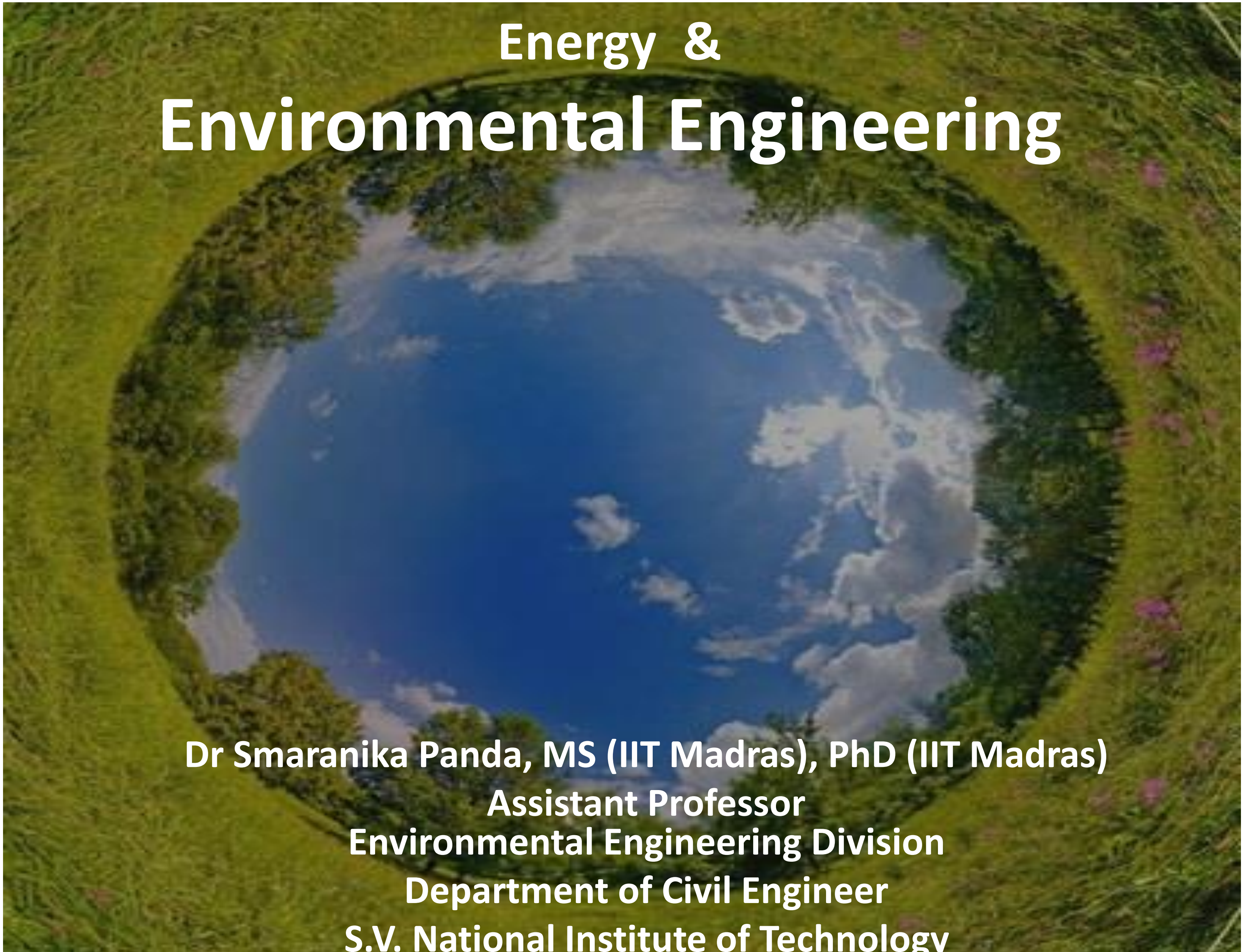

Energy &
Environmental Engineering

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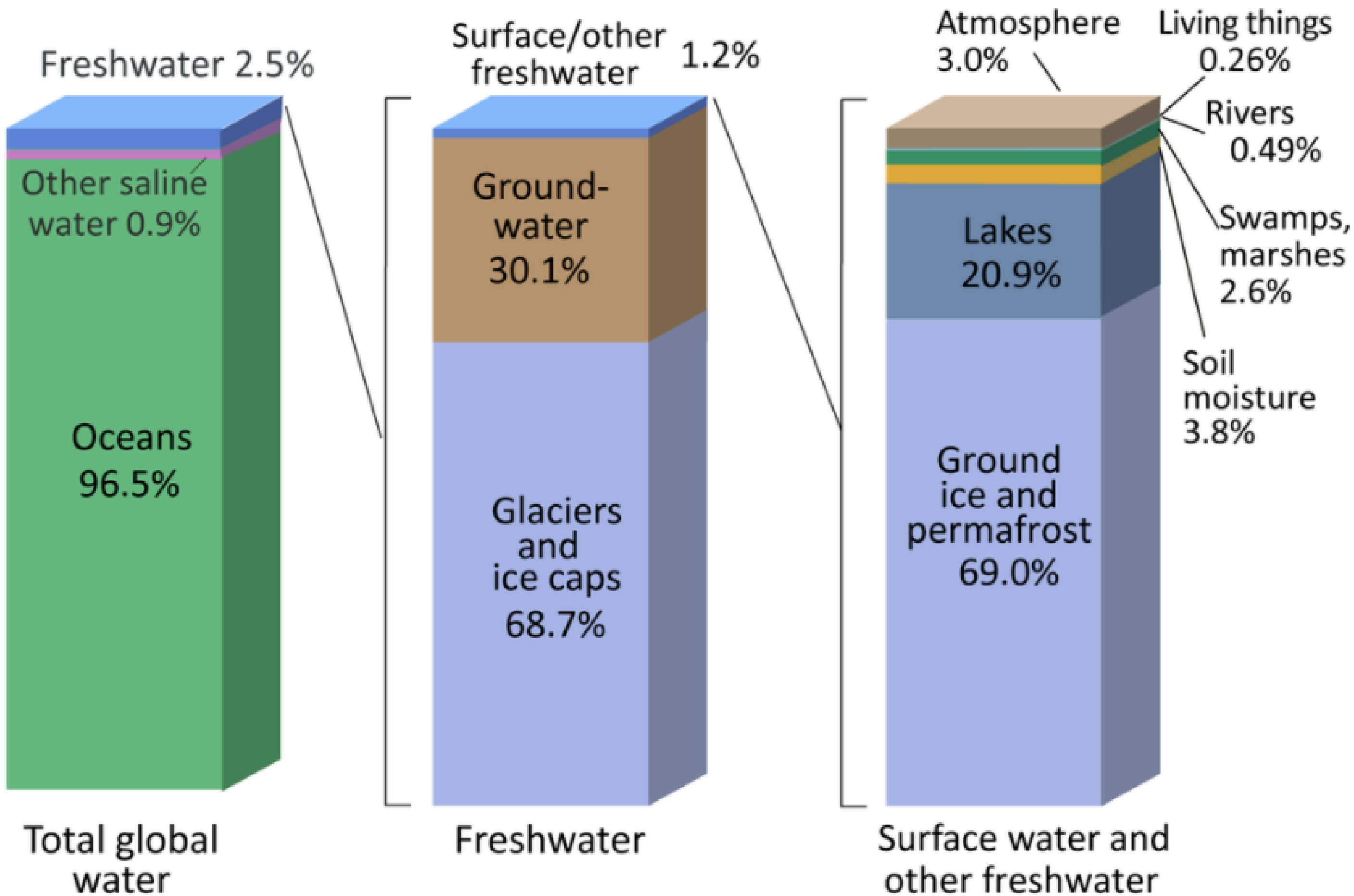
Module 2

- **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

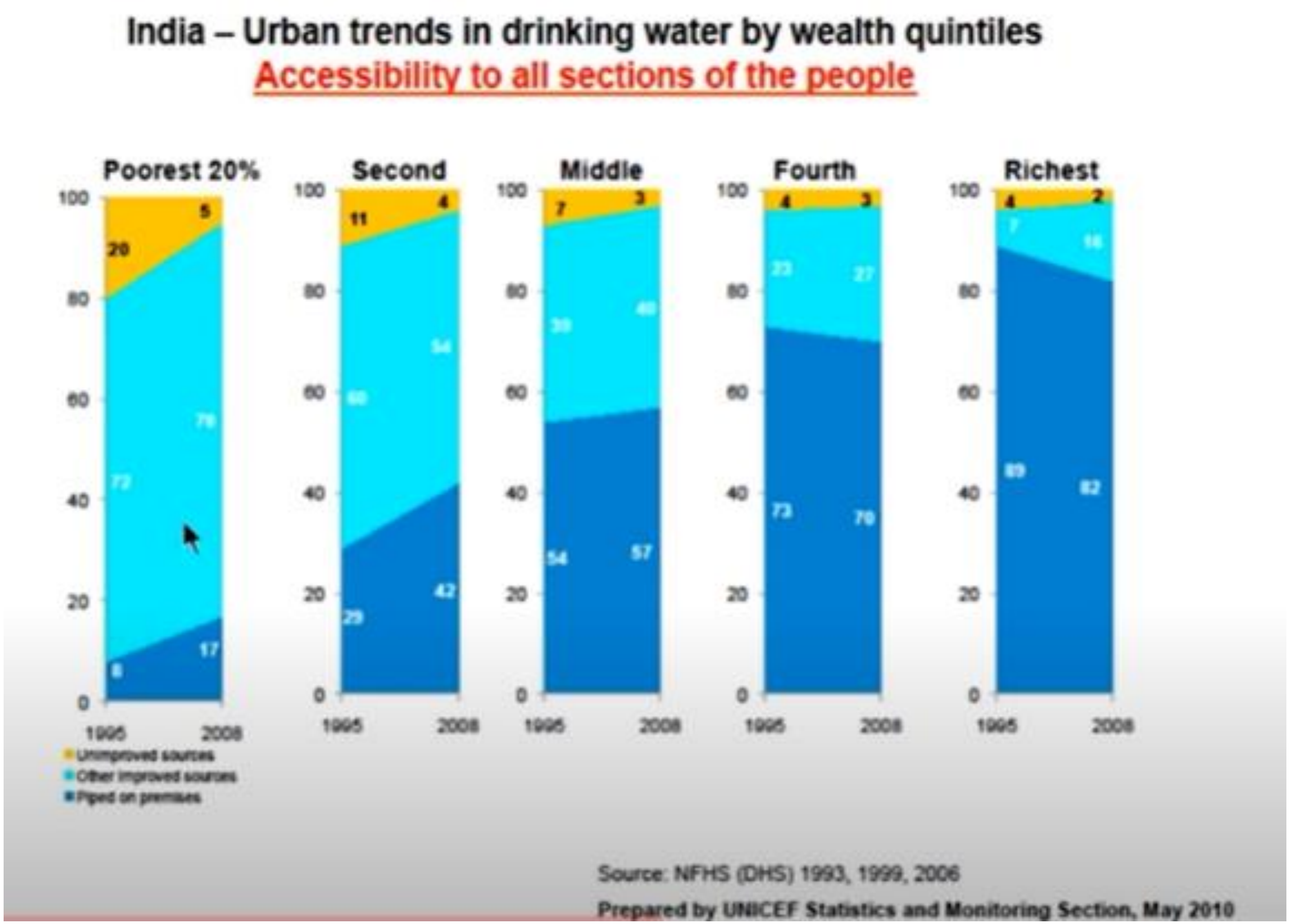
Attributes of Drinking Water

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

Unit Operation

Separating using Physical forces
Settling
screening
Gas transfer

Unit Process

Chemical or biological reaction along with physical forces
E.g. Coagulation, Flocculation, sedimentation, adsorption, ion exchange , biological processes etc

Selection of Treatment Process

1. Source water characteristics

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

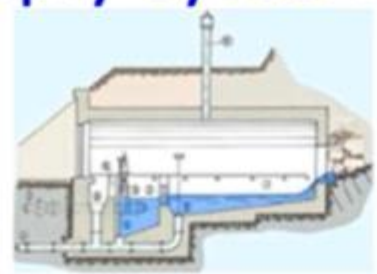
Objective of Public Water Supply System

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

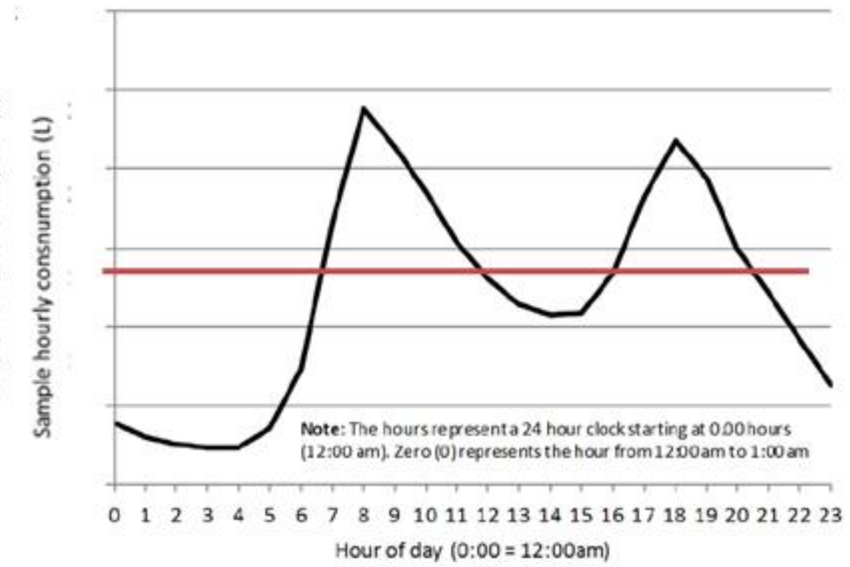
Fire Demand:

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

Coincidental draft – Max daily demand+ Fire demand

Total draft- Higher of the following

a) Coincidental draft

b) Max hourly demand

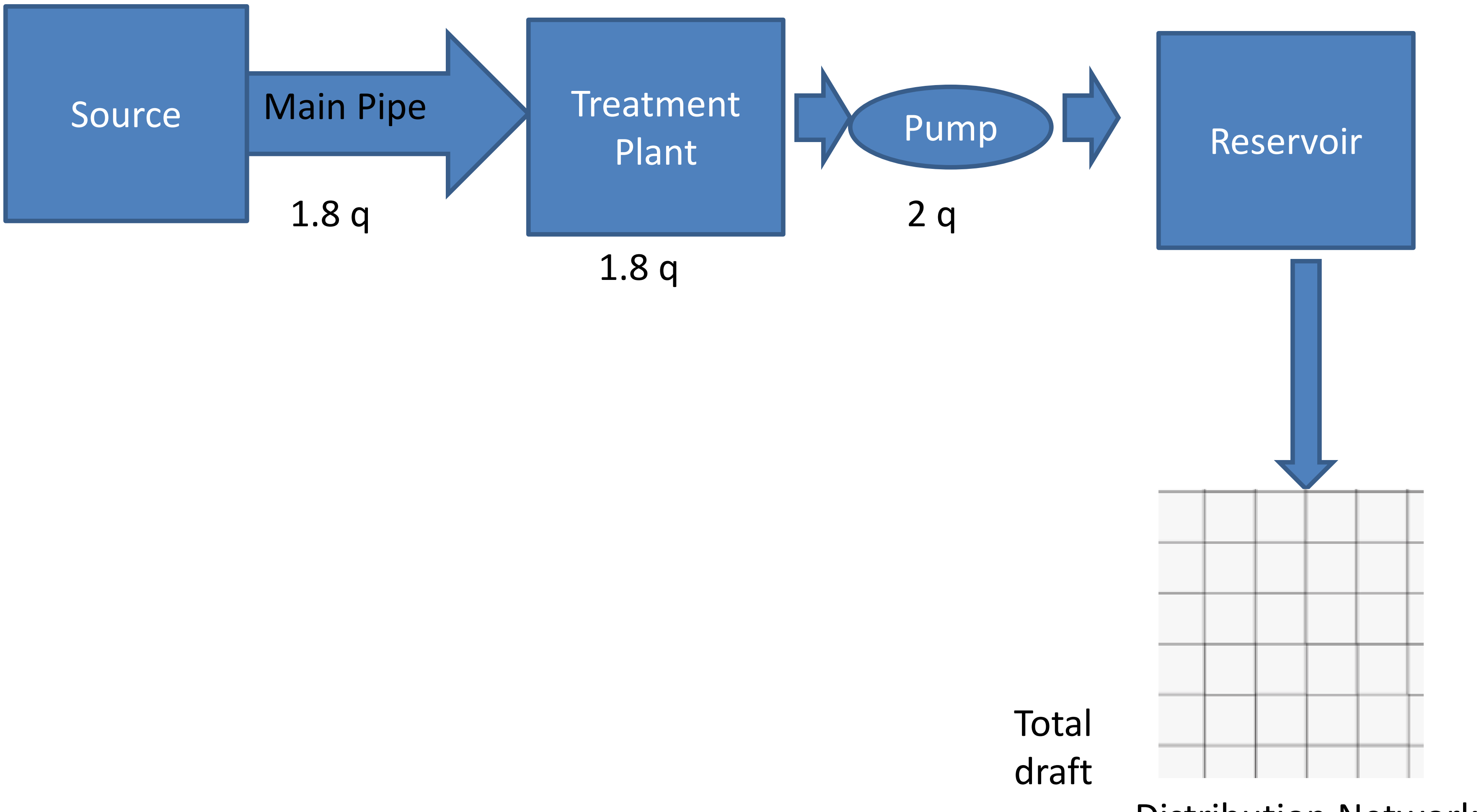
Max daily demand= 1.8 q

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


Source
Main Pipe
1.8 q
Treatment Plant
1.8 q
Pump
2 q
Reservoir
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
- P4 = 1.68 (1+ 0.3)^1= 2.18 lakh

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

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**

Cause-

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

Effects

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

Measurement

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

Unit

- JTU (Jackson turbidity unit)- SiO_2 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 (H_2S, CH_4), 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 $\downarrow$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 ions in liquid
Indirect measurement of dissoved solid in water

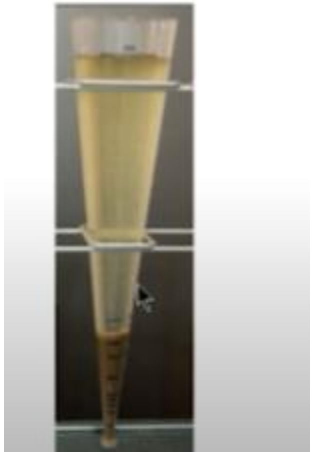
$$\text{Conductivity} = 2.5 \times 10^{-5}\ (\text{TDS})$$

Not applicable for waste water

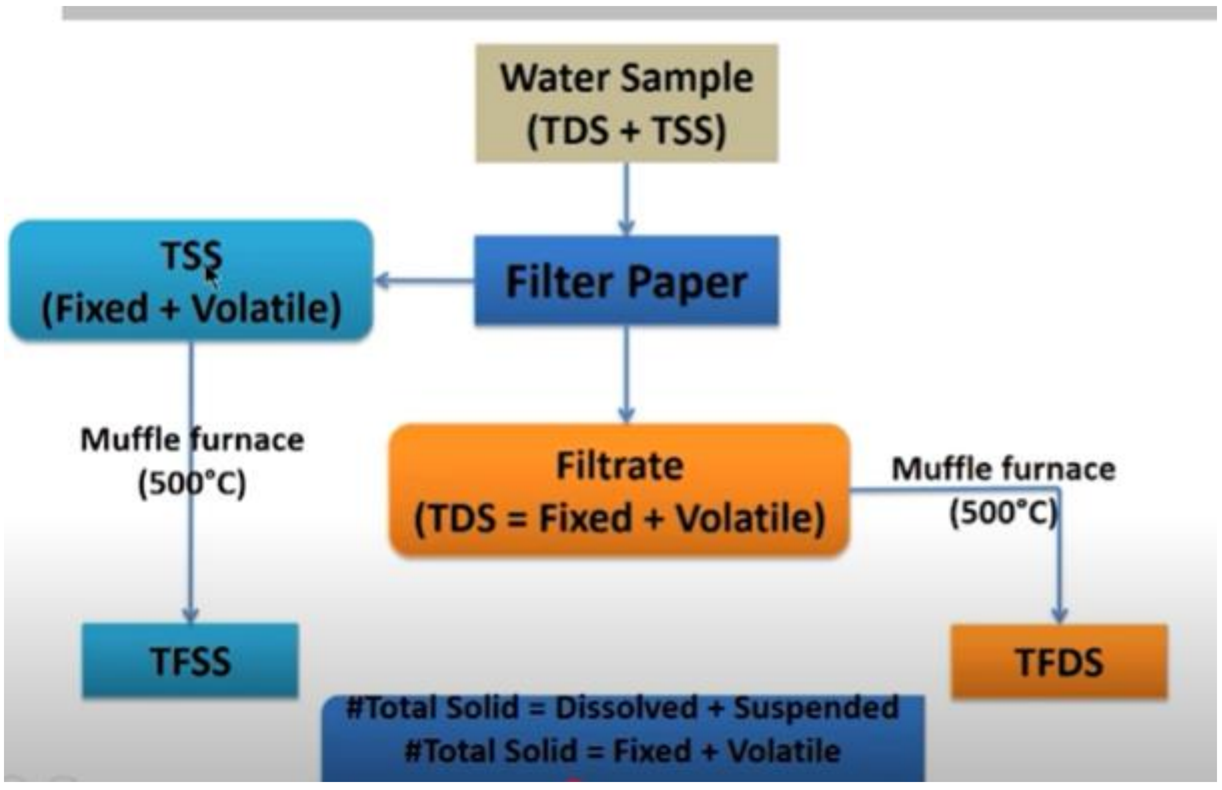
Chemical Parameters

- Solids
  - Settleable soilds
  - Dissolved solids & suspended solids/colloi solids
  - Volatile and fixed solids
  - Setttleable solids- using “imhoff cone”

-Waste water allow to settle for 30 min



Chemical Parameters



Courtesy to Dr Ligy Phillip, IIT Madras

Chemical Parameters

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^-

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

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

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

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.

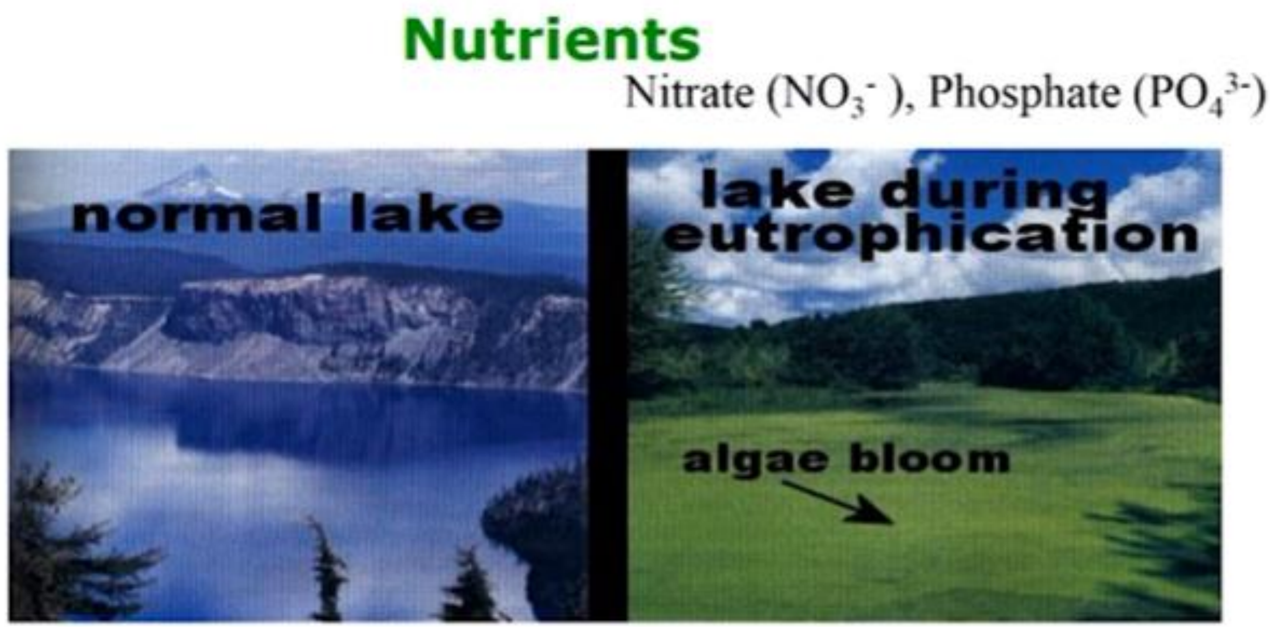
- Hardness ≈ alkalinity is called temporary hardness.
- Hardness – Alkalinity = Permanent Hardness

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

Alkalinity = 400 mg/l of $CaCO_3$

Temporary hardness ?? Permanent hardness ??

- Nitrate (NO_3^-) and Phosphate (PO_4^{3-}) cause eutrophication (algea bloom) of water bodies 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

- Contamitant water for agricultural land willl 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_cZ3nEB4JLRm1w-qEdJtm9hcAsxJK9k0L6sthu4Skoho_EDg

Courtesy to Dr Ligy Phillip, IIT Madras

Chemical Parameters

Pesticides (DDT, BHC, Endosufan)

Poly aromatic hydrocarbon

Poly chlorinated biphenyls

PoPs

VOC – Volatile organic compoumds

EDA

Inorganic compunds like (Flouride, arsenic , nitrate

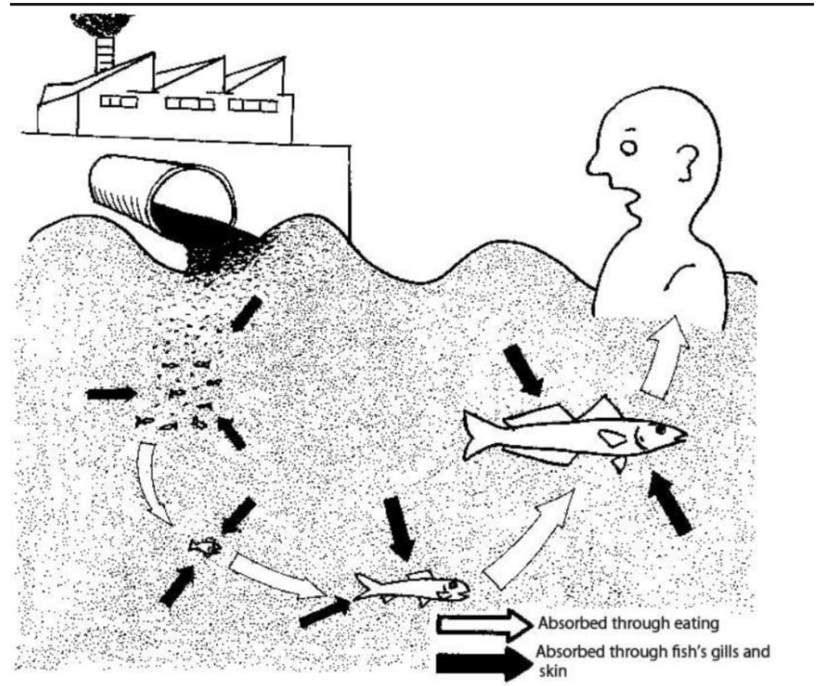
Pharmaceutical active agents)

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 & O3) and naturally present organics sucg as humic acid and fulvic acids
- E.g. tri halo methane (THM), Halo acetic acids and many organochloro compounds
- There compounds are non bio degradable, 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

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

River Ganga

Courtesy to Dr Ligy Phillip, IIT Madras

Raw water quality- Source of water and point of intake of water

- Gangotri- Mountain
- Haridwar- Plains- Mass bathing by pilgrims
- Kanpur- Domestic and industrial (more than 100 tanneries
- Allahabad and Varanasi – Pilgrim centre (mass bathing- kumbha mela, partially burn dead bodies in to river)
- Patna- Domestic and industrial

Treatment requirement varies in each areas

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**

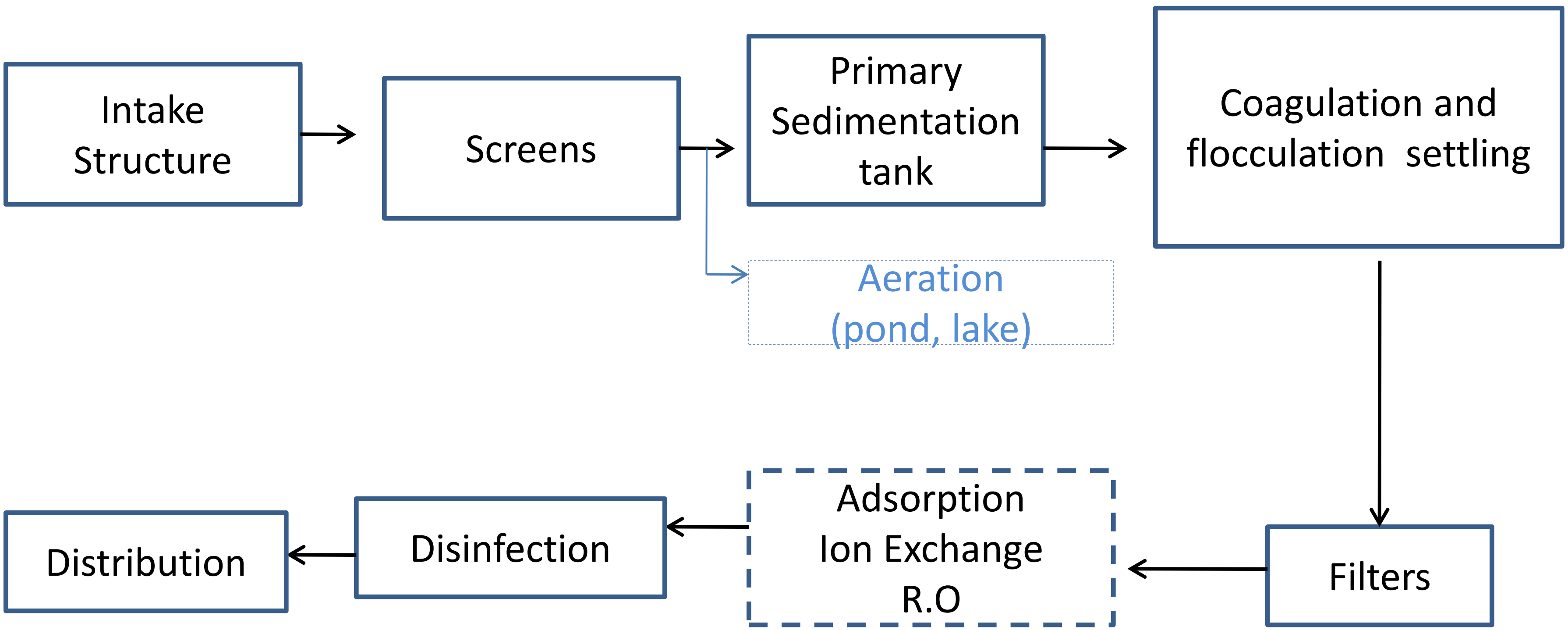
Water quality requirement for beneficial use

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

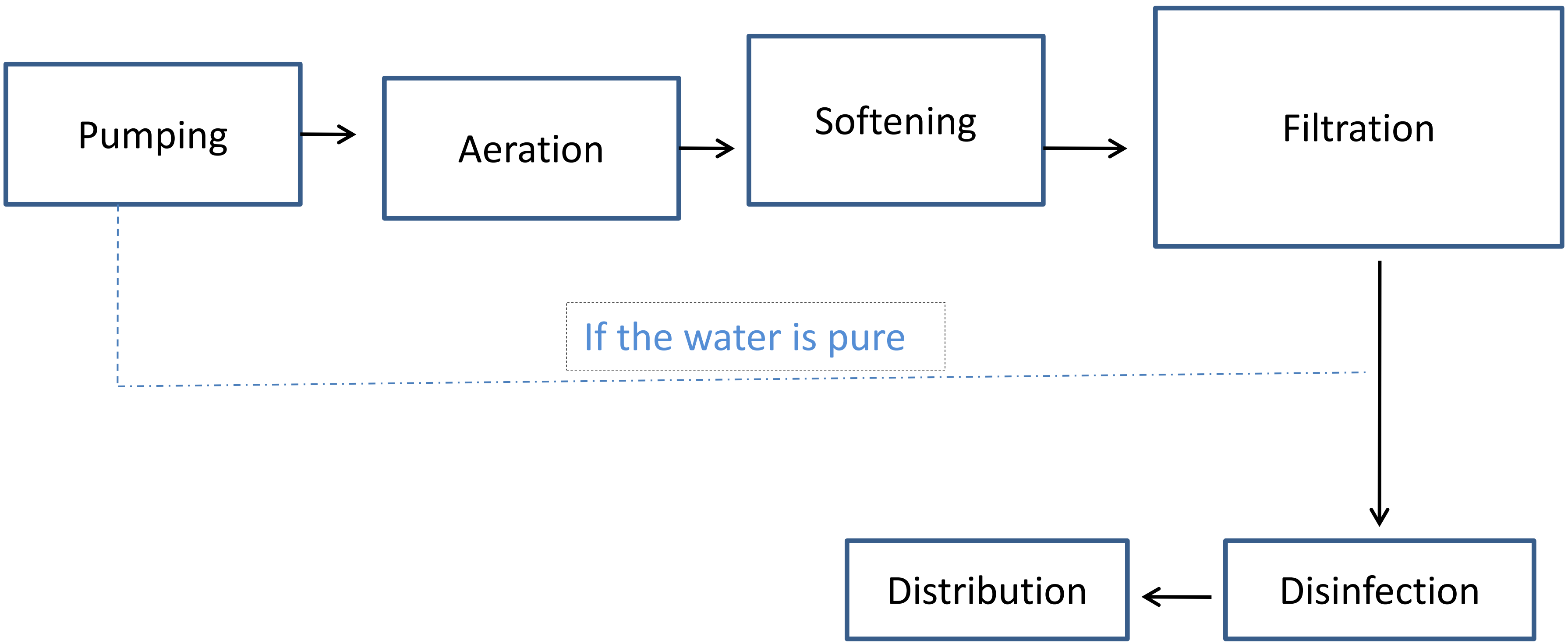
Water Treatment

Surface water



Water Treatment

Ground water



Water Quality Indices

WQI is an empirical expression which indicates physical, chemical and biological parameters of water

- Precise number to communicate to layman
- Average of physico chemical parameters
- Developed through expertise questionnaire survey and fixing the value

WQI can be used in the following purposes

- To provide overall status of water quality
- Study the effectiveness of policies and environmental programs on water quality
- To compare the water quality of varying sources and sites
- To assist the policy makers and public to avoid subjective assessments

Waste Water Treatment

- Refuse- Rejected material
- Garbage- Dry refuse, organic
- Rubbish- Dry refuse, inorganic
- Sewage- liquid waste, foul in nature, domestic
- Sullage- liquid waste, not foul in nature, domestic
- Sanitary sewage- domestic as well as industrial sewage
- Sewer- a conduit or pipe to carry sewage
- Sewerage- a system of collection and conveyance of sewage
- Storm water- runoff
- Dry weather flow- Sanitary sewage/sewage
- Wet weather flow- sewage+storm water

Systems of sewerage

- Separate system- separate for sewage and storm water
- Combined system- one sewer both for sewage and storm water
- Partially separate system- one sewer for sewage and some storm water(roofs/courtyards) and open drains beside the roads

Sewer design

- Open channel flow (not pressure flow)
- Sewer is designed to flow half full or 3/4th full.
- Estimation of sewage flow-
  - 75 to 80% of water supply

  - ❑ Average daily sewage flow- q lit/day
  - ❑ Max daily sewage flow = 2q lit/day
  - ❑ Max hourly sewage flow = 3q lit/day
  - ❑ Minimum hourly flow rate = (1/3) q lit/day

- Sewer is designed for maximum hourly flow and checked for minimum flow (against silting)

- Storm water q can be calculated by various empirical methods

Waster water characteristics

- Sewage – 99.9% water + 0.1% solid (organic soilds, it will not remain stable, it will undergo decomposition)

Aerobic Decomposition
•Presence of O_2
•End of decomposition- CO_2, Sulphates, Nitrates

•Natural Manure, fertilizer

Anerobic Decomposition
•Absence of O_2
•End of decomposition- CO_2, CH_4, H_2S, NH_3
•Highly inflammable
•Gobar gas plant

Characteristics of waste water

Physical

- Turbidity
- Colour- Indicates stage of decomposition Fresh sewage- light colour, septic sewage- dark colour
- Odour – Fresh sewage less odour, undergoing decomposition- high odour
- Temperature – indicates rate of decompostion
  - High temp- good decomposition

Characteristics of waste water

Chemical properties

- Solids – Suspended solids
- Colloidal solids
- Dissolved solid
  - TS= SS+DS+CS
  - Evaporation techniques
  - Fixed and volatile components
  - Settleable solids- Imhoff cone

Characteristics of waste water

Chemical properties

- Organic matter – Bio degradable (decomposed by bacteria) & non biodegradable (cant decomposed by bacteria)
- Dissolved oxygen – Amount of O_2 available in water
- Pure water holds 9.2 mg/l of O_2 at 20 degree Centigrate- known as saturated DO
- For fish survival O_2 needed is 4 PPM

Organic matter can be measured by BOD, COD etc

Characteristics of waste water

Chemical Oxygen Demand- Oxygen required by an oxidizing agent (chemicals) for oxidation of both biodegradable and non biodegradable organics

Biochemical oxygen demand (BOD)- Amount of O2 needed during microbial decomposition of biodegradable organics at a particulate temperature for a particular incubation period

Theoretical Oxygen Demand (ThoD)- Amount of oxygen required for decomposition which is calculated theoretically

Chemical Parameters

- BOD is generally expressed in BOD_5 or BOD_3.
- BOD_5 measures at 20°C for incubation period of 5 days.

  Organic matter + DO + microbes

  CO_2 + H_2O + more cells + energy

- Indicator of the pollution status of streams.

- $BOD_5 = (DO_i - DO_f) \times$ Dilution factor
  - DO = 9 mg/L at 20°C
  - BOD test is valid for (i) $DO_f > 1$ mg/L

    (ii) DO consumed ≥ 2 mg/L

- Biological reactions are generally first order.

  $dL/dT \propto L$; where L = organic matter

$$\boxed{L = L_0 e^{-kt}}$$

L_0 = ultimate oxygen demand

Therefore, BOD exerted;

$$\boxed{y = L_0(1- e^{-kt})}$$

- BOD5 = (2/3) BODu (ultimate BOD)
- In 5 days almost 2/3 organic matter gets decomposed due to bacteria
- In 20 days almost 95-99% Organic Matter gets decomposed by bacteria
- The exact amount of decompostion depend on temperature and type of organic matter
- ThoD > CoD> BOD

Chemical Parameters

Chemical Oxygen Demand

O.M + Potassium dichromate (electron acceptor) Cr^{6+} $\xrightarrow{\Delta 2H^+}$

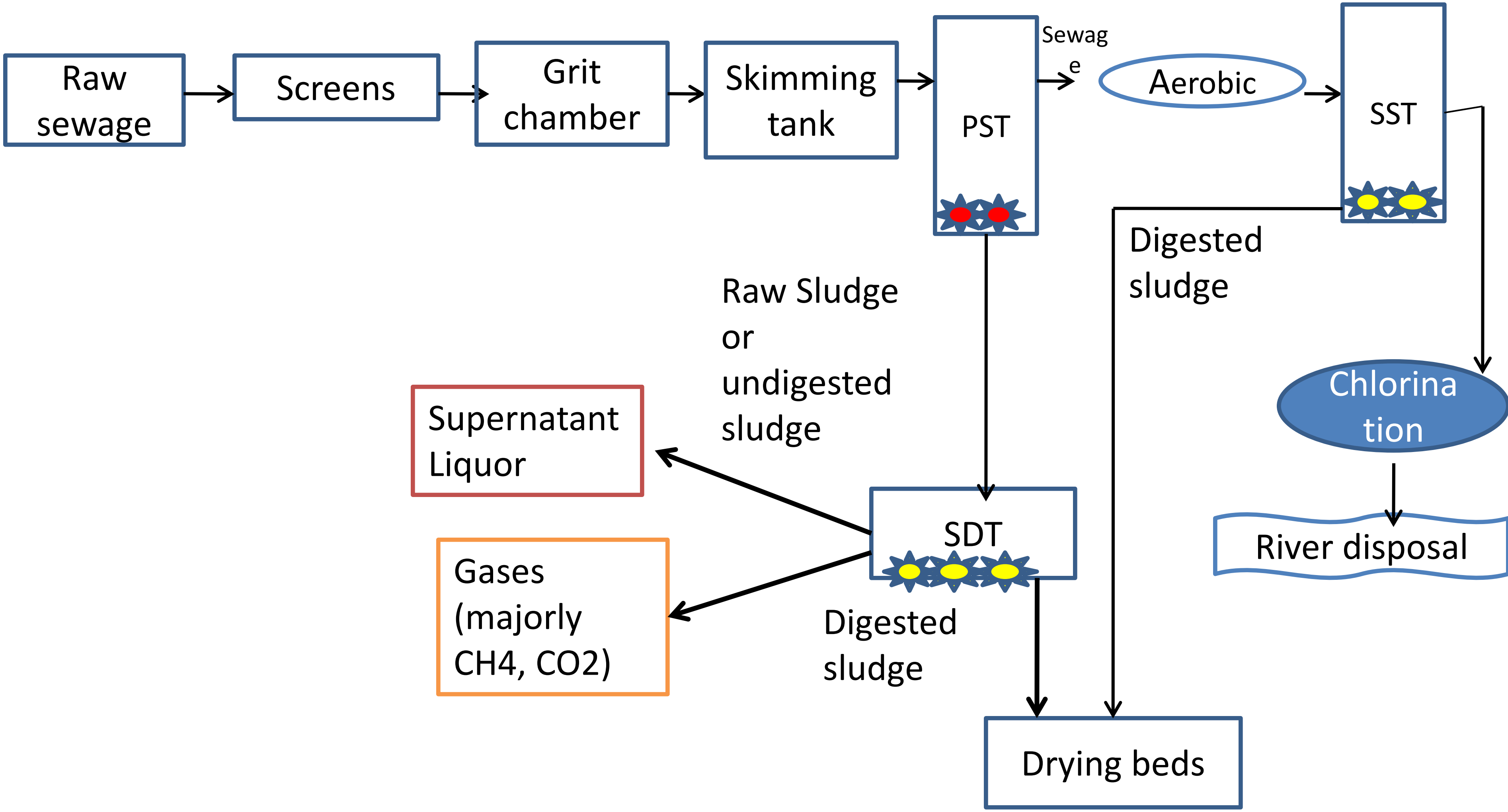
$\longrightarrow CO_2 + H_20 + NO_3 + Cr^{3+} + Cr^{6+}$

Nitrogen

- Oxidation of NH3-N to NO3-N is called nitrification

$$NH_3 \xrightarrow[+O_2]{\text{Nitrosomonas}} NO_2 \xrightarrow[+O_2]{\text{Nitrobater}} NO_3$$

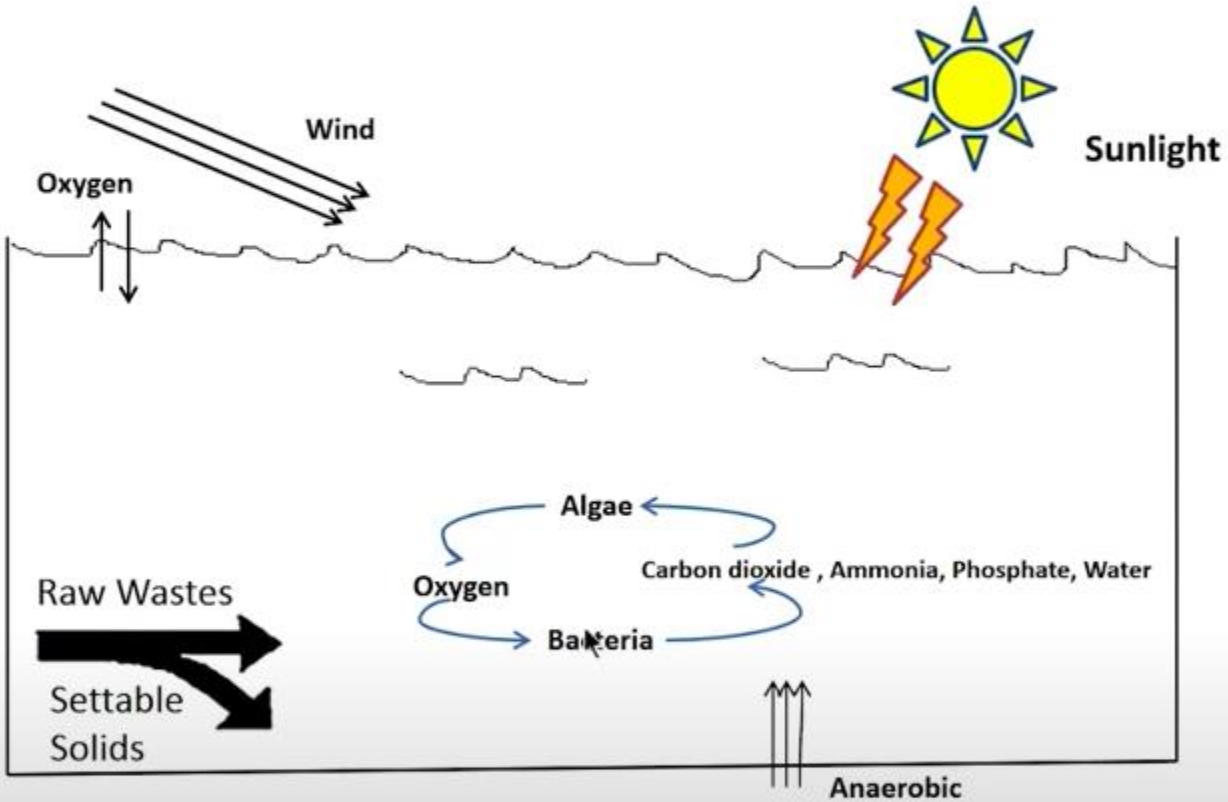
Waste Water Treatment



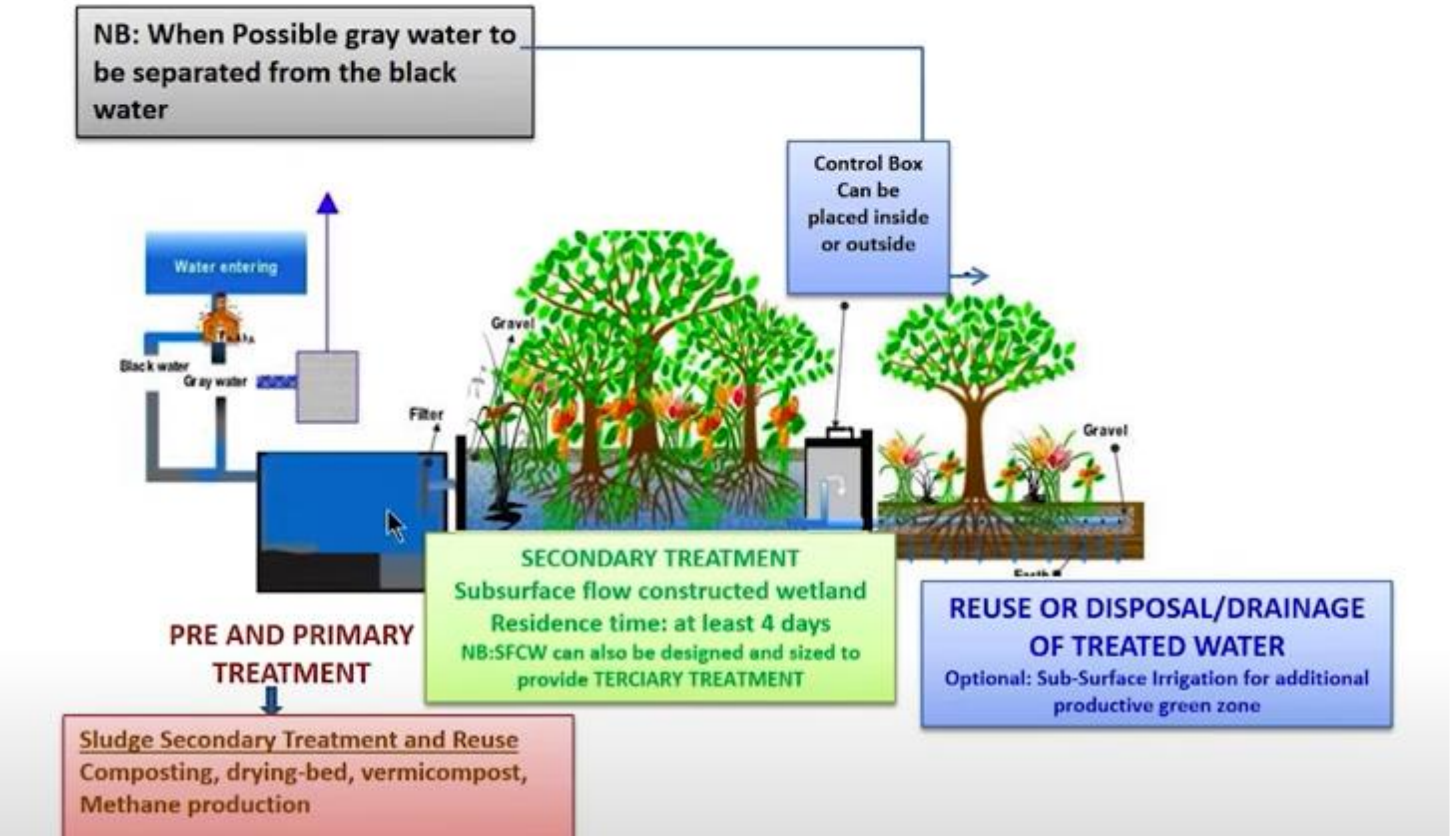
- Primary treatment : Objective- To remove suspended easily settleable and floating materials,
  - Screens, Traps, Grit Chambers (Preliminary treatment)
  - Sedimentation Tanks, Imhoff Tanks

- Secondary treatment: To remove Colloidal & dissolved Organic Matter
  - Activated Sludge Process ,
  - Trickling Filters
  - Waste Stabilization Ponds
  - Aerobic Lagoons
  - Constructed Wetlands
  - Rotating Biological Contractors (MoUD, 2008)
  - Fluidised Aerated Bed (FAB) Reactor (MoUD, 2008)
  - Sequencing Batch Reactors (SBR) (MoUD, 2012)
  - Membrane Bio Reactors (MBR) (MoUD, 2012)
  - Moving Bed Bio Reactors (MBBR) (MoUD, 2012)

Single Oxidation Pond



Constructed wetlands



- Tertiary Treatment Options : It is provided for polishing the secondary treatment units to meet the reuse/ discharge effluent standards
- Pathogens, Nutrients etc
  – Chlorination
  – Ozonation
  – Membrane Filtration (CPHEEO, 2012
  – Micro-filtration membrane
  – Ultra-filtration membrane
  – Nano-filtration membrane
  – Reverse Osmosis

- Based on Cost-Benefit or Cost-Effectiveness and requirements, a system of Wastewater Treatment can be designed from the above available options

Tertiary Removal techniques for various pollutants

Table 11-17
General characteristics of membrane processes

Membrane process	Membrane driving force	Typical separation mechanism	Operating structure (pore size)	Typical operating range, μm	Permeate description	Typical constituents removed
Microfiltration	Hydrostatic pressure difference	Sieve	Macropores (>50 nm)	0.08–2.0	Water + dissolved solutes	TSS, turbidity, protozoan oocysts and cysts, some bacteria and viruses
Ultrafiltration	Hydrostatic pressure difference	Sieve	Mesopores (2–50 nm)	0.005–0.2	Water + small molecules	Macromolecules, colloids, most bacteria, some viruses, proteins
Nanofiltration	Hydrostatic pressure difference	Sieve + solution/ diffusion + exclusion	Micropores (<2 nm)	0.001–0.01	Water + very small molecules, ionic solutes	Small molecules, some harness, viruses
Reverse osmosis	Hydrostatic pressure difference	Solution/ diffusion + exclusion	Dense (<2 nm)	0.0001–0.001	Water, very small molecules, ionic solutes	Very small molecules, color, hardness, sulfates, nitrate, sodium, other ions
Dialysis	Concentration difference	Diffusion	Mesopores (2–50 nm)	—	Water + small molecules	Macromolecules, colloids, most bacteria, some viruses, proteins
Electrodialysis	Electromotive force	Ion exchange with selective membranes	Micropores (<2 nm)	—	Water + ionic solutes	Ionized salt ions

Waste water generation in India

- Due to agricultural growth, industrialization and urbanization wastewater generation increased in recent years which is emerging as potential source for demand management after essential treatment

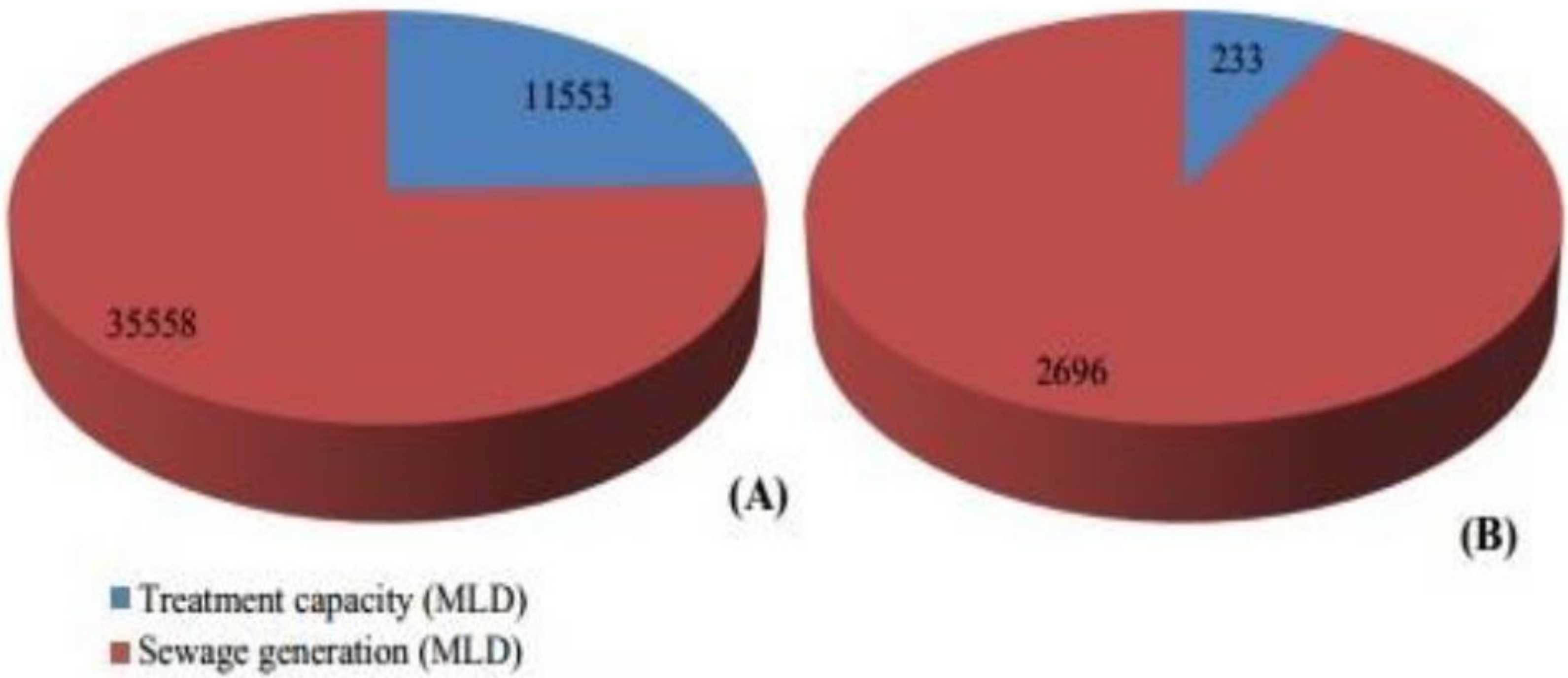
- An estimated **38354 (MLD) sewage** is generated in major cities of India, but the **sewage treatment capacity is only of 11786 MLD** (~30%)

- Similarly, only **60% of industrial waste water**, mostly large scale industries, is treated. (CPCB, 2009)

- Likely to face twin edged problem to deal with reduced fresh water availability and increased wastewater generation in coming decades (Kaur et al, 2012)

- Discharge of untreated sewage into water bodies has resulted in contamination of 75% of all surface water bodies across India (CPHEEO, 2012)

Waste water generation & treatment facility in India



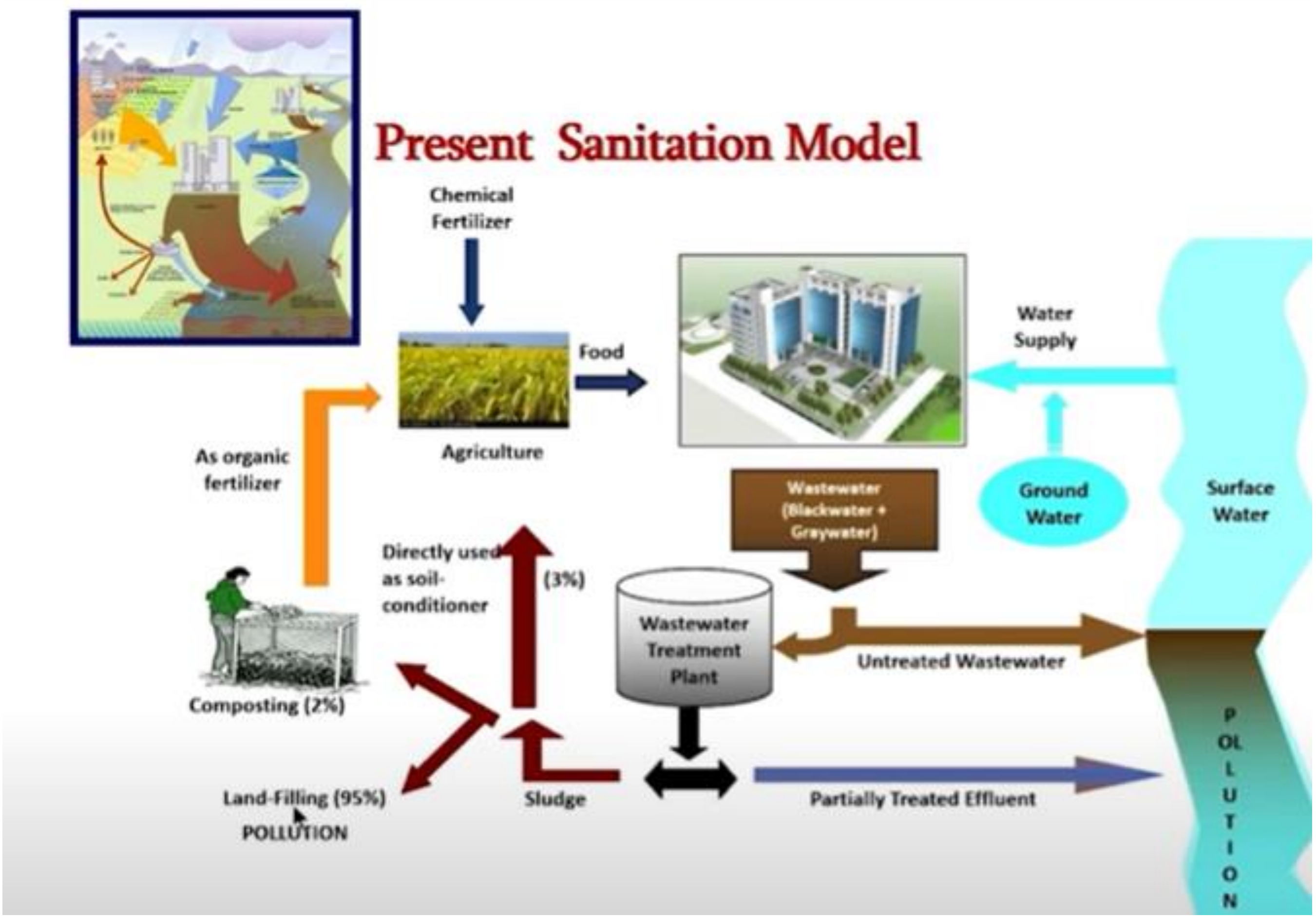
Sewage generation and treatment capacity in 498 Class I cities and 410 class II towns in India. (CPCB, 2009)

Waste water disposal

The mode of disposal is:

- indirectly into the rivers/ lakes/ ponds/ creeks in 118 cities;
- On to the agriculture land in 63 cities
- Directly into rivers in 41 cities.
- In 44 cities, it is discharged both into rivers and on agriculture land.
- In many of the coastal cities, the wastewater finds its way into estuaries, creeks, bays etc. (Around 25% of total wastewater)

Present sanitation Model- India



Paradigm Shift in Recent past

- NE Water Singapore- Purifying conventionally treated wastewater through microfiltration, reverse osmosis and ultraviolet irradiation. Treated domestic wastewater for Industrial use
- –“Zero Liquid Discharge” norm for major industries
- –“Recycled water” for domestic use
- –Treated wastewater for groundwater recharge & irrigation

Few terms

- ETP- Effluent treatment plant
- STP- Sewage treatment plant
- ZLD- Zero Liquid discharge
- CETP- Common effluent treatment plant

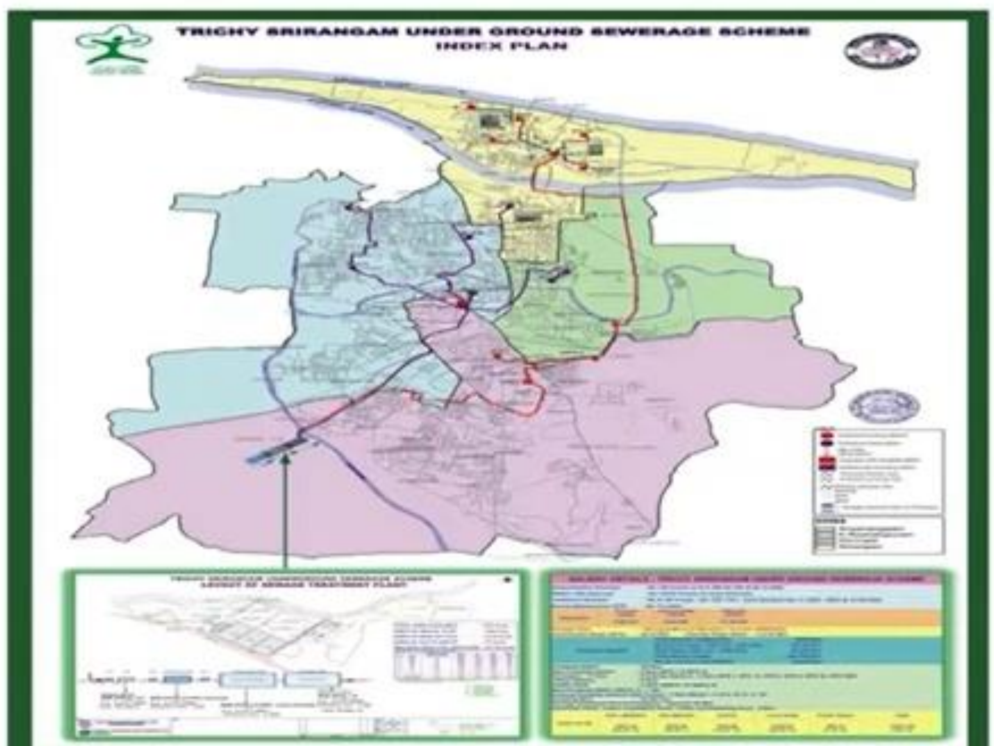
State wise operational CETPS in India*

Sr. no.	State	No. of CETP	Flow, MLD
1.	Andhra Pradesh	3	12.75
2.	Delhi	15	133.2
3.	Gujarat	28**	500.35
4.	Himachal Pradesh	4	1.1
5.	Haryana	1	1.3
6.	Karnataka	9@	-
7.	Madhya Pradesh	3	0.9
8.	Maharashtra	23#	173.35
9.	Punjab	4	57.7
10.	Rajasthan	2	71.15
11.	Tamil Nadu	36	44.4
12	Uttar Pradesh	2	70
Total		130	1066.20

Source: *Central Pollution Control Board Report on Performance Status of Common Effluent Treatment Plants in India, October 2005.
**Gujarat Pollution Control Board, 2010 .
@Karnataka Pollution Control Board, 2012.
#Maharashtra Pollution Control Board, 2012.

Waste water management systems

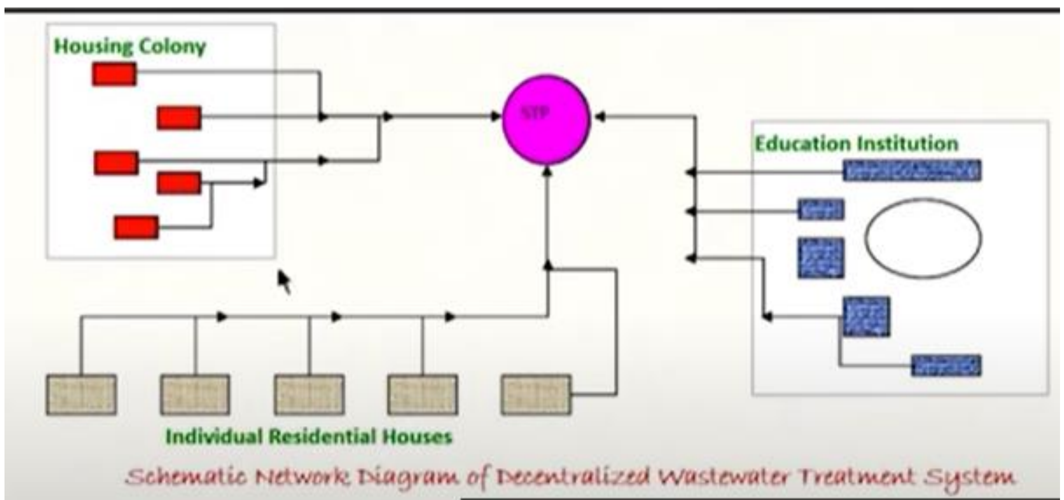
- Centralized: All the waste water generated is collected through pipelines– 100 of km long, to be taken low lying area away from city, treat it and dispose



Waste water management systems

<u>Decentralized WWMS:</u>

Single/group of houses/ colonies can have a STP and water can be treated.



<u>Onsite systems</u>

Septic tanks

Policies and Institutional set up for WWTs

Policies and Institutional set-up for WWTs

- The existing policies for regulating wastewater management are based on certain environmental laws and certain policies and legal provisions like
  - Water Prevention and Control of Pollution Rules, 1975
  - National Environment Policy, 2006;
  - National Sanitation Policy, 2008
  - Hazardous waste (Management and Handling) Rules, 1989
  - Municipalities Act; District Municipalities Act etc