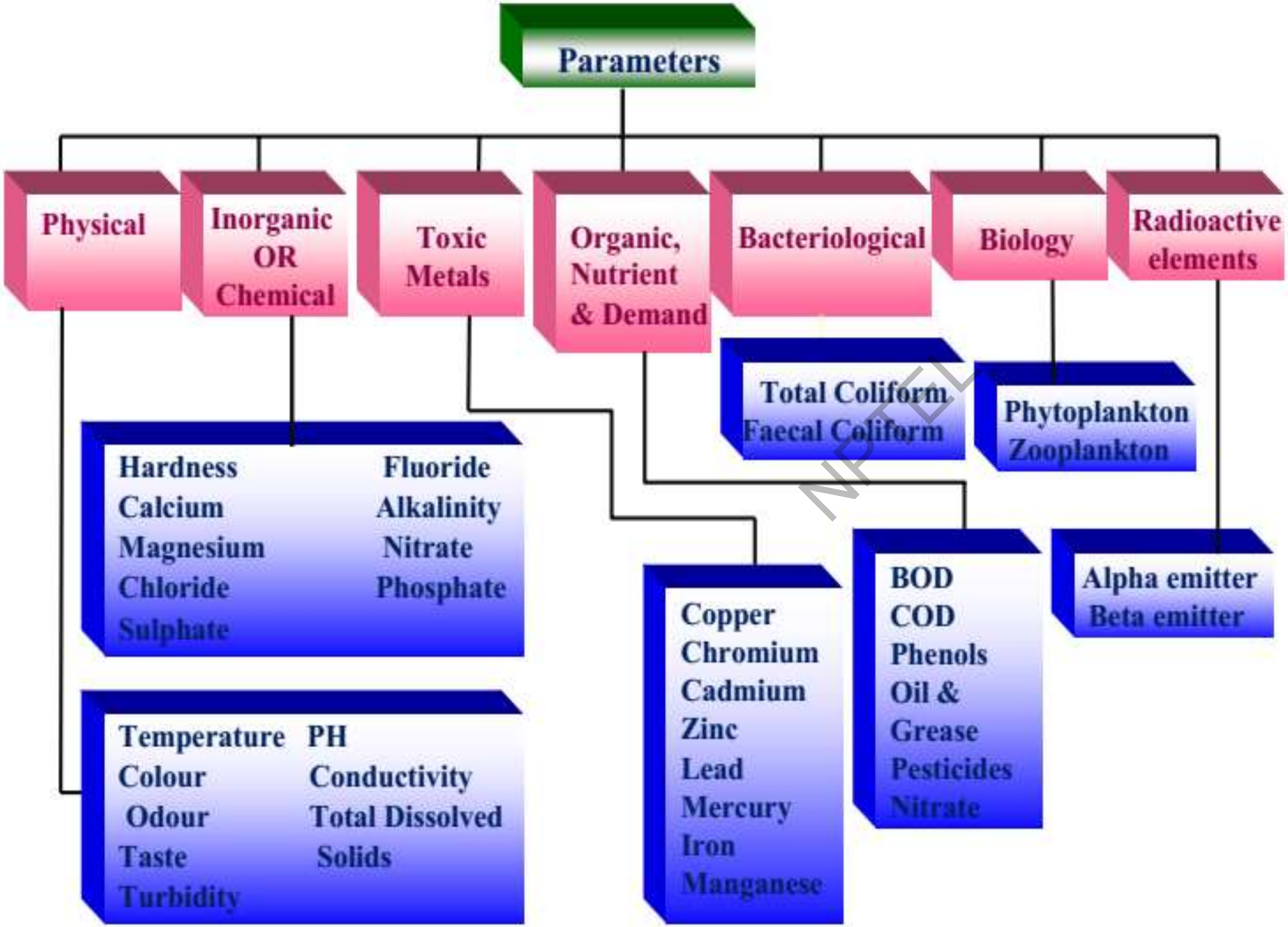
Mineral water


Aesthetically acceptable
Free from bacteria
Safe Water/ Wholesome Water
Chemically safe
Organic substances absent
Radioactive elements absent

Polluted Water

Presence of undesirable substances in the quantities which are harmful to man vegetation or property is referred to **Polluted Water**


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


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

Characteristics of water

Physical

Chemical

Biological

- Turbidity
- Colour
- Taste and Odour
- Temperature of Water
- Specific Conductivity

Characteristics of water

Physical

Chemical

Biological

Total Solids and Suspended Solids

pH value of Water

Hardness of Water

Chloride Content

Nitrogen Content

Metal and other chemical substances in water

Dissolved gases

Characteristics of water

- Physical
- Chemical
- Biological
  - Bacteria
  - Protozoa
  - Viruses
  - Worms
  - Fungi

Water Quality Consideration

Irrigation

pH

Conductivity

Sodium & Potassium

Nutrients

Specific compounds

Industries

As per specific requirement

Domestic Consumption

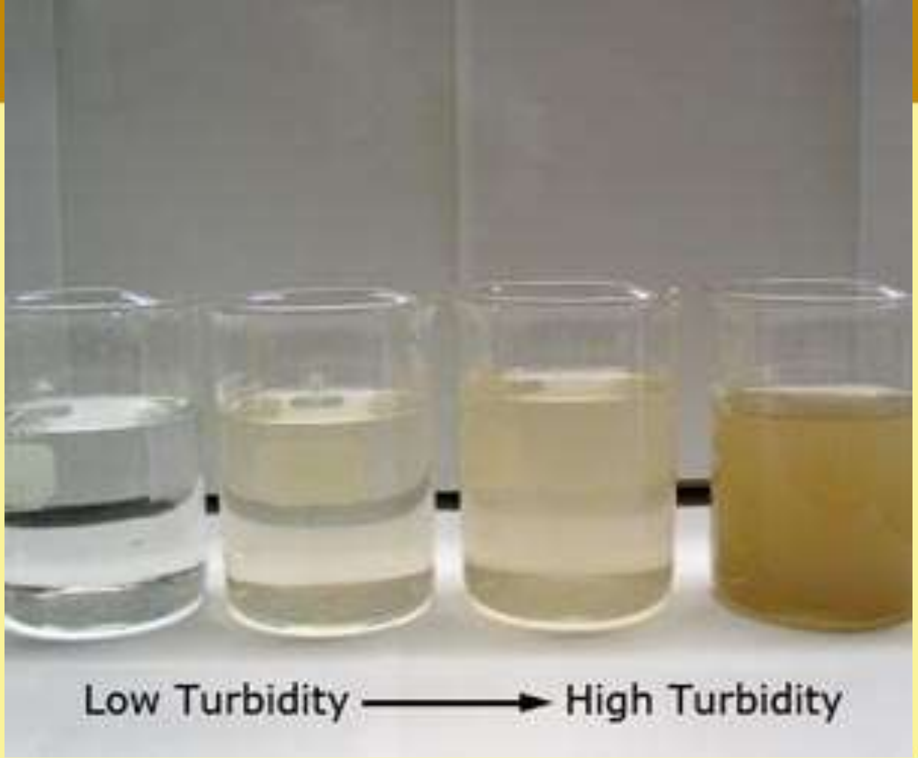
As per BIS Standards

Water Bodies

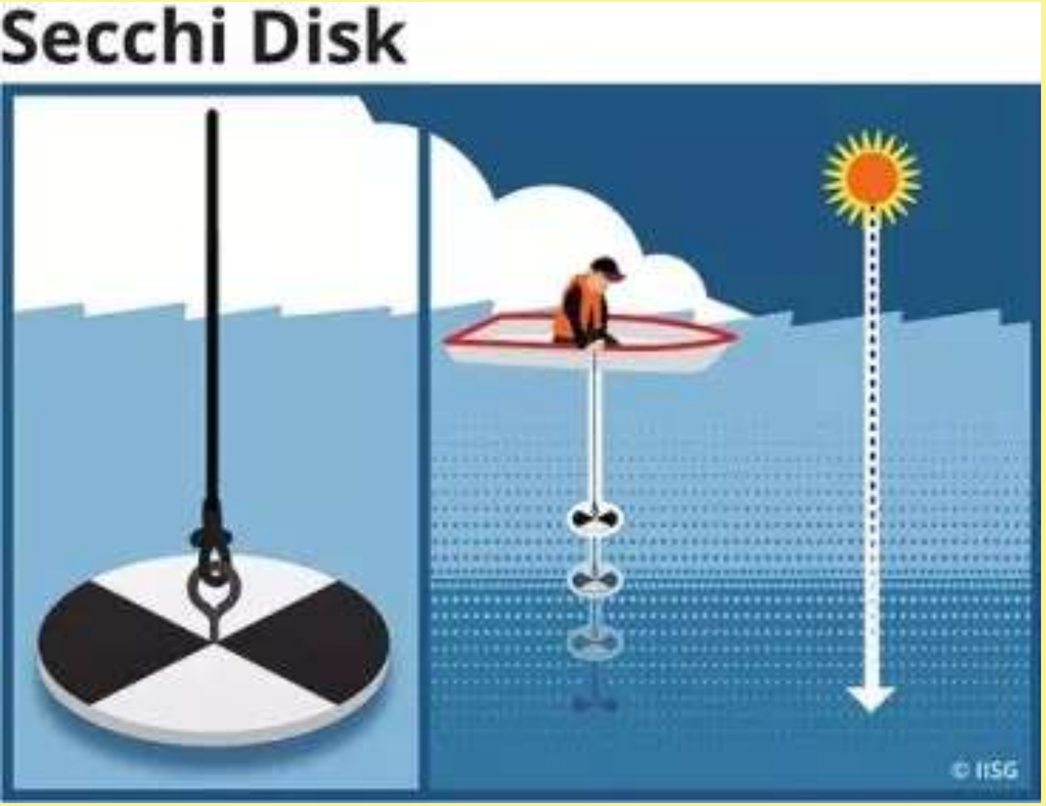
As per CPCB guidelines

Turbidity

- Turbidity is the measure of relative clarity of a liquid. It is a measure of resistance offered by suspended and colloidal particles present in water to the passage od light.
- It is an optical characteristic of water and is a measurement of the amount of light that is scattered by material in the water when a light is shined through the water sample.



Turbidity


Secchi Disk
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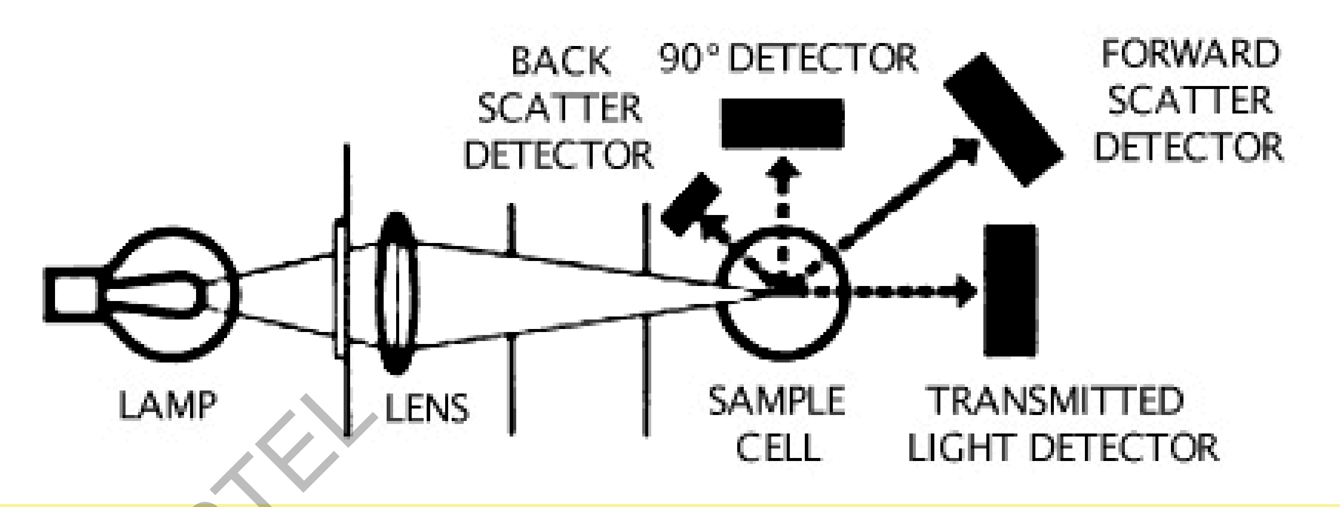
DIGITAL TURBIDITY CUM NEPHELOMETER
LAB Solutions

Turbidity


DIGITAL TURBIDITY CUM NEPHELOMETER
LAB Solutions


BACK SCATTER DETECTOR
90° DETECTOR
FORWARD SCATTER DETECTOR
LAMP
LENS
SAMPLE CELL
TRANSMITTED LIGHT DETECTOR

Colour

The presence of colour in water is not objectionable from health point of view, but may spoil the colour of the clothes being washed. The standard unit of colour is that which is produced by one milligram of platinum cobalt dissolved in one litre of distilled water.

Colour determined by an instrument is known as tintometer.
Unit: True Colour Unit (TCU)

Taste and odour

Due to dissolved organic matter or inorganic salts, dissolved gases etc.

The **threshold odour number** is the **dilution factor** at which the odour is just detectable.

Dilution factor = $\frac{Volume\ of\ raw\ water\ sample + Volume\ of\ distilled\ water\ used\ for\ dilution}{Volume\ of\ raw\ water\ sample}$

Instrument: Osmoscope

Permissible limit: 1 to 3

NPTEL ONLINE CERTIFICATION COURSES

Course Name: Introduction to Environmental Engineering and Science – Fundamentals and Sustainability Concepts

Faculty Name: Dr. Brajesh Kumar Dubey

Department : Civil engineering

Topic Water Quantity and Quality

Lecture 35: Water quality Contd...

Conductance(G)

$\propto$ Area (A)
$\propto$ 1/Distance (L)

$G = K(A/L)$
$A = 1 cm^2$
$L = 1$ cm
$G = K$

K is called conductivity or specific conductance

Conductance is measured between two spacially fixed and chemically inert platinum electrodes

Conductivity Measurement

Definition

Measure of the ability of aqueous solution to carry an electric current

- Concentration of ions
- Mobility
- Valency
- Temperature

Unit

μ mho/cm
or
μs/cm

Significance

- Degree of Minerilization
- Effect on plants and animals
- Check purity of distilled water
- Monitoring seasonal variation of raw water or wastewater
- Determine sample size for chemical analysis
- Check results of chemical analysis
- Estimate TDS

If 10 ml water sample diluted with 190 ml distilled water at which odour is just detectable, then TON of sample is

Sol : TON = $\frac{A+B}{A} = \frac{10+190}{10}$ = 20

Temperature

Impurities in water

Suspended Impurities

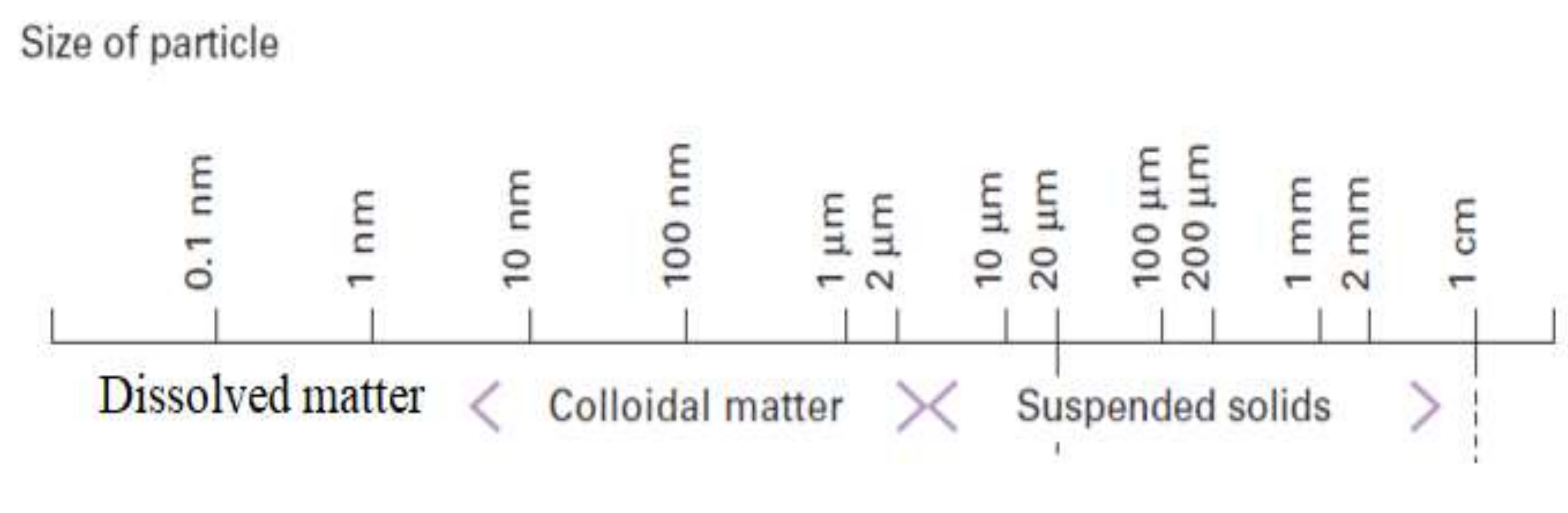
Suspended impurities are Suspended solids that are not completely soluble in water and are present as particles. These particles usually impart a visible turbidity to the water.

Colloidal Impurities

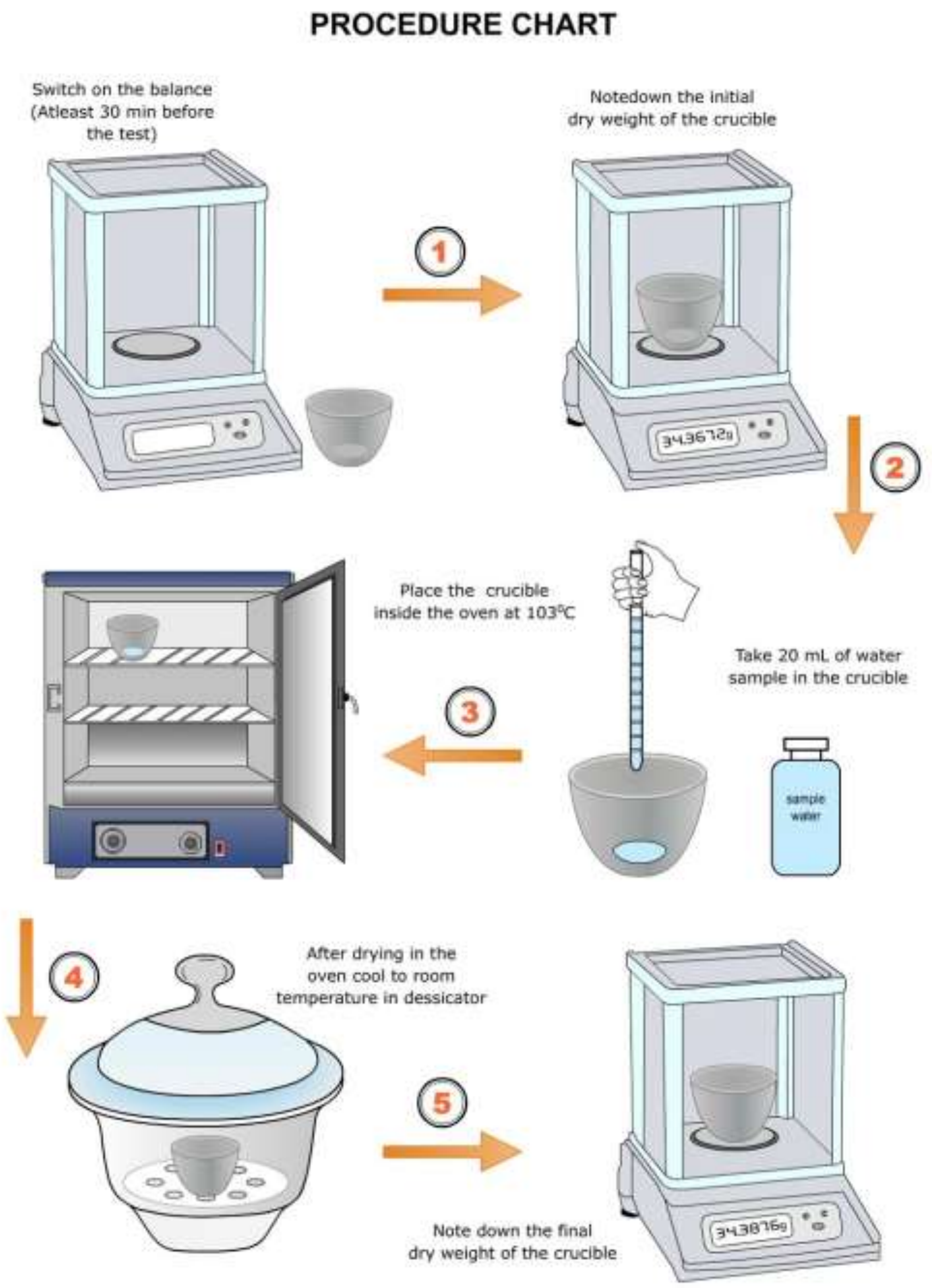
Colloidal refers to items of a small size that are floating in a medium of one of three substances: a solid, a liquid, or a gas.

Dissolved Impurities

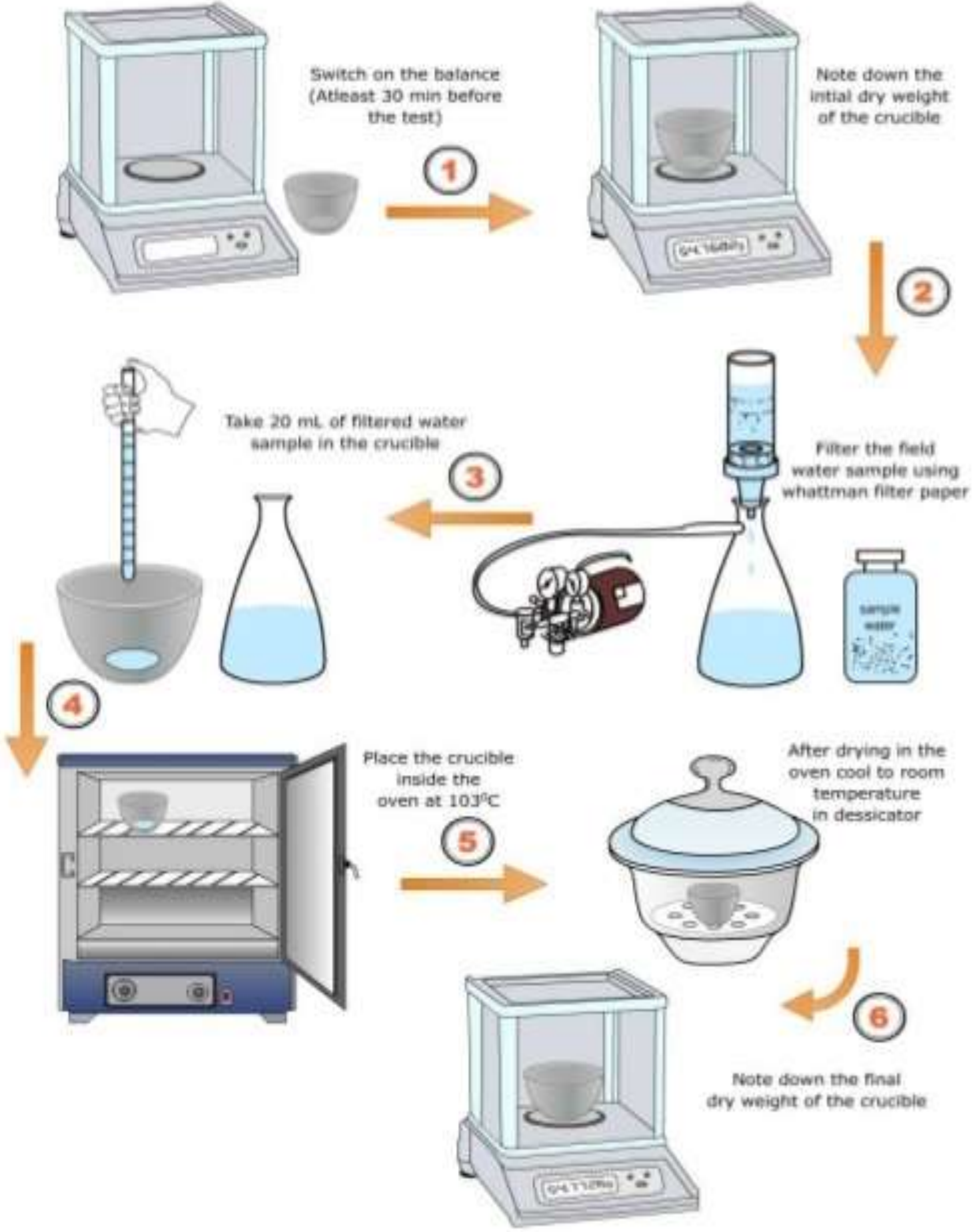
It includes organic compounds, inorganic salts and gases. Salts, metals, lead and arsenic, gases



Total solid


PROCEDURE CHART
Switch on the balance (Atleast 30 min before the test)
1
Notedown the initial dry weight of the crucible
2
Take 20 mL of water sample in the crucible
sample water
3
Place the crucible inside the oven at 103°C
4
After drying in the oven cool to room temperature in dessicator
5
Note down the final dry weight of the crucible

Total dissolved solid



A 100 ml water sample is drawn on to a empty dry container whose initial weight is 95.452 gm. After oven drying the sample at 103^0C for 24 hours its final weight measured to be 95.486 gm. Then total solid's concentration in mg/l.

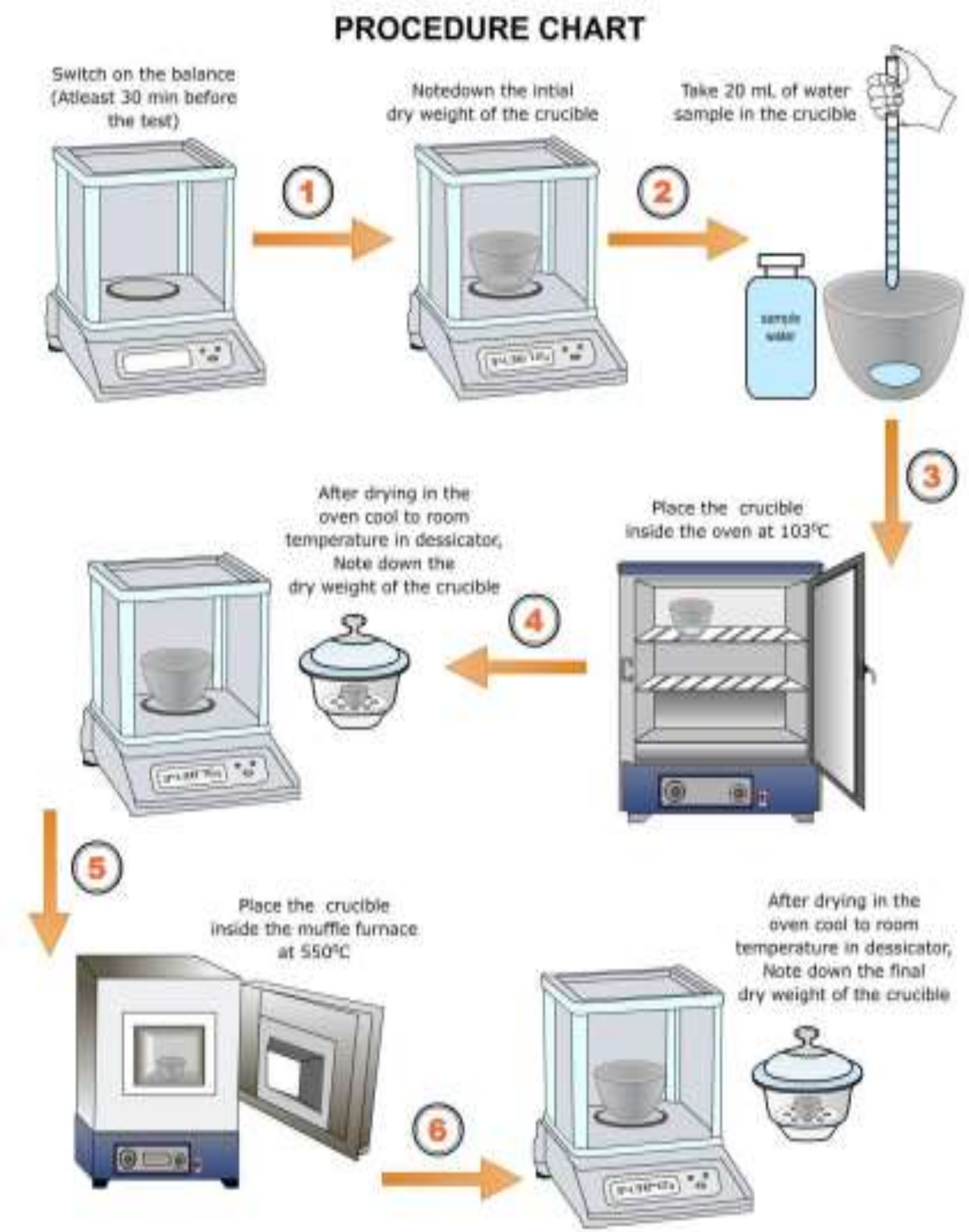
Sol : Total solids = $\frac{W_2 - W_1}{V} \times 10^6$

W_2= final weight in gm,

W_1= initial weight in gm,

V = volume of water sample in ml

= $\frac{95.486 - 95.452}{100}$ X 10^6 = 340 mg/l



Volatile solid

pH

$$pH = -\log [H^+]$$

If H^+ concentration increases, pH decreases and then it will be acidic.
If H^+ concentration decreases, pH increases and then it will be alkaline.

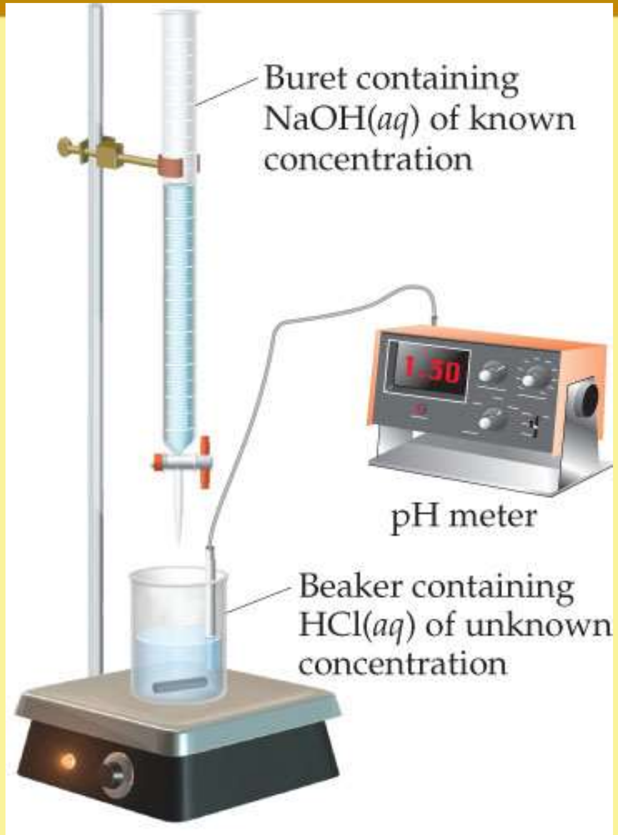
$pH + pOH = 14$
if the pH of water is more than 7, it will be alkaline
and if it is less than 7, it will be acidic.

The alkalinity is caused by the presence of bicarbonate of calcium and magnesium or by the carbonates of hydroxides of sodium, potassium, calcium and magnesium. Some, but not all of the compounds that cause alkalinity also cause hardness.

pH Measurement:

$$pH = -\log[H+]$$

0	10^{0}	1
1	10^{-1}	0.1
2	10^{-2}	0.01
3	10^{-3}	0.001
4	10^{-4}	0.0001
5	10^{-5}	0.00001
6	10^{-6}	0.000001
7	10^{-7}	0.0000001
8	10^{-8}	0.00000001
9	10^{-9}	0.000000001
10	10^{-10}	0.0000000001
11	10^{-11}	0.00000000001
12	10^{-12}	0.000000000001
13	10^{-13}	0.0000000000001
14	10^{-14}	0.00000000000001



pH Measurement: Titration

Indicator	pH range of indicator dye	Original color	Final color produced
Methyl orange	2.8 – 4.4	Red	Yellow
Methyl red	4.4 – 6.2	Red	Yellow
Phenol red	6.8 – 8.4	Yellow	Red
Phenolphthalein	8.6 – 10.3	Yellow	Red

A water having pH value equal to 9 will have a hydrogen ion concentration equal to

$$pH = -\log [H^+]$$

$$[H^+] = 10^{-9} \text{ mol/lit}$$

If H^+ ion concentration is 10^{-6} mol/lit. What is pOH

Sol : pH = $log_{10} \frac{1}{H^+}$ = $log_{10} \frac{1}{10^{-6}}$ = 6

pH + pOH = 14

: pOH =14 – 6 = 8

Hardness

Hard waters are undesirable because they may lead to greater soap consumption, scaling of boilers, causing corrosion and incrustation of pipes, making food tasteless etc.

Temporary Hardness: If bicarbonates and carbonates of calcium and magnesium are present in water, the water is render hard temporarily as this hardness can be removed to some extent by simple boiling or to full extent by adding lime to water. Such a hardness is known as temporary hardness or carbonate hardness.

Hardness

Permanent Hardness: If sulphates, chlorides and nitrates of calcium or magnesium are present in water, they can not be removed at al by simple boiling and therefore, such water require special treatment for softening. Such a hardness is known as permanent hardness or non-carbonate hardness.

Hardness

Carbonate hardness = Total hardness or Alkalinity (which ever is less)

Non-carbonate hardness = Total hardness – Alkalinity

Carbonate hardness is equal to the total hardness or alkalinity which ever is less
Non-carbonate hardness is the total hardness in excess of the alkalinity. If the alkalinity is equal to or greater than the total hardness, there is no non-carbonate hardness.

Total hardness = Carbonate hardness + Non-carbonate hardness

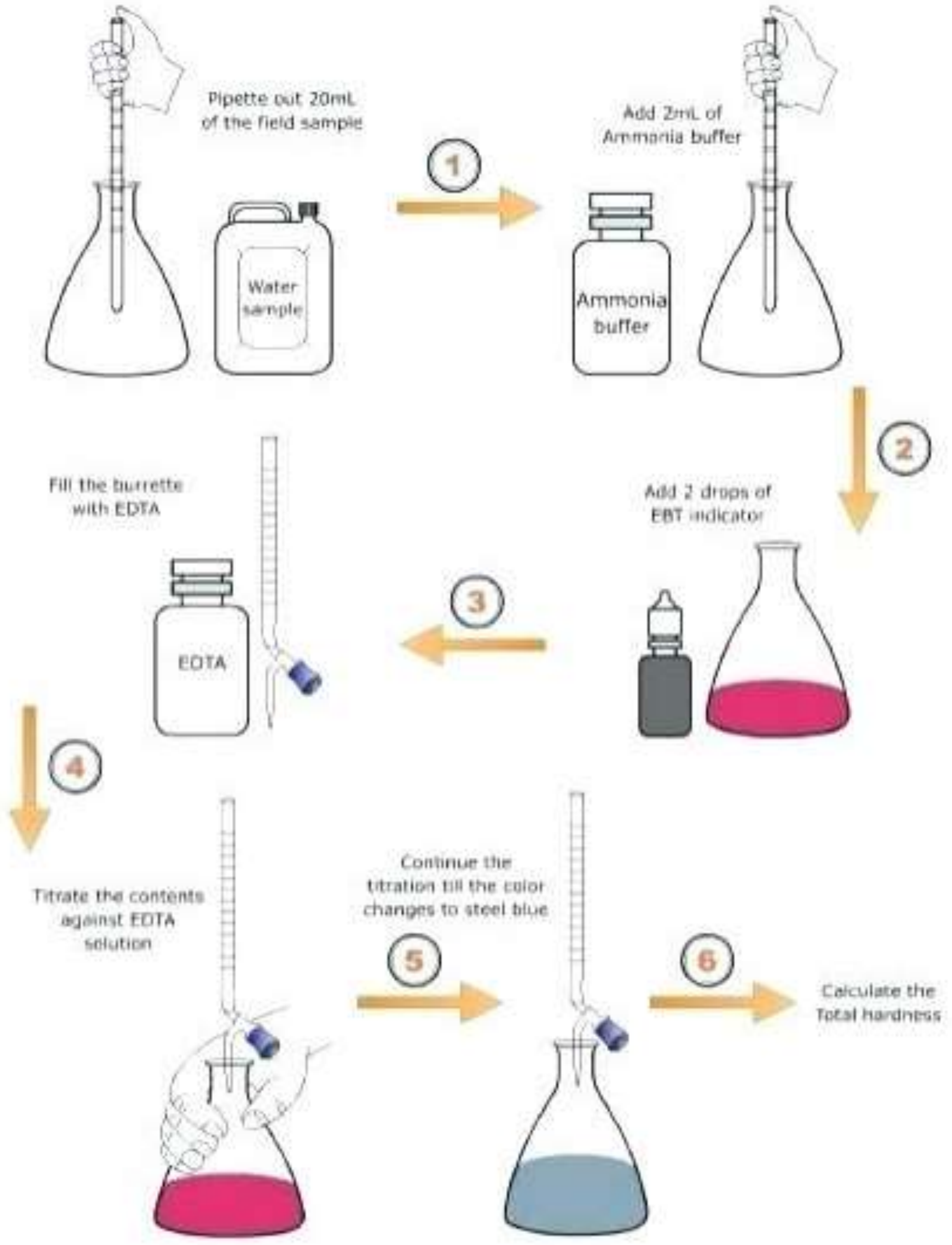
Hardness

Total hardness (TH) = Carbonate hardness (CH) + Non-carbonate hardness (NCH)

If TH > alkalinity, then CH = Alkalinity

If TH $\leq$ alkalinity, then CH = TH, NCH = 0

Hardness measurement procedure



Total hardness in mg/L as $CaCO_3$ = [Ca^{++} in mg/L × $\frac{Equivalent\ weight\ of\ CaCO_3}{Equivalent\ weight\ of\ Ca} +$

Mg^{++} in mg/L × $\frac{Equivalent\ weight\ of\ CaCO_3}{Equivalent\ weight\ of\ Mg}$

For a water sample the total alkalinity is 200 mg/l as $CaCO_3$. The Ca^{++} is 120 mg/l, mg^{++} is 60 mg/l. What is total hardness, Carbonate hardness, non-carbonate hardness.

Total hardness in mg/L as $CaCO_3$ = [Ca^{++} in mg/L $\times \frac{Equivalent\ weight\ of\ CaCO_3}{Equivalent\ weight\ of\ Ca} +$ Mg^{++} in mg/L $\times \frac{Equivalent\ weight\ of\ CaCO_3}{Equivalent\ weight\ of\ Mg}$

Sol: TA = 200 mg/L as $CaCO_3$

$$TH = Ca^{2+} \text{ X } \frac{50}{20} + Mg^{2+} \times \frac{50}{12}$$

$$= 120 \text{ X } \frac{50}{20} + 60 \times \frac{50}{12} = 550 \text{ mg/L as } CaCO_3$$

: TH > TA

CH =TA = 200 mg/L as $CaCO_3$

NCH = TH – CH = 550 – 200 = 350 mg/L as $CaCO_3$

The chemical analysis of water sample indicates the presence of cations as follows Na^{+} = 20 mg/l Ca^{++} = 45 mg/l mg^{++} = 60 mg/l, HCO_3 = 248, SO_4 = 220, CL = 79.2. Compute total hardness, carbonate hardness and non-carbonate hardness equivalent to $CaCO_3$.

Sol: Alkalinity = $HCO_3^{-} \times \frac{50}{61}$

$= 248 \times \frac{50}{61} = 203.3$ mg/l as $CaCO_3$

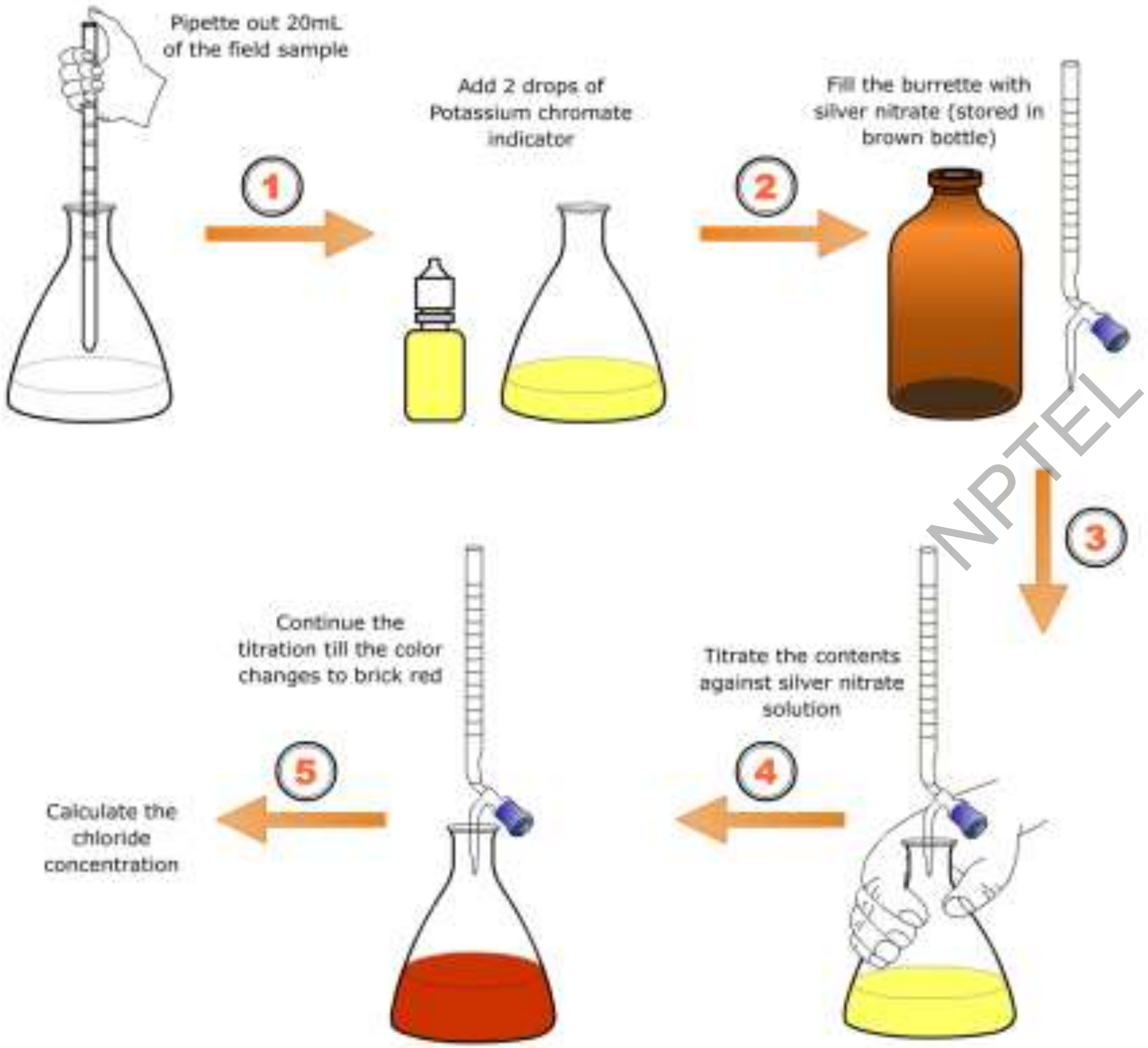
TH = $Ca^{++} \times \frac{50}{20} + Mg^{++} \times \frac{50}{12}$

$= 45 \times \frac{50}{20} + 60 \times \frac{50}{12} = 362.5$ mg/l as $CaCO_3$

TH> Alkalinity

CH = Alkalinity = 203.3 mg/l as $CaCO_3$

NCH = 362.5 – 203.3 = 159.2 mg/l as $CaCO_3$



Chloride content

Present in the form of sodium chloride.
Imparts salty taste.

Nitrogen content

The presence of nitrogen in water may occur in one or more of the following reasons:

1. Free ammonia: It indicates very first stage of decomposition of organic matter. It should not exceed 0.15mg/l

2. Organic nitrogen: It indicates the quantity of nitrogen present in water before the decomposition of organic molten has started. It should not exceed 0.3mg/l

3. Nitrites: Not fully oxidized organic matter in water.

4. Nitrates: It indicates fully oxidized organic matter in water (representing old pollution).

Nitrogen content

- Nitrites is highly dangerous and therefore the permissible amount of nitrites in water should be nil.
- Ammonia nitrogen + organic nitrogen = kjeldahl nitrogen
- Nitrates in water is not harmful. However the presence of too much of nitrates in water may adversely affect the health of infants causing a disease called **methemoglobinemia** commonly called **blue baby disease.**
- The nitrate concentration in domestic water supplies is limited to 45 mg/l.

Metal and other chemical substances in water

Iron – 0.3ppm, excess of these cause discoloration of clothes.

Manganese – 0.05ppm

Copper – 1.3ppm

Sulphate – 250 ppm

Sulphate (SO_4) can be found in almost all natural water. The origin of most sulphate compounds is the oxidation of sulfite ores, the presence of shales, or the industrial wastes.

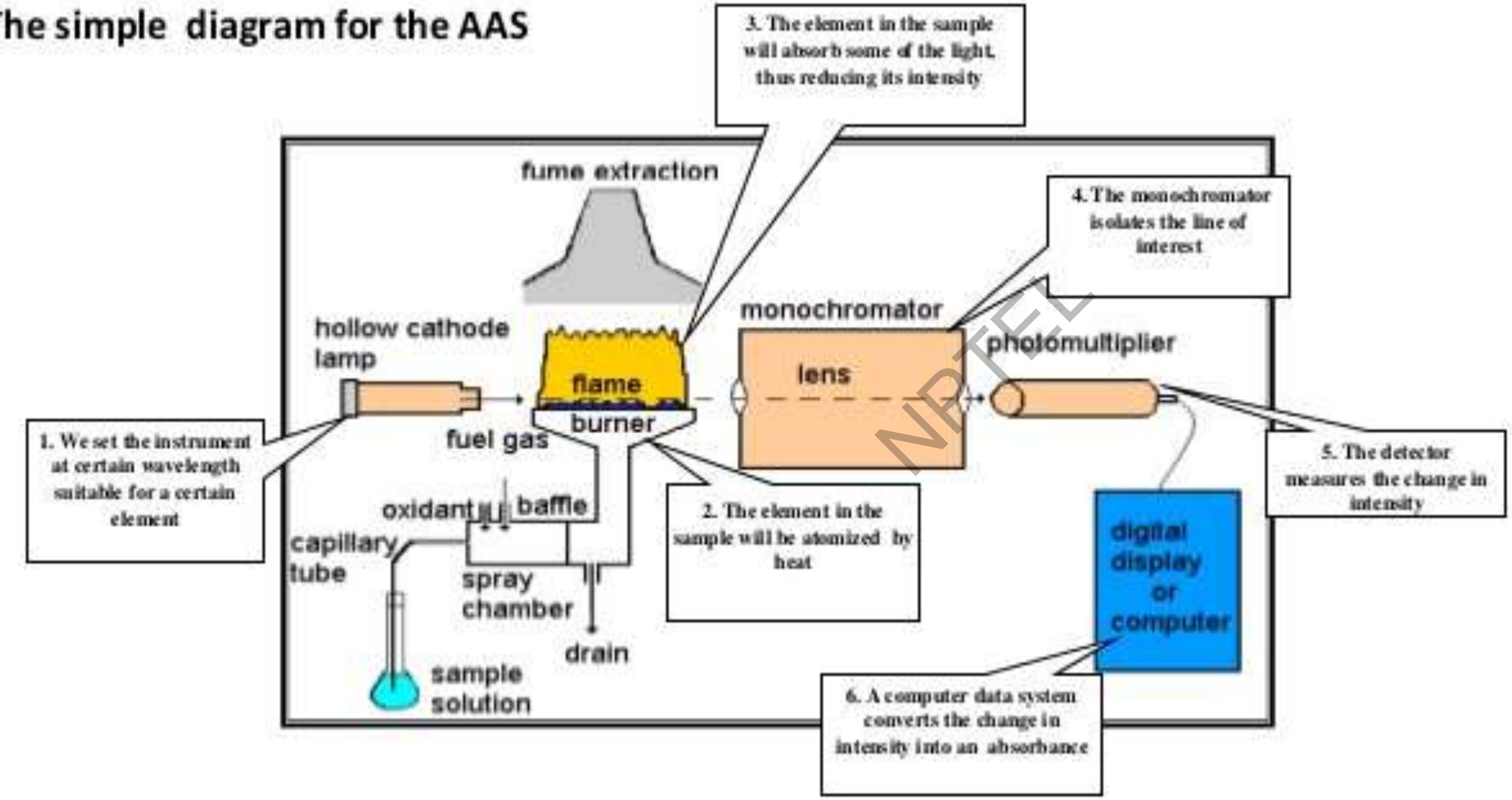
Sulphate is one of the major dissolved components of rain. High concentrations of sulphate in the water we drink can have a laxative effect when combined with calcium and magnesium, the two most common constituents of hardness.

Metal and other chemical substances in water

Fluoride – 1.5 ppm, excess of this effects human lungs and other respiratory organs. Fluoride concentration of less than 0.8 – 1.0 ppm cause dental cavity (tooth decay). If fluoride concentration is greater than 1.5ppm, causing spotting and discolouration of teeth (a disease called fluorosis).

Atomic Absorption Spectroscopy

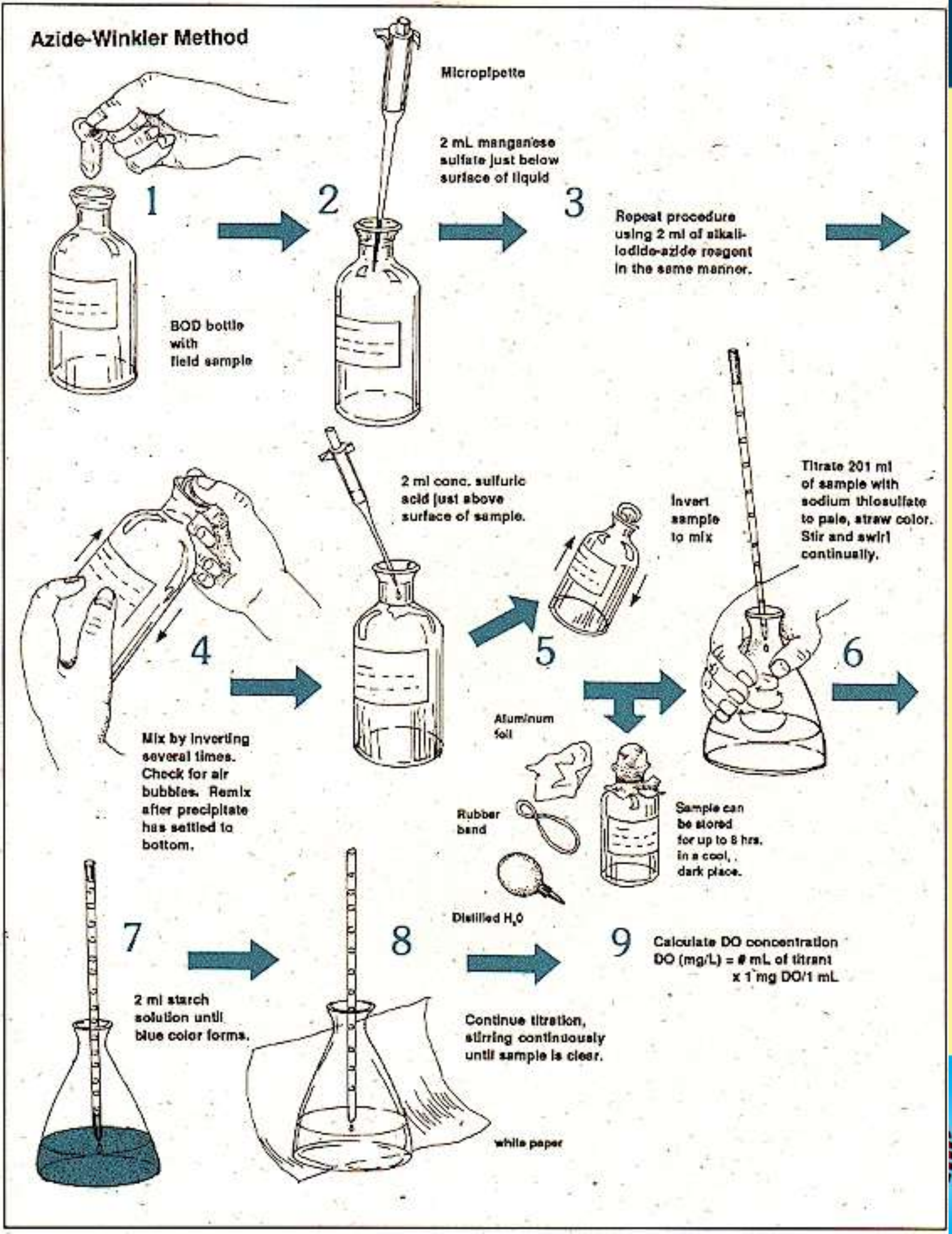
The simple diagram for the AAS



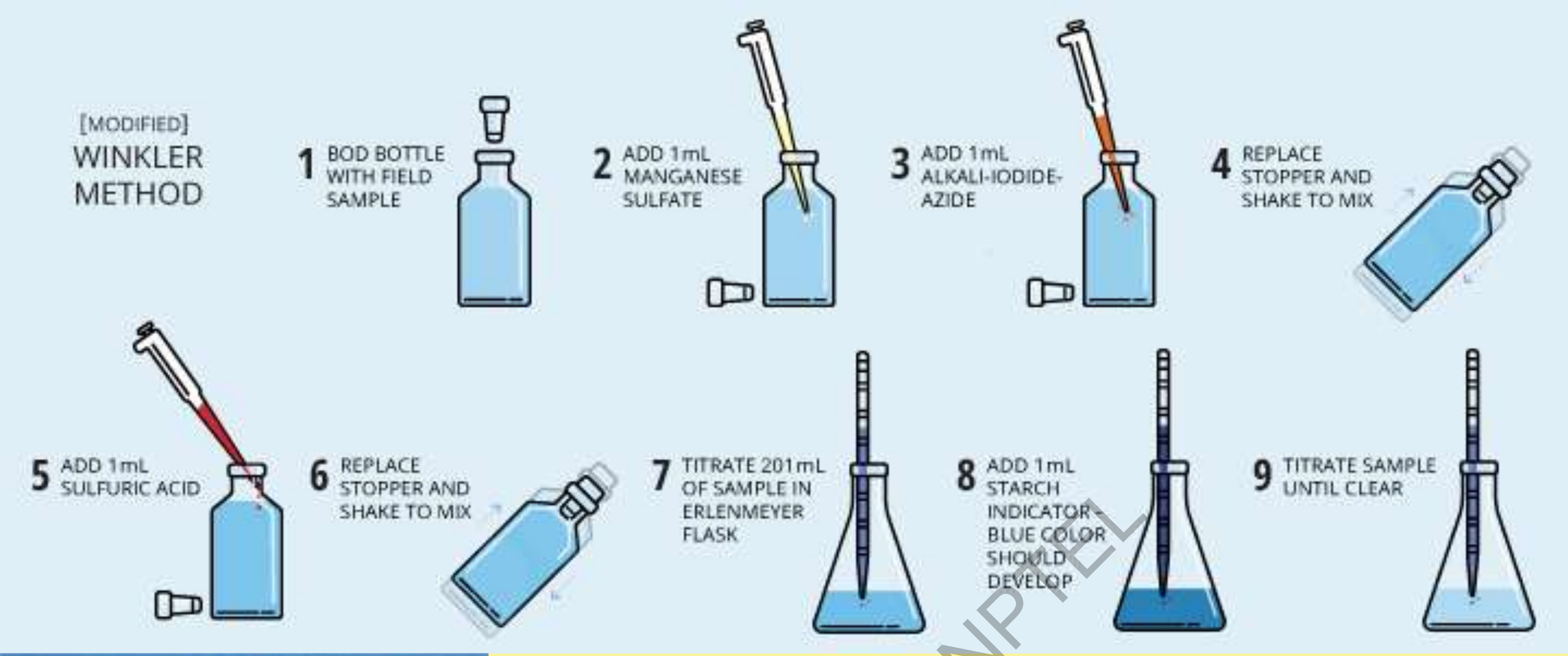
Dissolved oxygen

Oxygen gas is generally absorbed by water from the atmosphere but it being consumed by unstable organic matter for their oxidation. Hence, if the oxygen present in water is found to be less than its saturation level, it indicates presence of organic matter and consequently making the waters suspicious.

Dissolved oxygen



Dissolved oxygen



Characteristics of water

Physical

Chemical

Biological

- Bacteria
- Protozoa
- Viruses
- Worms
- Fungi

Bacterial and Microscopic Characteristics of Water
Five types of parasitic organisms (i.e. bacteria, protozoa, viruses, worms and fungi) are generally known to be infective to main and are found in water.

1. Bacteria

These are the minute single cell organisms possessing no defined nucleus and having no green material to help them manufacture their own food. They are reproduced by binary fusion and may of various shapes and sizes are 1 to 4 microns, examined by microscope.

a) Non-disease causing bacteria – Non pathogenic bacteria.

b) Disease causing bacteria – Pathogenic bacteria.

2. Protozoa

These are single cell animals and are the lowest and the simplest form of animal life. They are bacteria eaters and thus destroy Pathogens. They are counted by microscope.

3. Viruses

4. Worms

These are the larva of flies.

5. Fungi

These are those plants which grow without sunlight and live on other plants or animals, dead or alive.

Classification of bacteria based on oxygen requirement:

Aerobic bacteria: Those which require oxygen for their survival.

Anaerobic bacteria: Those which flourish in the absence of free oxygen.

Facultative bacteria: Those which can survive with or without free oxygen.

Pathogenic bacteria

These can be tested and counted in the laboratories but with great difficulty. These tests are therefore, generally not performed in routine to check up of the water quality. The usual routine tests are generally conducted to detect and count the presence of coliforms which in themselves harmless organisms, but their presence or absence indicates the presence or absence of pathogenic bacteria.

Methods to measure the presence of coliform bacteria:

Membrane filter technique (modern technique)
Mixing different dilution of a sample of water with lactose froth and incubating them in test-tubes for 48 hours at $37\ ^0C$. the presence of acid or carbon dioxide gas in tubes will indicate the presence of coliform bacteria.
Most probable number (MPN) represent the bacterial density.

Coliform index

It may be defined as the reciprocal of the smallest quantity of a sample which would give a positive portion. Coliform sometimes called bacteria coli (B-coli) or Escherichia (E-coli) are harmless aerobic micro-organisms.

If not more than 1 coliform is present per 100ml of water, then water is said to be safe for drinking.

$$\frac{MPN}{100}\, ml = \frac{100\ \times Number\ of\ positive\ portion}{\sqrt{(ml\ in\ all\ positive\ portion) \times (ml.in\ all\ negative\ portion)}}$$

Water borne diseases

Avoid diseases that spread through water

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Thank you