Wastewater Treatment

- ➢ Quantity
- ➢ Characteristics
- ➢ Degree of Treatment → Discharge Norms/
  → Use Requirements
  - Inland waters
  - Groundwater
  - Wetlands
  - Estuaries, Ocean/Sea
  - Residential/Industrial/Horticulture/Agriculture

Environmental Quality & Environmental Pollution

Dimensions

- ➢ **Physical**
- ➢ **Chemical**
- ➢ **Physicochemical**
- ➢ **Biological**

Physical, Chemical, Physicochemical and Biological Dimensions may be assesed for three different phases of the Environment ….. Solid, …. Liquid, ….. And Gaseous.

Solid Phase is represented by Rocks and Soil, …. Liquid Phase is represented by Water, …. and Gaseous Phase by Air

Water – Pure/Impure and Contaminated/Polluted

- Water gains chemical characteristics of aesthetic, health, biological and economic importance by dissolving and suspending materials.
- The type, magnitude, and interactions of these materials determine whether water will have taste, odor, or in general potable or not, and whether it will be corrosive, or acceptable or harmful for a particular use, etc.

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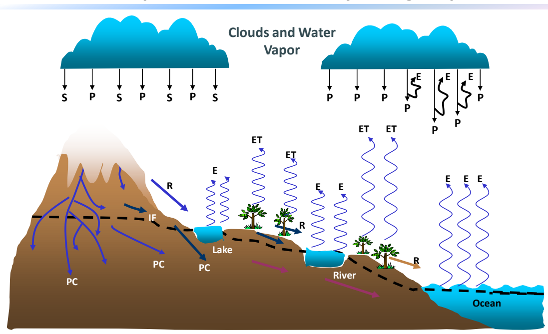
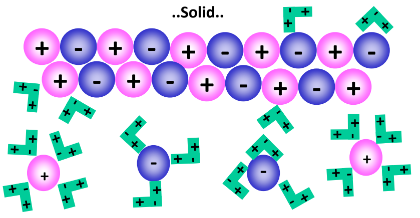
Schematic Representation of the Hydrologic Cycle



The Ability of Water to Dissolve Ions



__Note__ : The oxygen end of the water molecule is attracted to positive ions and the hydrogen end to negative ions. The ability of water to dissolve ions accounts for the presence of inorganic constituents in natural waters. The behaviour of ions in solution, however, is a complex subject.

Water – Origin and Sources of Impurities

Origin: Atmosphere

Ionic and Dissolved

Positive ions
Hydrogen (H^+)

Negative ions
Bicarbonate (HCO_3^-)
Chloride (Cl^-)
Sulfate (SO_4^{-2})

Gases
Carbon dioxide (CO_2)
Nitrogen (N_2)
Oxygen (O_2)
Sulfur dioxide (SO_2)

Suspended
Dust, pollen

Water – Important Chemical and Biological Impurities

Origin: Contact of Water with Soils, Rocks and Minerals

Ionic and Dissolved

Positive ions
Calcium (Ca^{+2})
Iron (Fe^{+2})
Magnesium (Mg^{+2})
Potassium (K^+)
Sodium (Na^+)
Zinc (Zn^{+2})

Negative ions
Bicarbonate (HCO_3^-)
Carbonate (CO_3^{-2})
Chloride (Cl^-)
Fluoride (F^-)
Nitrate (NO_3^-)
Phosphate (PO_4^{-3})
Hydroxide (OH^-)
Borates ($H_2BO_3^-$)
Silicates (H_3SiO_4)
Sulfate (SO_4^{-2})

Suspended
Clay, silt, sand and other inorganic soils

Colloidal
Clay
Silica
Ferric oxide
Aluminum oxide
Magnesium dioxide

Gases
Carbon dioxide (CO_2)

Water – Origin and Sources of Impurities

Origin: Decomposition of organic matter in the environment

Ionic and Dissolved

Positive ions
Ammonium (NH_4^+)
Hydrogen (H^+)
Sodium (Na^+)

Negative ions
Chloride (Cl^-)
Bicarbonate (HCO_3^-)
Hydroxide (OH^-)
Nitrite (NO_2^-)
Nitrate (NO_3^-)
Sulfide (HS^-)
Organic radicals

Colloidal
Vegetable coloring matter, organic wastes

Gases
Ammonia (NH_3)
Carbon dioxide (CO_2)
Hydrogen sulfide (H_2S)
Hydrogen (H_2)
Methane (CH_4)
Nitrogen (N_2)
Oxygen (O_2)

Suspended
Organic soils (topsoil), organic wastes

Water – Origin and Sources of Impurities

Origin: Living organisms in the environment

Colloidal
Bacteria, algae, viruses, etc.

Suspended
Algae, diatoms, minute animals, fish, etc.

Gases
Ammonia (NH_3)
Carbon dioxide (CO_2)
Methane (CH_4)

Water – Origin and Sources of Impurities

Origin: Municipal, industrial, and agricultural sources and other human activity

Ionic and Dissolved	
Positive ions	Negative ions
Inorganic ions, including a verity of heavy metals	Inorganic ions, organic molecules, color

Colloidal
Inorganic and organic solids, coloring matter, chlorinated organic compound, bacteria, worms, viruses

Suspended
Clay, silt, grit, and other inorganic solid; organic compounds; oil; corrosion products; etc.

Gases
Chloride (Cl_2) Sulfur dioxide (SO_2)

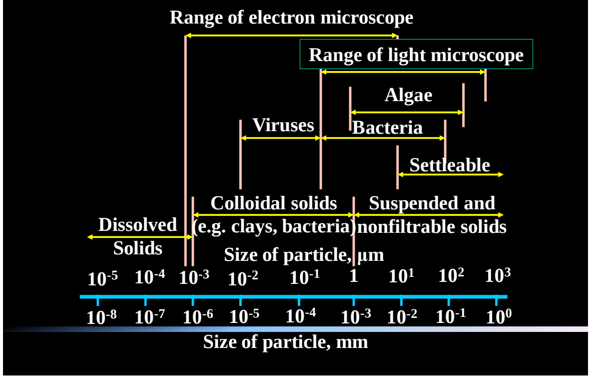
Sources of Bicarbonates, Sulfates, and Chlorides of Calcium, Magnesium, and Sodium Found in Natural Waters

Constituent	Source
Calcium Bicarbonate $Ca(HCO_3)_2$	Dissolution of limestone, marble, chalk, calcite, dolomite, and other minerals containing calcium carbonate
Magnesium Bicarbonate $Mg(HCO_3)_2$	Dissolution of magnesite, dolomite and dolomitic limestone, and other minerals containing magnesium carbonate
Sodium Bicarbonate $Na(HCO_3)_2$	White salt commonly known as baking soda, typically a manufactured product; also present in some natural waters
Calcium Sulfate $CaSO_4$	Minerals such as gypsum, alabaster, and selenite

Sources of Bicarbonates, Sulfates, and Chlorides of Calcium, Magnesium, and Sodium Found in Natural Waters

Constituent	Source
Magnesium Sulfate $MgSO_4$	Heptahydrate from ($MgSO_4 \cdot 7H_2O$) commonly known as Epsom salt or when found in the salt beds or mines, as epsomite; monohydrate from ($MgSO_4$ H_2O) occurs in a verity of minerals as a double salt with potassium chloride, potassium sulfate, etc.
Sodium Sulfate Na_2SO_4	Salt lakes, salt beds, caverns, etc., decahydrate from ($Na_2SO_4 \cdot 10H_2O$) is known as Glauber's salt
Calcium Chloride $CaCl_2$	Natural brines, salt beds, etc., and a by product of the chemical industry
Magnesium Chloride $MgCl_2$	Anhydrous forms found in natural brines, salt beds, etc.
Sodium Chloride NaCl	Salt beds, Salt lakes, connate waters, other natural brine

Particle sizes in W & WW



Water or Aqueous Systems

Solid Dispersed phase can be classified into three groups

Soluble or Dissolved (Solution or Molecular Dispersion)

- Size < 10^{-9} m (1 nm)
- Molecules or atoms
- Optically non- resolvable
- Stable Dispersed Phase

Colloidal (Colloidal Suspension)

- Size: 1 –500 nm
- Ultra microscopically resolvable
  - ➢ Electron microscope size < 0.5 μm
  - ➢ Microscopically resolvable Size: 0.5 – 20 μm
- Stable Dispersed Phase

Coarse (Coarse Suspension)

- Size > 20 μm
- Can be seen
- Can be easily separated/filtered
- Unstable Dispersed Phase or Unstable Dispersion

Dispersed phase can't be separated from dispersion phase easily, say be settling, filtration, etc.

Water Quality Parameters

- Various characteristics of water are used to assess water quality.
- Characteristics of water are generally assessed through a number of water quality parameters and these parameters are classified in a number of ways. Most often they are grouped as physical, chemical, and biological. The other way is to classify them in two groups i.e. GROSS & SPECIFIC parameters

GROSS PARAMETERS are focused on measuring a common effect, influence or impact due to presence of one or several or many species or substances.

SPECIFIC PARAMETERS on the other hand are necessary when individual physical properties or chemical entities or biological species such as toxic ion or organic compounds or biological species is of concern and, as such, are used to describe water quality as it applies to particular use.

Water – Judgement or Basis of Assessment

Concept of Beneficial Uses of Water

- There are several beneficial uses of water, and since each use of water has an individual set of constraints, an absolute definition of water quality can not be made.
- The basic concern in establishing water quality criteria for various beneficial uses are:
  - ➢ (1) Safety,
  - ➢ (2) Aesthetic, and
  - ➢ (3) Economic.

Water – Beneficial Uses (Domestic) and Quality

- **Safety** →
  - **Biologically Safe** → means absence of disease causing organisms (i.e. Pathogenic Organisms). Examples of organisms which cause some of the commonly known water born diseases.
  - Cholera → *Vibrio coma* or *Vibrio cholera* → Bacterial disease
  - Typhoid → *Salmonella typhosa* → Bacterial diseases
  - Bacillary dysentery → shigellosis → Bacterial
  - Dysentry → Entamoeba hystolytica (Amoebic dysentery) → Protozoan
  - Infectious hepatitis (Jaundice)-----Viral disease
  - Poliomyelitis ------------------------Viral disease

Water – Beneficial Uses (Domestic) and Quality

- **Chemically Safe** → No toxic chemical should be present
  - Example: Heavy metals like Pb, Hg, Cd, Zn, Cu, etc.
  - Radioactive chemicals.
  - Common elements → SO_4^{-2} → in high concentration causes indigestion (laxative effect)
  - NO_3^- If > 100 mg/l → infant illness called methemoglobinemia (in low acidity nitrate reducing bacteria thrive)
  - NO_3 → NO_2 → combines with hemoglobin (competes with O_2) Blue baby disease.
  - Fluoride → mottling of teeth/bones become week → Excessive concentration extracts Ca^{++}).
    → Dental carries, decay → (Low concentration of F^-).
    → Optimum concentration ≅ 1-1.5mg/l.
  - Trihalomethanes → CHX_3, $CHCl_3$, $CHBr_3$, $CHCl_2Br$, $CHBr_2Cl$ → mutagenic.

Water – Beneficial Uses (Domestic) and Quality

- *Aesthetics*: Absence of colour, odour, taste, turbidity → which can be perceived by human senses.
- *Economic*: More hardness → more soap consumption (earlier); → scale formation and corrosion.
- More iron → staining of cloths, rusting, clogging, etc.

Water – Beneficial Uses (Industrial) and Quality

- Water is an important raw material.
- Process Water → used in the production of the industry e.g. boiler water → high quality → scale /corrosion → DO.
- Product Water → food industry → biologically safe
- In Rayon Industry → Fe content → stains the rayon (low grade yarn is produced)
- Tannins → due to tanneries in Kanpur.
- Cooling Water → need not be high quality.
- Service Water → washing, etc.

Water – Beneficial Uses (Agricultural) and Quality

- Concerns
  - Health hazard → workers and consumers (major concern)
  - Soil sickness → chemicals, pH, acidity, etc.
  - Salinity.
- Total concentration of salts → conductivity or TDS.
- Relative proportion of sodium to other ions → sodium hazard to crop → high Na replaces Ca^{++}, Mg^{++}, K^+, etc.
- Excessive bicarbonate (HCO_3) → Precipitation of Ca, Mg in the root zone of crops
  - Residual Sodium Bicarbonate (RSB) = [CO_3] + [HCO_3] – [Ca] – [Mg]; meq/l
- Toxic chemicals → Boron content.

Water – Beneficial Uses (Live Stock) and Quality

- Drinking water for animals → Biologically and chemically safe → Human and animal Safety
  - Disease transmission → TB
- Economic loss if cattles are not healthy.
- Aesthetic → Not much important → Turbidity and colour → Not a problem
- Test should not be bad.

Water – Beneficial Uses (Fish Culture) and Quality

- Concerns
  - Temperature
  - DO > 5 mg/l
  - Turbidity → Photosynthesis is affected → Less food for fish → affects the food chain
  - Toxic chemicals

Water – Beneficial Uses (Recreational Use) and Quality

- Concerns
  - Aesthetic → Very important
  - Disease causing
    - organisms → skin diseases → mainly fungal.
    - Chemicals → Irritation of nose and eyes.

Water

Water Sources

- The two principal sources are ground or surface water. Depending on the hydrology of a basin, the levels of human activity in the vicinity of these source, and other factors, a wide range of water quality parameters can be encountered. One major distinction is based on the level of the dissolved salts (Total Dissolved Solids, TDS)
  - Fresh waters are those sources with TDS < 1000 mg/l
  - Brackish waters are those which have TDS > 1000 mg/l and can be used under special circumstances for specific uses with adequate treatment up to (say) 10,000 mg/l
  - Finally the most abundant source, the Ocean or Sea water, contains approximately 35,000 mg/l dissolved salts and consequently requires demineralization prior to use.

Understanding Water Quality Parameters

- What or Definition or Concept
- Why or Significance or Importance
  - From the Point of View of Beneficial Use → Aesthetic, Safety and Economic Considerations
  - From the Point of View of Conveyance & Treatment
- How or Principle and Method/Technique or Procedure

Physical Environment – A Dispersion System

Gaseous → Air

Liquid → Water

Solid → Soil and Rocks

Environmental Systems

Types of Dispersions

Dispersion Medium	Dispersed Phase	Type of Dispersion
Gas (Air)	Solid	Aerosol
Gas (Air)	Liquid	Mist
Liquid (Water)	Solid	Solution and/or Suspension
Liquid (Water)	Liquid (Oil)	Emulsion
Solid	Solid	Solid Gel
Solid	Liquid	Gel

Air (Gas), Water (Liquid) and Soil/Rock (Solid) Dispersion System

- In dispersion system particles of one phase are dispersed throughout a medium that is in a different phase.
- Dispersion may be a two-phased system or a three-phased system.
- Composed of a dispersion medium and a dispersed phase.
- Dispersion medium is a continuous medium in which the dispersed phase is distributed throughout.
- Dispersed phase is the phase that is composed of particles that are distributed throughout the Dispersion Medium.
- **Dispersed phase is discontinuous whereas Dispersion Medium is continuous.**

Wastewater Characteristics

Wastewater produced in domestic setting,

1. Black water: Toilet waste
(mainly Organic Carbon, Nitrogen, Phosphorus, microorganisms)

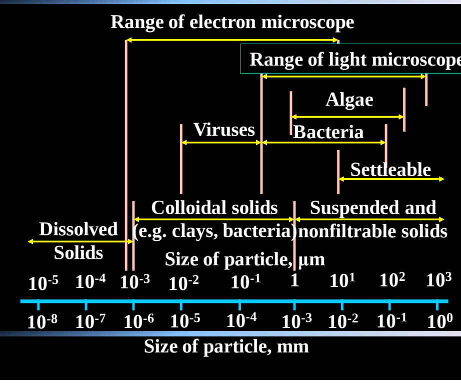
2. Grey water: Kitchen waste, bathing and cleaning waste
(mainly organic C, N and P, surfactants, salts, dirt, grit, other solid waste)

Domestic Wastewater (Sewage) = Black water + grey water

Wastewater/Sewage → Water + ?

Constituents	Part of	Solids	Parameter	Action
Inorganics (Na, K, Ca, Mg, NH_4, Fe, Mn, Cu, Cd, Ni, .. ; OH, CO_3, HCO_3, Cl, SO_4, NO_2; NO_3, PO_4, ..)	TDS	FDS	TDS	None
	TSS	FSS (Specific Gravity > 2.5	TSS	Screening/ Settling
Organics (Carbon, Nitrogen, Phosphorous, ...)		VSS Specific Gravity $\underset{-}{\sim}$ 1 (Microbes & Non-Microbial)	TSS	Primary Settling
			TOC/BOD/ COD	Conversion to CO_2, H_2O, Microbial Mass and Settling/ Micro-Filtration
			NH_4-N	" + → NO_2 & NO_3-N
			TKN	" + → NH_4-N →
				NO_3-N → N_2
	TDS	VDS (Non-Microbial)	PO_4	Conversion to Microbial Mass

Particle sizes in W & WW



Environmental Systems

Types of Dispersions

Dispersion Medium	Dispersed Phase	Type of Dispersion
Gas (Air)	Solid	Aerosol
Gas (Air)	Liquid	Mist
Liquid (Water)	Solid	Solution and/or Suspension
Liquid (Water)	Liquid (Oil)	Emulsion
Solid	Solid	Solid Gel
Solid	Liquid	Gel

Wastewater Characteristics

Wastewater → Water + Waste

Domestic Wastewater (Sewage) = Black water + grey water (Sullage)

Organic Carbon = BOD_5
BOD_5 added by permanent population = 50 g /capita/d
BOD_5 added by temporary population = 25 g /capita/d

Fresh Sewage

Microbes
Chemicals → Acids, Bases, Insecticides, Pesticides, Antibiotics, etc.
N + P

TSS & TDS → Organic (VS → VSS + VDS; BOD/COD; N & P) & Inorganic (FSS + FDS)

Wastewater Quality

In 2023:	In 2053:
BOD_5 added = 50(9870) + 25(1500) = **531 kg/d**	BOD_5 added = 50(12300) + 25(3000) = **690 kg/d**
Average Flow: 531 kg in 1.47 ML = **361 mg/L BOD_5**	Average Flow: 690 kg in 2.46 ML = **281 mg/L BOD_5**
Assume: BOD_5 : N (as N) : P (as P) on wt. basis) = **100: 10: 2**	Assume: BOD_5 : N (as N) : P (as P) on wt. basis) = **100: 10: 2**
Av: BOD_5 = 361mg/L; TKN = 36.1 mg/L (as N); Total-P = 7.2 mg/L (as P)	Av: BOD_5 = 281 mg/L; TKN = 28.1 mg/L (as N); Total-P = 5.6 mg/L (as P)
Commercial wastewater is assumed to have the same characteristics as domestic wastewater	Commercial wastewater is assumed to have the same characteristics as domestic wastewater

Wastewater/Sewage Treatment

Preliminary Wastewater Treatment

Primary Wastewater Treatment

Secondary Wastewater Treatment

Tertiary Wastewater Treatment

Wastewater → Water + Waste

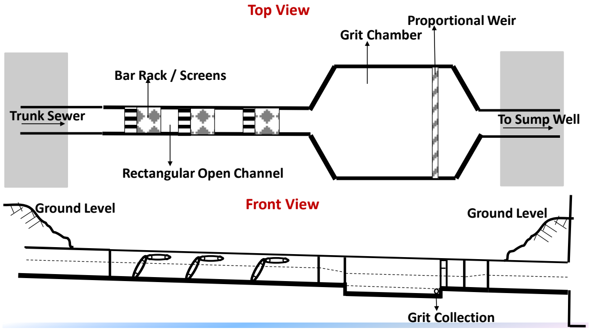
Bigger Solids (Fixed & Volatile Solids)
+
Coarser & Heavier Solids (FSS)

+
Coarser but Lighter Solids (VSS)

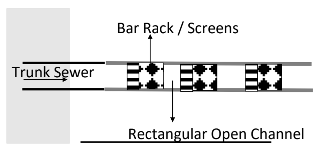
+
Finer & Lighter Solids (Colloidal & Dissolved; VSS & VDS)

+
Other Dissolved Solids (VDS & FDS)

Preliminary Wastewater Treatment



Preliminary Wastewater Treatment



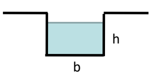
Screen Channel Design

Velocity in screen channel should be > 0.6 m/s (self-cleansing velocity)

q_1 = 0.30 m^3/s;

Choose:
n = 0.013; S = 0.002;
b = 0.70 m (same as trunk sewer dia.)

Preliminary Wastewater Treatment



Q = Design flow
b = Channel width
h = depth of flow
S = channel slope
A = flow cross section
V_H = flow velocity

Assuming rectangular channel, R = (b.h)/(b + 2.h);
A = b.h;
$q_1 = A.V_H = (1/n).A.(R)^{2/3}.(S)^{1/2}$;

Choose h such that q_1 = 0.3 m^3/s; h = 0.504 m
$V_H = q_1/(A)$ = 0.850 m/s; $V_H > V_{sc}$, hence okay

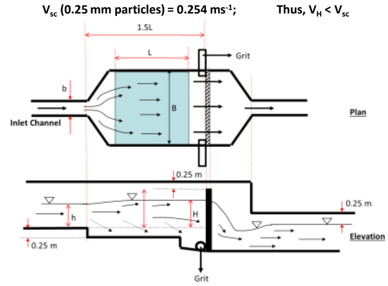
Checking for q_2:
$q_2 = A.V_H = (1/n).A.(R)^{2/3}.(S)^{1/2}$;

Choose h such that q_1 = 0.15 m^3/s; h = 0.298 m
$V_H = q_2/(A)$ = 0.720 m/s; $V_H > V_{sc}$, **hence okay**

Preliminary Wastewater Treatment

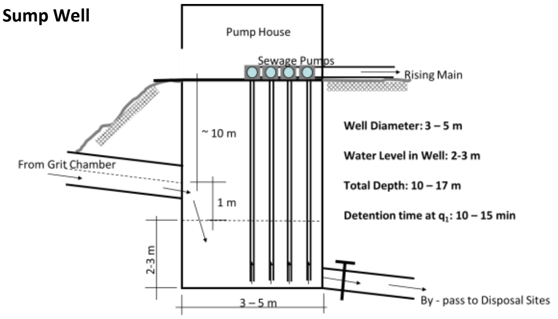
Grit Chamber: To remove inorganic particles up to 0.25 mm in diameter

V_{sc} (0.25 mm particles) = 0.254 ms^{-1}; **Thus, $V_H < V_{sc}$**

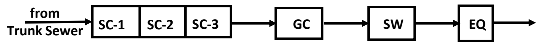


Preliminary Wastewater Treatment

Sump Well



Preliminary Wastewater Treatment



Screenings

Grit

Fresh Sewage

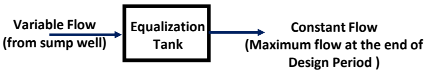
Aged/Septic Sewage

Equalization Tank (Flow Equalization)

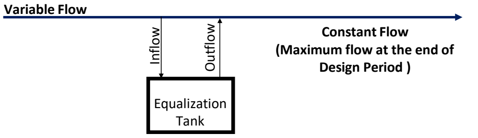
Time of Day	Flow	Cumulative Volume	Time of Day	Flow	Cumulative Volume
0-1	0.9Q	0.9Q.n	12-13	1.3Q	10.9Q.n
1-2	0.7Q	1.6Q.n	13-14	1.2Q	12.2Q.n
2-3	0.5Q	2.1Q.n	14-15	1.2Q	13.4Q.n
3-4	0.4Q	2.5Q.n	15-16	1.1Q	14.5Q.n
4-5	0.3Q	2.8Q.n	16-17	1.1Q	15.6Q.n
5-6	0.3Q	3.1Q.n	17-18	1.1Q	16.7Q.n
6-7	0.4Q	3.5Q.n	18-19	1.1Q	17.8Q.n
7-8	0.7Q	4.2Q.n	19-20	1.2Q	19.0Q.n
8-9	1.1Q	5.3Q.n	20-21	1.3Q	20.3Q.n
9-10	1.6Q	6.7Q.n	21-22	1.3Q	21.6Q.n
10-11	1.4Q	8.1Q.n	22-23	1.2Q	22.8Q.n
11-12	1.4Q	9.5Q.n	23-24	1.2Q	24Q.n
			Total	24Q	

Q = Maximum Flow, m^3/h ; n = duration, hr

Equalization Tank (Flow Equalization)



In- Line Equalization



Off - Line Equalization

Equalization Tank (Flow Equalization)

Determination of Equalization Tank Volume