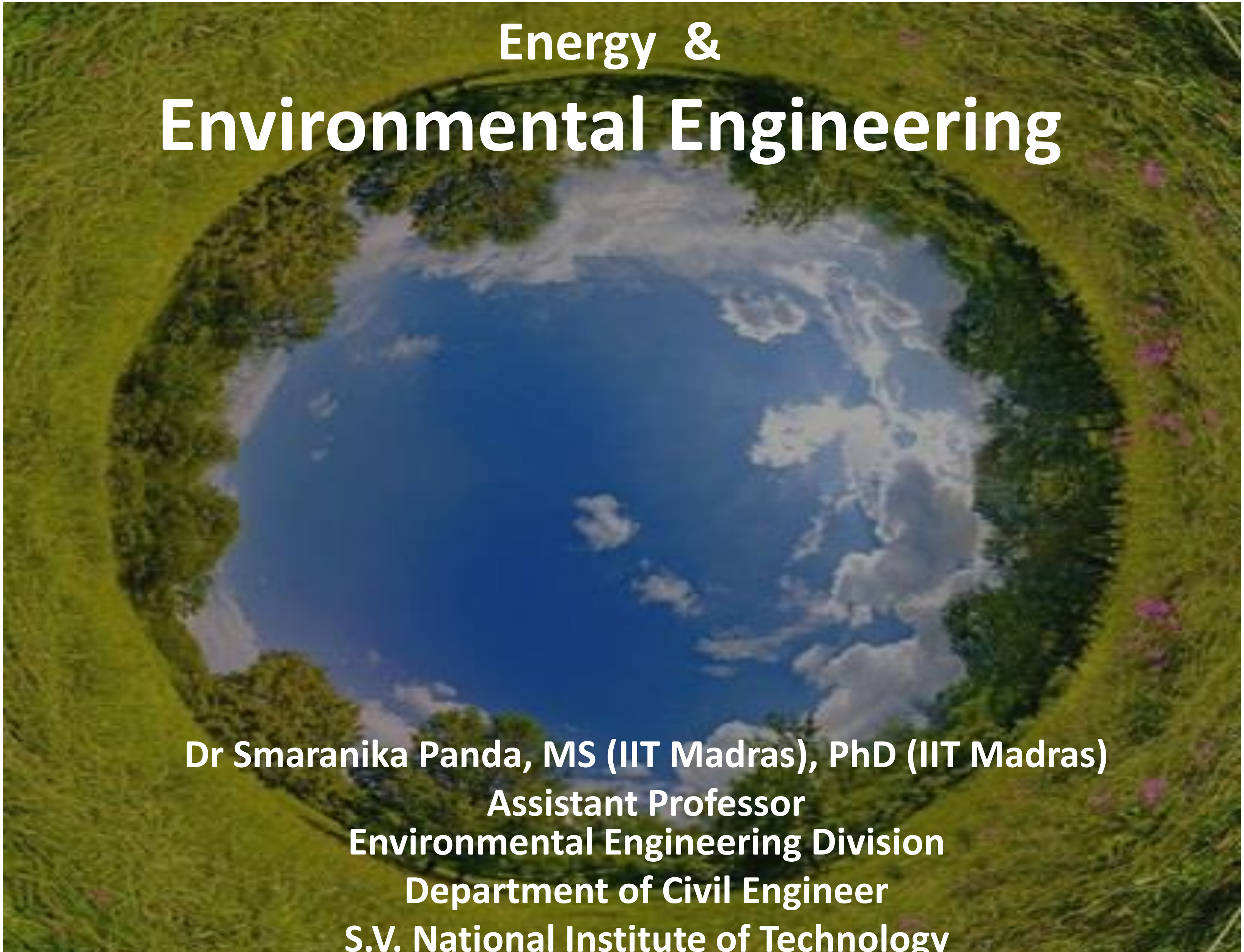

Energy &
Environmental Engineering

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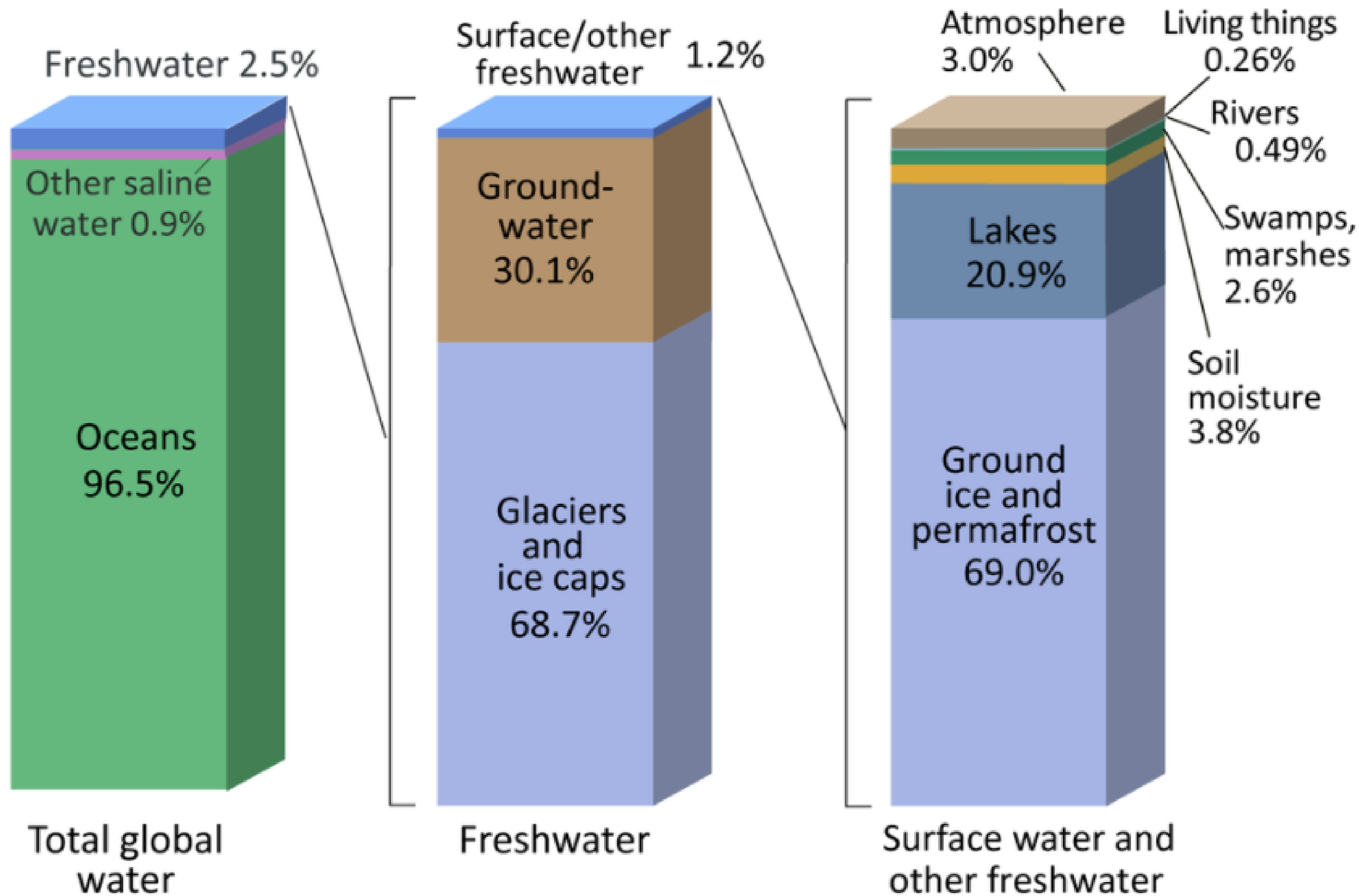
Module 2

- **ENVIRONMENTAL POLLUTION (10 hours)**

- Water, air, soil, noise, thermal and radioactive, marine pollution: sources, effects and engineering control strategies. Drinking water quality and standards, Ambient air and noise quality standards

Source of water



Credit: U.S. Geological Survey, Water Science School. https://www.usgs.gov/special-topic/water-science-school
Data source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources. (Numbers are rounded).

Sources of water and pollutants

Ground water

- Hardness
- Alkalinity
- Iron
- Manganese
- Fluoride
- Arsenic
- Bacterial Contamination
- Industrial Pollutant, Pesticides etc

Surface water

- Chemicals- Phenols, pesticides, PAH, Nitrate, phosphate (from fertilizers), heavy metals
- Physical- turbidity, colour, odour, taste
- Biological- Bacteria, viruses, protozoa EDA- Endocrine disrupting agents

Sources of water and pollutants

Sea Water

- Chloride
- Dissolved solids

Waste Water

- 99% water
- 80% of water supply comes out as water
- Microbes
- Nutrients

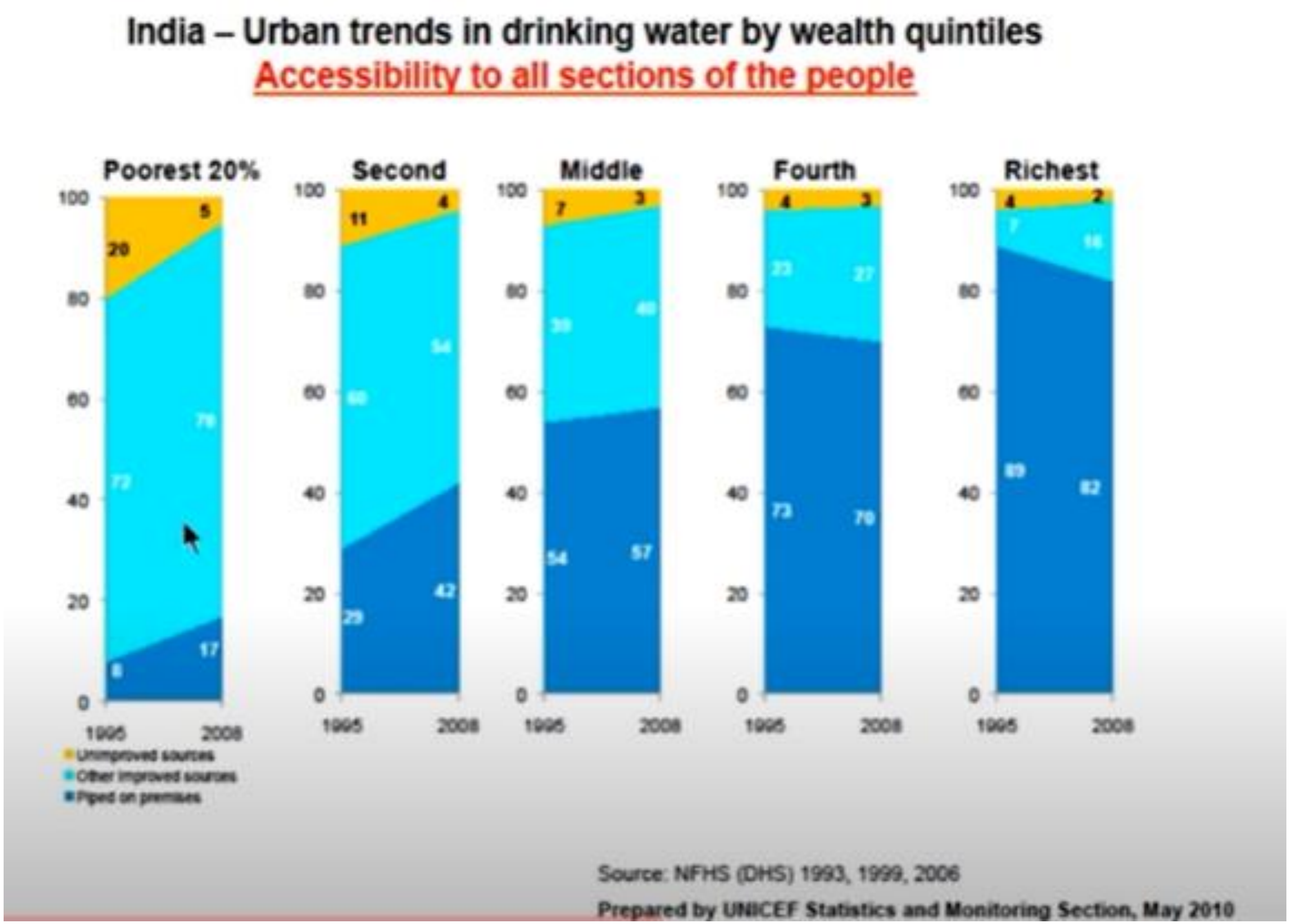
Attributes of Drinking Water

Potable

Palatable

- Aesthetic – Free from color, odor, taste, pleasing (Physical Perception – Subjective)
- Safety – Bacteriological (free from pathogens.
- Chemicals – Free from toxicants (Anthropogenic & natural)

Drinking water supply: India



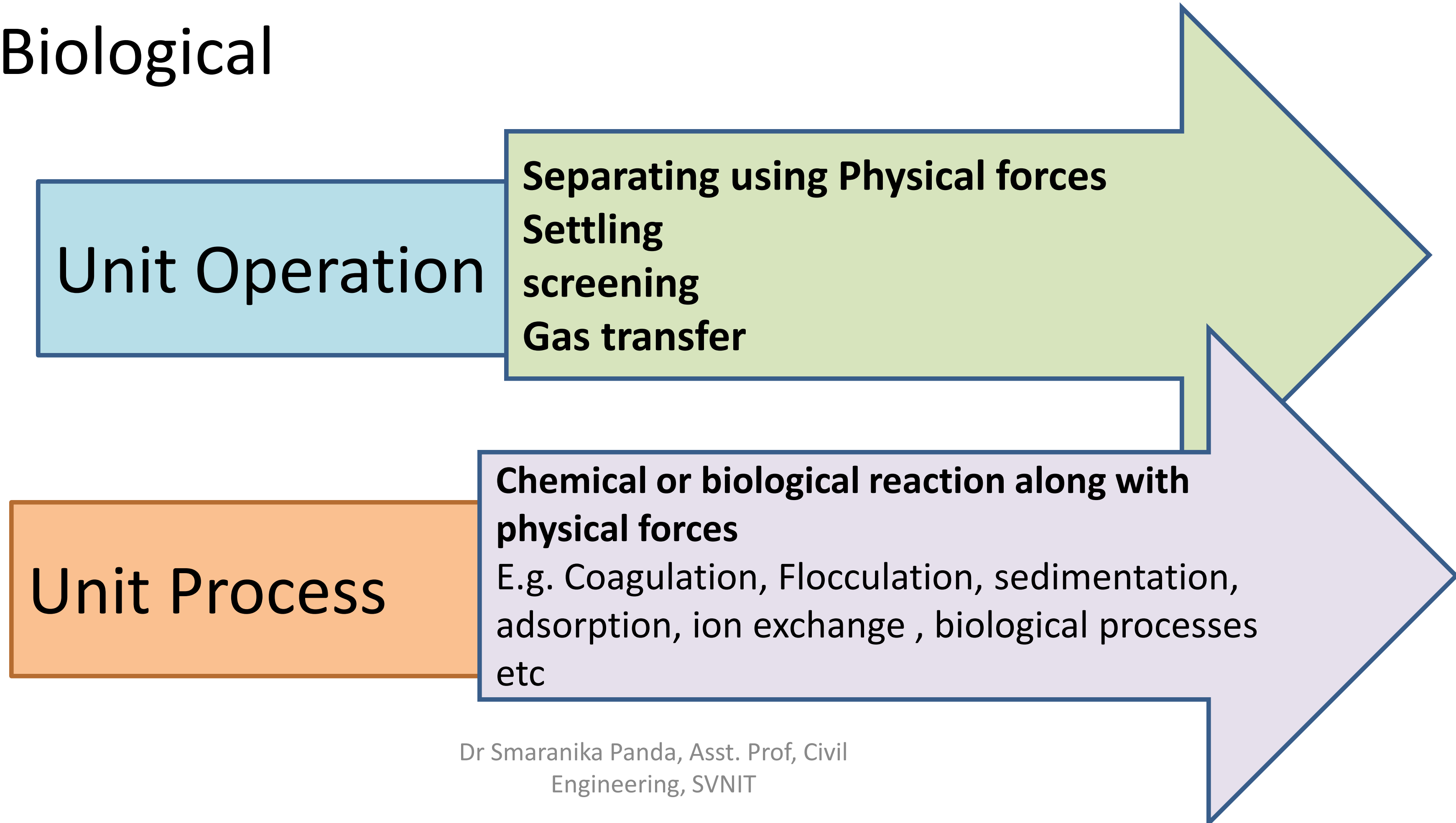
Treatment Process

Method of treatment ?????????????????????????

Based on nature of pollutant and its concentration

Treatment Processes

- Physical
- Chemical (physico chemical)
- Biological



Selection of Treatment Process

1. Source water characteristics

2. Beneficial use- drinking, domestic use, industrial, agricultural use, recreational etc

Objective of Public Water Supply System

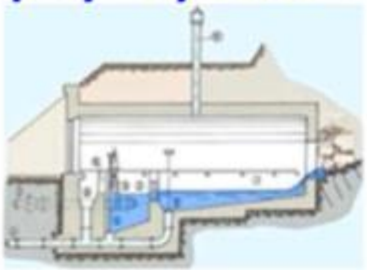
1. Quantity-
- Population and other requirements
- Ensured by selecting the suitable source

2. Quality --
- Should be potable and palatable
- Ensured by selecting the suitable treatment system

3. Collection and treatment
- Collect and treat of WW generated

Components of a Water Supply system

- Water Source
- Collection
- Treatment system
- Distribution system
- Point of use



Water demand

- Rate of demand- represented in lpcd

litres per capita per day

- Design period
- (Future) population

Types of demand:

✓ Domestic
✓ Industrial
✓ Public use
✓ Losses and thefts

Water demand

Low Income Group-	lpcd
Domestic	135
Industrial and commercial	70
Public	10
Losses and thefts	55
Total	270 lpcd

High Income Group-	lpcd
Domestic	200
Industrial and commercial	70
Public	10
Losses and thefts	55
Total	335 lpcd

Fire Demand:

3 jets of water @ 1100 lit/min
1 to 1.5 kg/cm^2

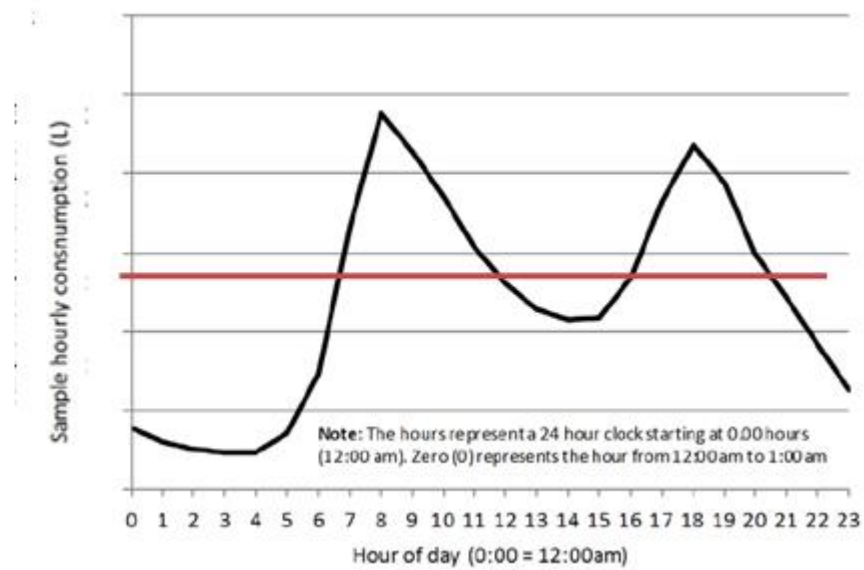
Fire Demand:

Kuichling formula
Freeman's formula
Under writers formula
Buston formula

Water demand

Rate of demand depends

- City size
- Habits
- Climatic condition
- Quality of water
- Metering system



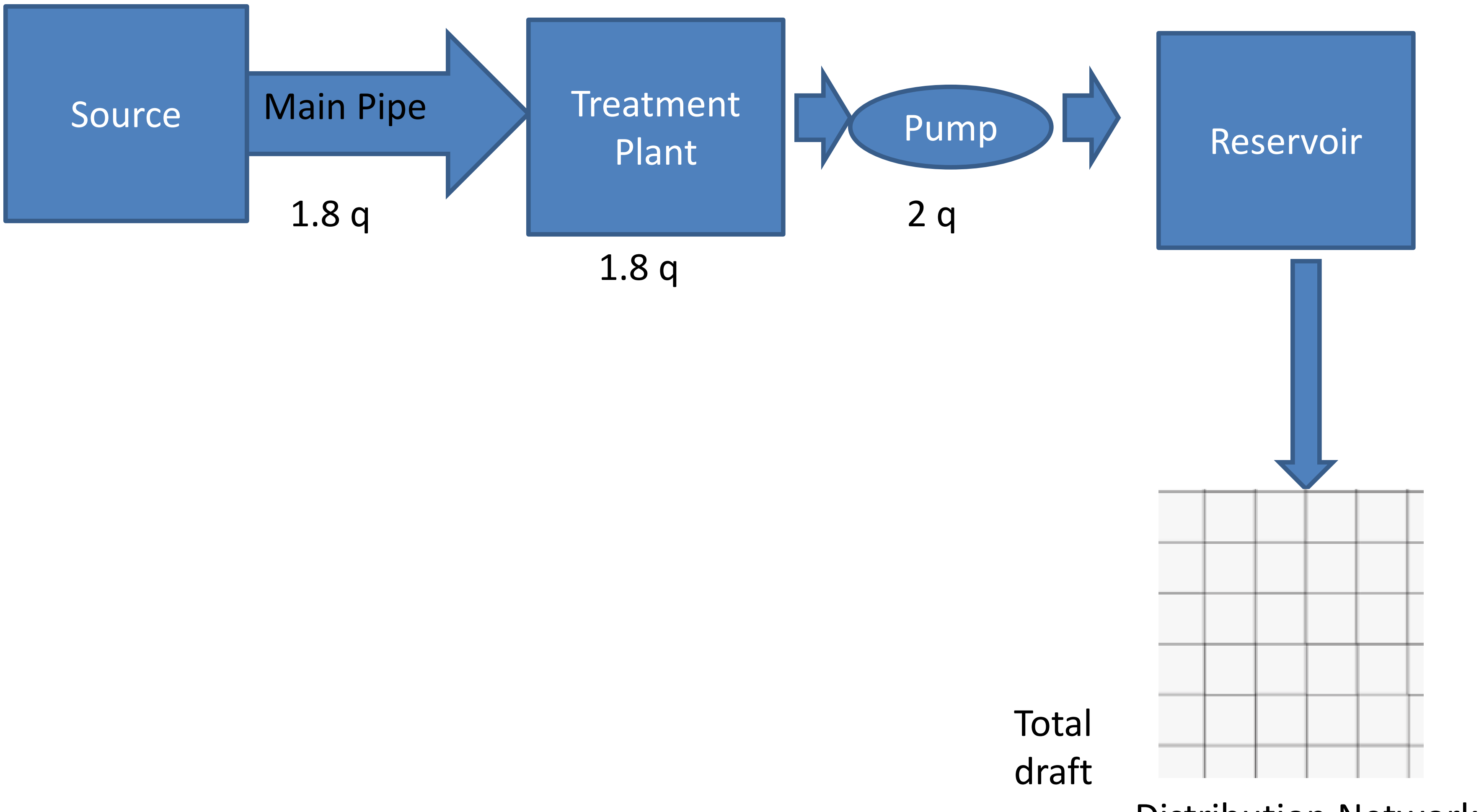
Let q :avg daily water demand

q/24- avg hourly water demand

Max daily demand= 1.8 q
Max hourly demand = 1.5x (avg hourly demand of a max day)
= 1.5 x (1.8q/24)
= 2.7 (q/24) lit/hr
= 2. 7 q lit/day

Coincidental draft – Max daily demand+ Fire demand
Total draft- Higher of the following

a) Coincidental draft
b) Max hourly demand


Source
Main Pipe
Treatment Plant
Pump
Reservoir
1.8 q
2 q
1.8 q
Total draft
Distribution Network

Water demand

- Design period- 30 to 40 years

- Population forecast

✓ Arithmetic increase method

$$\boxed{P_n = P_0 + n\bar{x}}$$

✓ Geometric increase method

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

✓ Incremental increase method

$$\boxed{P_n = P_0 + n\bar{x} + \frac{n(n+1)}{2}\bar{y}}$$

✓ Deceasing rate method

✓ Simple graphical method------------ Logistic curve

✓ Comparative graphical method

Q) If the water consumptions – 300 lpcd (litre/day/person)
Population = 4,00,000
Calculate max hourly draft of a max day, & max daily draft in MLD (million litre/day)

Total average daily demand = $300 \times 4 \times 10^5$
$= 120 \times 10^6$
$= 120$ MLD

Max daily draft = $1.8 \times q = 1.8 \times 120 = 216$ MLD
Max hourly demand = $2.7\, q = 2.7 \times 120 = 324$ MLD

- The population of a town in 3 consecutive decades 1 lakh, 1.4 lakh, 1.68 lakh. Calculate the population of this town on 4th consecutive decade according to geometric increase method

- r1= (1.4-1)/1= 0.4
- r2= (1.68-1.4)/1.4= 0.2
- r = (r1r2)^0.5 =(0.4*0.2)^0.5 =0.3

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

- P4 = 1.68 (1+ 0.3)^1= 2.18 lakh

Population of a city at previous consecutive decades was 4,00,000, 5,58,000, 7,76,000 and 10,98,500. The anticipated population using incremental increase method

Population	X	Y
P1 = 4,00,000	x1= P2-P1 = 1,58,000	
P2 = 5,58,000	x2= P3-P2 = 2,18,000	Y1= x2-x1 = 60,000
P3= 7,76,000	X3= 10,98,500-7,76,000= 322500	y2-= x3-x2= 1,04,500
P4 =10,98,500	Xavg =(X1+X2+X3)/2= 2,32,834	Yavg = (y1+y2)/2 = 82250

$$P_n = P_0 + n\bar{x} + \frac{n(n+1)}{2}\bar{y}$$

P4= 10,98,500+ 1x 232,834+ 82250= 14,13,584

Question

- P = 28000 with average water consumption 4200 m^3/d. Existing plant design capacity 6000 m^3/d. Expected population = 44000 during next 20 years. The number of years from now the plant will reach the design capacity. Consider the growth as arithmetic ?

  a) 5.5 years b)8.6 years c) 15 years d) 16.5 years

Po = 28,000

Avg per capacity demand = 4200/28000= 0.15 m3/d/person

Population equivalent to design capacity of the unit = 6000/0.15 = 40,000 persons

Xavg = (44000-28000)/2= 8000

Pn = Po+ nxavg

= (40000-28000)/8000 = n

=1.5 decade

=15 years

Water Quality Parameters

Water Quality

Physical

1) Turbidity
2) Temperature
3) Colour
4) Odour
5) Taste

Chemical

1) Solids
2) BOD, COD
3) Hardness
4) Alkalinity
5) pH
6) Nitrate, Phosphate
7) Chloride content
8) POP (persistent organic pollutants
9) PAHs
10) EDA- Endocrine disrupting Agents

Biological

1) Virus
2) Protozoa
3) Helminths
4) Bacteria
5) Rotifer
6) Algae and Fungi

Turbidity

Cloudiness of water; Measure of extent to **which light is either absorbed or scattered by suspended material in water**

<u>Cause-</u>

- It is caused by suspended material such as clay, silt, organic material, plankton, and other particulate materials in water

<u>Effects</u>

- Turbid particles provide surface of absorption for toxic material and become harmful.
- Turbid particles hinder disinfection – bacteria smaller in size

<u>Measurement</u>

- Turbidity is a qualitative measurement
- Measured using turbidity meter
- Principle: light scattering

<u>Unit</u>

- JTU (Jackson turbidity unit)- SiO2 standard
- NTU (Nephelometric turbidity units (NTU)/FTU (Formazine turbidity Unit)

Colour

It is caused by suspended and dissolved matter in water.

Heavy growth due to algae also impart colour to water.

Causes

True colour- Caused due to dissolved solids

Apparent colour- Caused due to suspended and colloidal solids

Measurement

Spectro-photometric method

Hazen colour unit

Platinum cobalt scale-colour matching technique.

Odour, taste and temperature

Causes

Dissolved gases (H2S, CH4), salt, organic compounds etc cause odour

Intensity of taste and odour is measured by, Threshold Odour Number = $\frac{A+B}{A}$

Where, A = sample Volume, B = volume of diluted water; A+B = 200 units

Permissible is 1 to 3

Measurement

Osmoscope

olfactometer

Temperature- affects chemical and biological reactions. An increase in 10 deg C doubles the biological activity.

$\uparrow$Temperature $\qquad$ $\downarrow$Solubility of gas

Chemical parameters

1. pH

   -log $[H^+]$

In water $[H]^+ [OH]^- = 10^{-14}$ mole/lit

In distilled water (neutral water), $[H]^+ = [OH]^- = 10^{-7}$ mole/lit

In raw water, $[H]^+ \neq [OH]^-$

- In a water treatment plant,

  PH values of incoming and outgoing waters are 7.2 and 8.4 respectively. Assuming a liner variation of pH with time, the average pH of water

pH1= 7.2,

pH2= 8.4

Log [1/H1+]= 7.2

H1+= 10^-7.2 mole/lit

Log [1/H2+] = 8.4

H2+= 10^-8.4

Avg H+ = (10^-7.2 + 10^-8.4)/2 =

Avg pH = 7.47

2. Two sample of water A and B have pH value 4.4 and 6.4 respectively. How many time more acidic sample A than sample B.

3. Solution A--- volume- 300 ml, pH= 7

   Solution B ---volume-700 ml and pH= 5

   Avg H+ = 300x10^-7+ 700*10^-5)/ (300+700)= 7.03*10^-6

   log (1/H+) = 5.15

Chemical parameters

2. Conductivity (S or mS/cm)

- Measures of ions in liquid
- Indirect measurement of dissolved solids in water.

$$\text{Conductivity} = 2.5\times10^{-5}\,(\text{TDS})$$

Not applicable for wastewater

Chemical Parameters

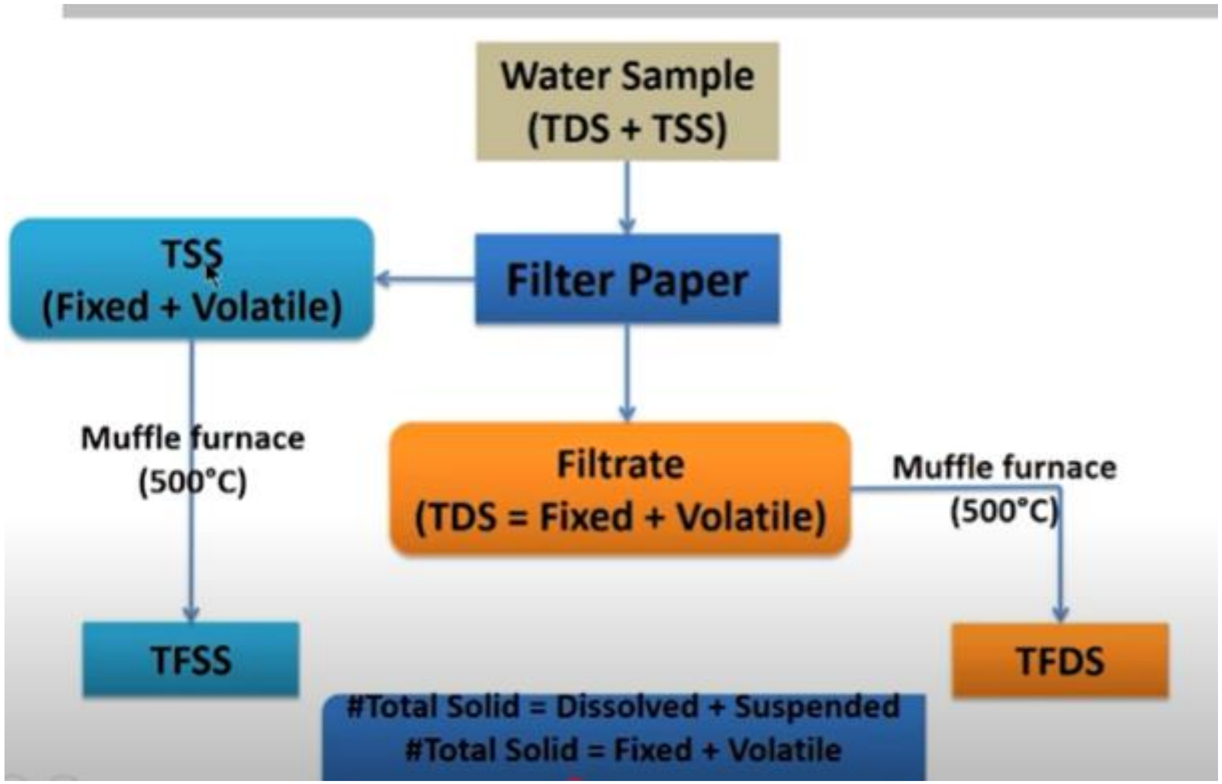
3. Solids

- Settleable solids
- Dissolved solids and Suspended solids/Colloidal
- Volatile and Fixed solids

➢ Settleable solids – "Imhoff cone"

- Wastewater allow to settle for 30 mins.

Chemical Parameters



Chemical Parameters

4. Alkalinity and Acidity

- Alkalinity is the acid neutralizing capacity of water
- Acidity is the base neutralizing capacity of water

➢ Alkalinity is due to – HCO_3^-, CO_3^{2-}, OH^- etc.

➢ Acidity is due to – H^+, H_2CO_3, HCO_3^- etc.

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

$$H_2CO_3 \rightleftharpoons 2H^+ + HCO_3^-$$

$$HCO_3^- + OH^- \rightleftharpoons CO_3^{2-} + H_2O$$

Chemical Parameters

Hardness

Causes

- Contributed by Ca 2+, Mg2+, Fe2+, Mn2+ Sr2+ etc
- Represented interms of mg/l as CaCO3

Temporary hardness

- Majorly by Ca^{+2} and Mg^{2+} in the form of HCO_3^- CO_3^{-2}
- Can be removed by simple boiling of water where calcium carbonate ($CaCO_3$) precipitates as solubility reduces with increase in temperature

Permanent hardness

- Contributed by Ca^{+2} and Mg^{2+} in the form of Cl^- , SO_4^{-2} , NO_3^{-2}
- Can't be removed by simple boiling
- Can be Removed by softening techniques like ion exchange etc.

- Hardness ≈ alkalinity is called temporary hardness.
- Hardness – Alkalinity = Permanent Hardness

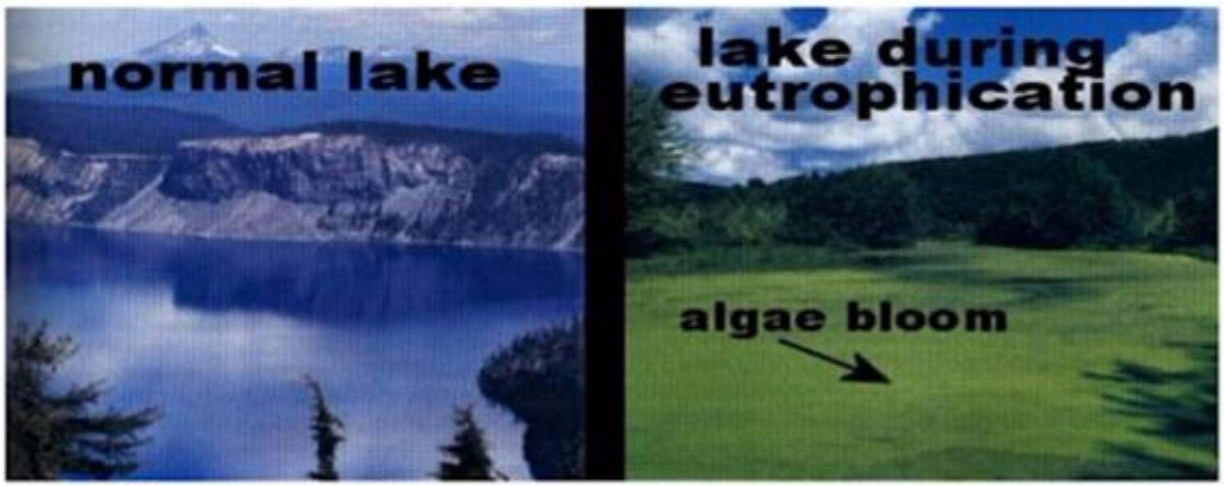
E.g. Hardness = 600 mg/l of $CaCO_3$

Alkalinity = 400 mg/l of $CaCO_3$

Temporary hardness ?? Permanent hardness ??

Nutrients

Nitrate (NO_3^-), Phosphate (PO_4^{3-})



NO_3^- and PO_4^{3-} cause eutrophication (excess algal growth) of Water bodies and hence should be removed.

Chemical Parameters

Nitrogen content (nitrates, Ammonia)

- Presence of nitrogen indicates organic matter
- Organic Nitrogen+ NH3-N – Kjedhal N
- Presence of free ammonia (NH4+) = **Recent pollution**
- **Nitrites** and **Nitrates** indicate partly or **old pollution**.
- Nitrites are highly dangerous , permissible limit=zero
- Too much(45mg/L) nitrate (NO_3^{2-})affect infants, causing **blue baby disease** as Infants abdomen is slightly alkaline
- NO_3^{2-} converts to NO_2^{-} which has high affinity to haemoglobin and hence O2 deficiency occur

Trace elements for aquatic growth – NITRATE AND PHOSPHATE

Excess Nitrate cause Eutrophication

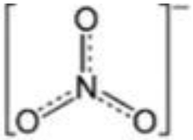
Phosphorus

Non toxic to human health.

Interferes water treatment, facilitates rapid growth of algae or aquatic plants.

Chemical Parameters

Nitrate



If the water is high in nitrate level it leads the kids 'blue baby syndrome' disease.

The use of contaminated water for agricultural land, will contaminate not only water, also ground water.

Mostly for vegetation we are using toxic pesticides, because of this only the nitraate level in groundwater is increasing constantly

http://upload.wikimedia.org/wikipedia/commons/thumb/e/e1/Cyanotic_neonate.jpg/150px-Cyanotic_neonate.jpg

http://t2.gstatic.com/images?q=tbn:ANd9GcT_cZJnEB4lLRm1w-qEdJtm9hcAsxJK9kDL6sthu45koho_EDg

Chemical Parameters

Pesticides (DDT, BHC, Endosufan)

Poly aromatic hydrocarbon

Poly chlorinated biphenyls

PoPs

VOC – Volatile organic compoumds

EDA

Inorganic compunds like (Flouride, arsenic , nitrate

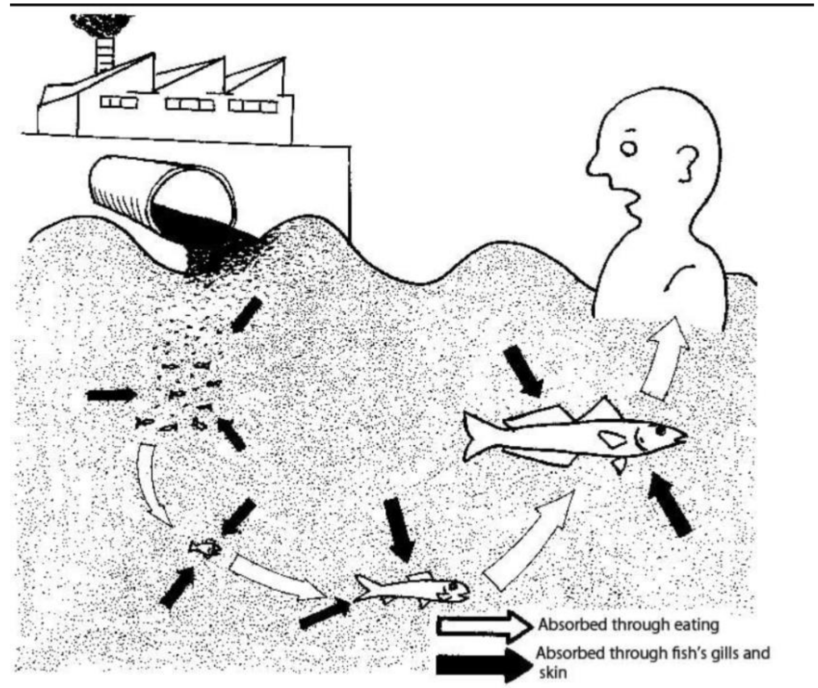
Pharmaceutical active agents)

Heavy metals

Chemical Parameters

Heavy metals

- Any toxic metal or metalloid- Pb, Hg, Cd, Cu, Zn, Cr, As, Fe
- All these elements are needed in trace amount. These are present in enzymes
- Biomagnifications.
- Minamata Bay— Japan
- Methyl mercure (CH_2Hg)



Flouride, Arsenic

Sources- Anthropogenic

- Flouride causes- Skeletal and non skeletal flourosis, Teeth and bone flourosis

Effects when the level of fluoride increases in water

World Health Organization (WHO) guideline for fluorides in drinking water is up to 1.5 mg/L (WHO,1984).

Level of Fluoride **(mg/L)**	Symptoms
< 1.5	**No Problem**
1.5-3.0	Teeth Fluorosis
3.1-6.0	Less Skeletal Fluorosis
> 6.0	More Skeletal Fluorosis

Very Less   Less   High   Severe

Chemical Parameters

Disinfection by-products (DBPs)

- Reaction between oxidants (such as Cl and O_3) and naturally present complex organics such as humic and fulvic acids.
- Example : Tri Halo Methanes (THM), Haloacetic acids and many organo-chlorine compounds.
- These compounds are non-biodegradable, xenobiotic and carcinogenic in nature.

Biological Parameters

- Imp quality to be considered
- WHO- 80% of all disease is transmitted through contaminant water
- 10% of extra money can save 80% money in health sector

Bacterial disease	Viral	Protozoa
Typhoid Cholera Bacillary dysentery	Hepatitis –A, B Meningitis Common cold H1N1 Dengue	Amoebic dysentery

- Pathogens
  - Viruses, Bacteria, Fungi, Algae, Protozoa, Helminthes

Water quality- Biological

- Water should be disinfected to kill the pathogens
- Bacteriological estimation is the most important water quality
- Estimated by indicator organism in terms of MPN
- E.g. E Coli, Total Coliform

Biological Parameters

- Diseases are classified into 4 categories- in relation to water

Water borne disease

❑Caused by consuming contaminated water

Water based disease

➢Caused by aquatic organisms – part of life in contaminated water and another part as parasite in human or animals
➢e.g. Any worms (round worm, hook worm, tape worm

Biological Parameters

- Diseases are classified into 4 categories- in relation to water

Water related vector disease

- ❑Carrier of the disease, Mosquitoes
- ❑
- ❑Malaria, dengu, yellow fever

Water scarce disease

- ➢Due to insufficient water supply- hygiene condition get effected
- ➢e.g. skin diseases, eye infection, parasite infection

Biological parameters

Water Washed Diseases

- This is a diseases happens for persons who avoid to be personally hygiene.
- If there is sufficient availability of water for bathing and washing will lead to water washed diseases
- Parasitic infection
- Scabies and rash

http://diseasespictures.com/wp-content/uploads/2012/11/Trachoma-2.jpg

Water quality standards

- **Standards: Agencies such as USEPA, CPCB, BIS, EU, WHO are responsible for setting up water quality standards**
- **Drinking water – Highest purity**
- **Standard depends on End usage of water**

- ❑ **Prescribed values**
- ❑ **Strictly enforced by law--- violation are punishables**

- **Attributes of standards**

1. **It should fulfil the requirement for which it is set**
2. **Easily measurable**
3. **Technically feasible**
4. **Economically viable**

- **With development of technologies, new standards are added up**

WATER QUALITY STANDARDS (BIS)

S. No.	Parameter	BIS, Indian Standards (IS 10500:1991)		World Health Organization (WHO Guideline) Maximum allowable concentration
		Desirable Limit	**Permissible Limit**	
1	PH	6.5-8.5	No relaxation	6.5-8.5
2	Total Hardness (as CaCO3)	300 mg/L	600 mg/L	500 mg/L
3	Chlorides (as Cl)	250 mg/L	1000 mg/L	250 mg/L
4	Dissolved Solids	500 mg/L	2000 mg/L	1000 mg/L
5	Calcium (as Ca)	75 mg/L	200 mg/L	-
6	Sulphate (as SO42-)	200 mg/L	400 mg/L	400 mg/L
7	Nitrate (as NO3-)	45 mg/L	100 mg/L	10 mg/L

Water quality monitoring

- Periodical monitoring is essential

- Sophisticated and expensive instruments: Not accessible to many

- Easy to use and affordable monitoring systems are essential

Water Treatment

Source of water

Beneficial use of water


Yamuna
TIBET
Lhasa
HIMALAYAS
Brahmaputra
Delhi
NEPAL
Gandak
Mt. Everest
Kanpur
Sankisa
Kapilavatthu
Kathmandu
Chambal
Ghāghara
Kusinārā
BHUTAN
Allahābād
Patna
Kosi
Brahmaputra
Yamuna
Vārānasi
Betwa
Rajagaha
Son
Gaya
BANGLADESH
Padma
Sanci
Dhaka
Hugli
INDIA
Calcutta

Quality of water

Raw water quality – source of water & point of intake of water
River Ganga
Gangothri –Mountain
Haridwar – Plains – Mass Bathing by Pilgrims
Kanpur – domestic & industrial (more than 100 tanneries)
Allahabad & Varanasi – Pilgrim centre (Mass bathing – Kumba mela, partially burnt dead bodies in to river etc.)
Patna – Domestic & Industrial

Water quality requirement for beneficial use

Domestic use

1. Bacteriological safety
2. Color , odour, taste
3. Free from toxic compounds

Industrial use

1. **Process water-** Drinking water standard, but varies based on industry
   Water used in different processes. e.g. TDS is helpful fixing the dye.
2. **Product water –** Drinking water standard
   soft drinks
3. **Cooling water-** free from hardness (scale formation, heat exchange capacity reduces), non corrosive and non scaling
4. **Service water-** used for cleaning purpose, transportation (carrying raw material and waste, fly ash made into slurry and transported), it does not need much quality

Water quality requirement for beneficial use

Agricultural use

1. TDS – most imp parameter
   saline, sea water cant be used , high conc of Na, Cl ions replaces essential minerals Ca^{2+} and Mg^{2+}
   Plants obtain water through osmosis, If salt conc is high in soil, water from plants move into soil and affect plant growth

2. Soluble sodium percentage

$$SSP = \frac{(Na^+ + K^+)}{(Ca^{2+} + Mg^{2+} + Na^+ + K^+)} \times 100.$$

SSP < 60

3. Sodium Adsorption ratio

$$SAR = \frac{Na^+}{\sqrt{(Ca^{2+} + Mg^{2+})/2}}.$$

SAR < 9

The concentration of the ions in SSP and SAR in **meq L^{-1}**

Water quality requirement for beneficial use

Agricultural use (continued)

4. Free from Heavy metals- or else biomagnification
5. Free from toxic compounds
6. Leafy vegetables and vegetables which are eaten raw should be cleaned with pathogen free water

Issue- Sewage farming (turbid water)- clogging of pores----- unsuitable for agriculture

Live stock

1. **Pathogen free**
2. **Free from toxic compounds**
3. **For fish cultivation- free from turbidity (fish breathe through their gills, get clogged if turbid water is used**
4. **Temperature- optimum temperature**
5. **Free from pathogen**

Water quality requirement for beneficial use

Recreational water

1. Navigational water – free from odour, pathogens (chance of water spillage there)
2. Lawn irrigation- Free from lawn and pathogens
3. Swimming pool- free from turbidity, pathogens, odour, colour, toxic compounds (residual chlorine -0.1mg/l)
4. Bathing Ghats

Water Treatment

Surface water