CVL100:Environmental Science(2-0-0)

Lecture 3:
Water Quality Parameters and Water Treatment

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(Tuesday and Friday)

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Excess Nutrients

- Nitrogen and phosphorus are nutrients required by all living organisms. They are considered pollutants when they are in excess.
- Excessive nutrients often lead to large growths of algae which in turn become oxygen-demanding material whey they die and settle.

Excess Nutrients

$$106\ CO_2 + 16\ NO_3^- + HPO_4^{2-} + 122\ H_2O \rightarrow C_{106}H_{263}O_{110}N_{16}P + 138\ O_2$$

algae

$$Algae + O_2 \Rightarrow CO_2 + H_2O + NH_3$$

Nitrogen and phosphorus are typically the limiting factors

Phosphorus

- Phosphorus is typically the limiting nutrient in lakes, and algae growth is linked to phosphorus inputs.
- P Sources
  - fertilizers
  - detergents
  - wastewater
- P can exist in a variety of chemical forms

Nitrogen

- Nitrogen is often the limiting nutrient in ocean waters and some streams
- Nitrogen can exist in numerous forms, but nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_3) are most commonly measured
- Sources are primarily from fertilizers and acid deposition

Factors Controlling Eutrophication

- Stoichiometry of photosysnthesis (C,N,P, O & H)

$$106\ CO_2 + 16\ NO_3^- + HPO_4^{2-} + 122\ H_2O \rightarrow C_{106}H_{263}O_{110}N_{16}P + 138\ O_2$$

$$\frac{N}{P} = \frac{16 \times 14}{1 \times 31} = 7.2$$

It takes ~ 7 times more N than P to produce a given mass of algae

- *Liebig's law of the minimum* – growth will be limited by the availability of the nutrient that is least available relative to the need
- Most fresh water systems are phosphorus limited

Salts

- Dissolved solids, or salts, may be present as any number of ions
  - cations: Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}
  - anions: Cl^{-}, SO_4^{2-}, HCO_3^{-}
- Typically measures as *total dissolved solids* (TDS)
- Water classification
  - freshwater <1500 mg/L TDS
  - brackish water 1500 – 5000 mg/L
  - saline water >5000 mg/L
  - sea water 30-34 g/L

Salts

- Sources
  - industrial discharges
  - deicing
  - evaporative losses
  - minerals
  - sea water intrusion
- Effects
  - natural fresh water population threatened
  - limits use for drinking
  - crop damage/soil poisoning (cannot use for irrigation)

Suspended Solids

- Organic and inorganic particles in water are termed suspended solids
- May be distinguished from colloids, particles that do not settle readily

- Sources
  - storm water
  - wastes
  - erosion

- Problems
  - sedimentation
  - may exert oxygen demand
  - primary transport mechanism for many metals, organics and pathogens
  - aesthetic
  - complicates drinking water treatment

Oxygen-Demanding Wastes

- When organic substances are broken down in water, oxygen is consumed

$$\text{organic C} + O_2 \rightarrow CO_2$$

- For example:

$$CH_3COOH + 2O_2 \Rightarrow 2CO_2 + 2H_2O$$

$$C_6H_{15}O_6N + 6O_2 \Rightarrow 6\,CO_2 + 6\,H_2O + NH_3$$

Oxygen-Demanding Wastes

- High oxygen levels necessary for healthy stream ecology.
- For example:
  - trout require 5-8 mg/L dissolved oxygen (DO)
  - carp require 3 mg/L DO

Oxygen Demanding Wastes-measurement/estimation

- Estimated stoichiometrically by theoretical oxygen demand (ThOD)

- Measured by oxygen demand potential
  - biochemical oxygen demand (BOD)
  - Nitrogenous oxygen demand (NBOD)
  - chemical oxygen demand (COD)

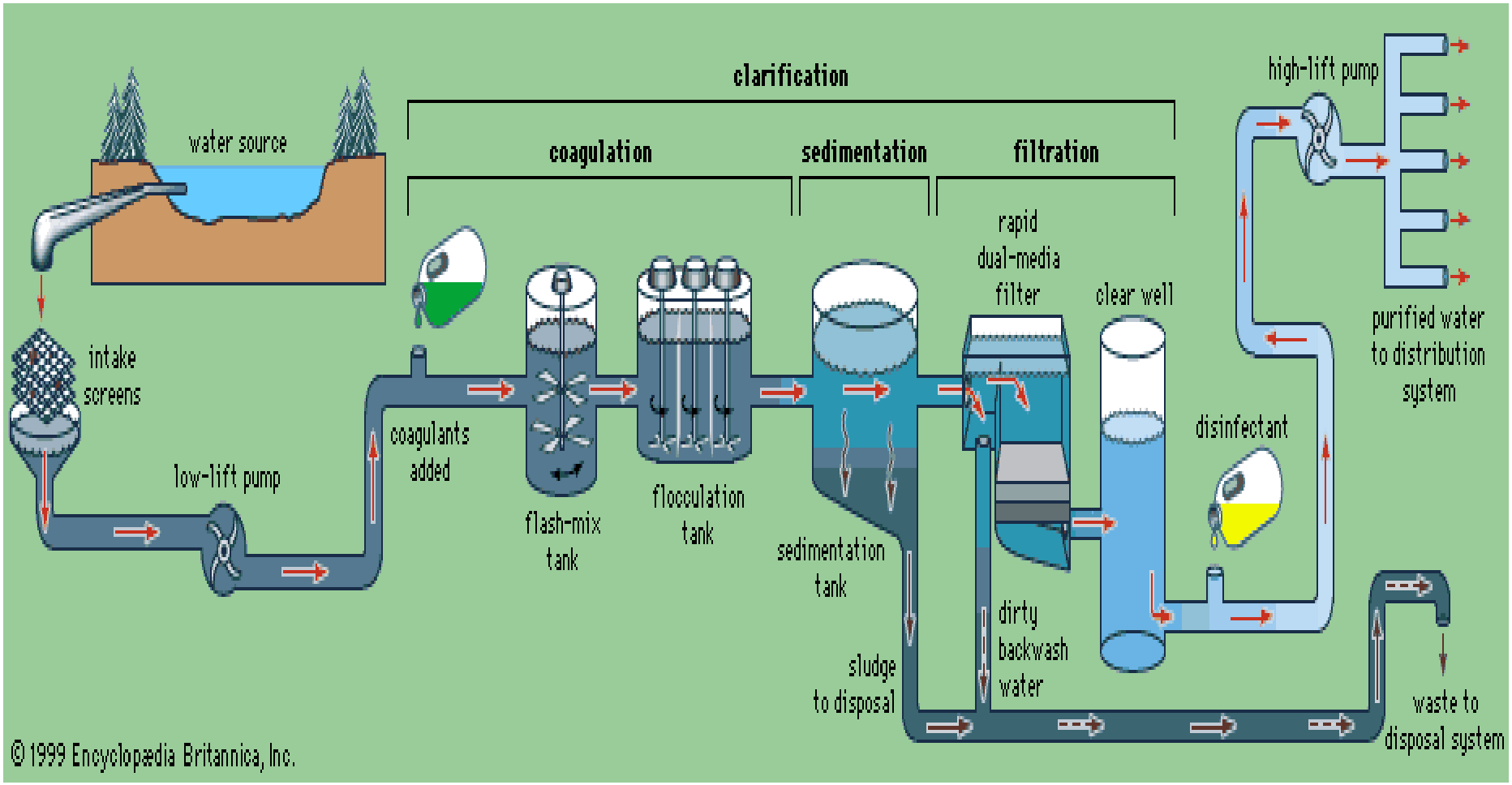
Example: Calculation of ThOD

- reaction:

  $CH_3COOH + 2O_2 => 2CO_2 + 2H_2O$

- 1 mole/L acetic acid requires 2 moles/L of oxygen
- Theoretical oxygen demand= 2 moles/L * 32g/mole=64000mg/L oxygen

Water Treatment



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Exercise 1

- Search name of treatment plant in your city and note names of processes and their sequence. Is it water treatment plant or wastewater treatment plant?

- Search names of 3 point-of-use system from market and note what contaminants it can remove and what is sequence of different units you can see. Draw it.

Overall Constituents

- constituents:
  - Ions (calcium; arsenate; chromate ions;nitrate)(anions/cations)
  - Organic compounds (pesticides, pharmaceutical compounds,etc.)
  - Pathogens (viruses, if we have human fecal pollution)
  - Solids (depends if there is a fracturing in subsurface or solids in surface water)
  - Gases(methane, etc.)
  - nutrients

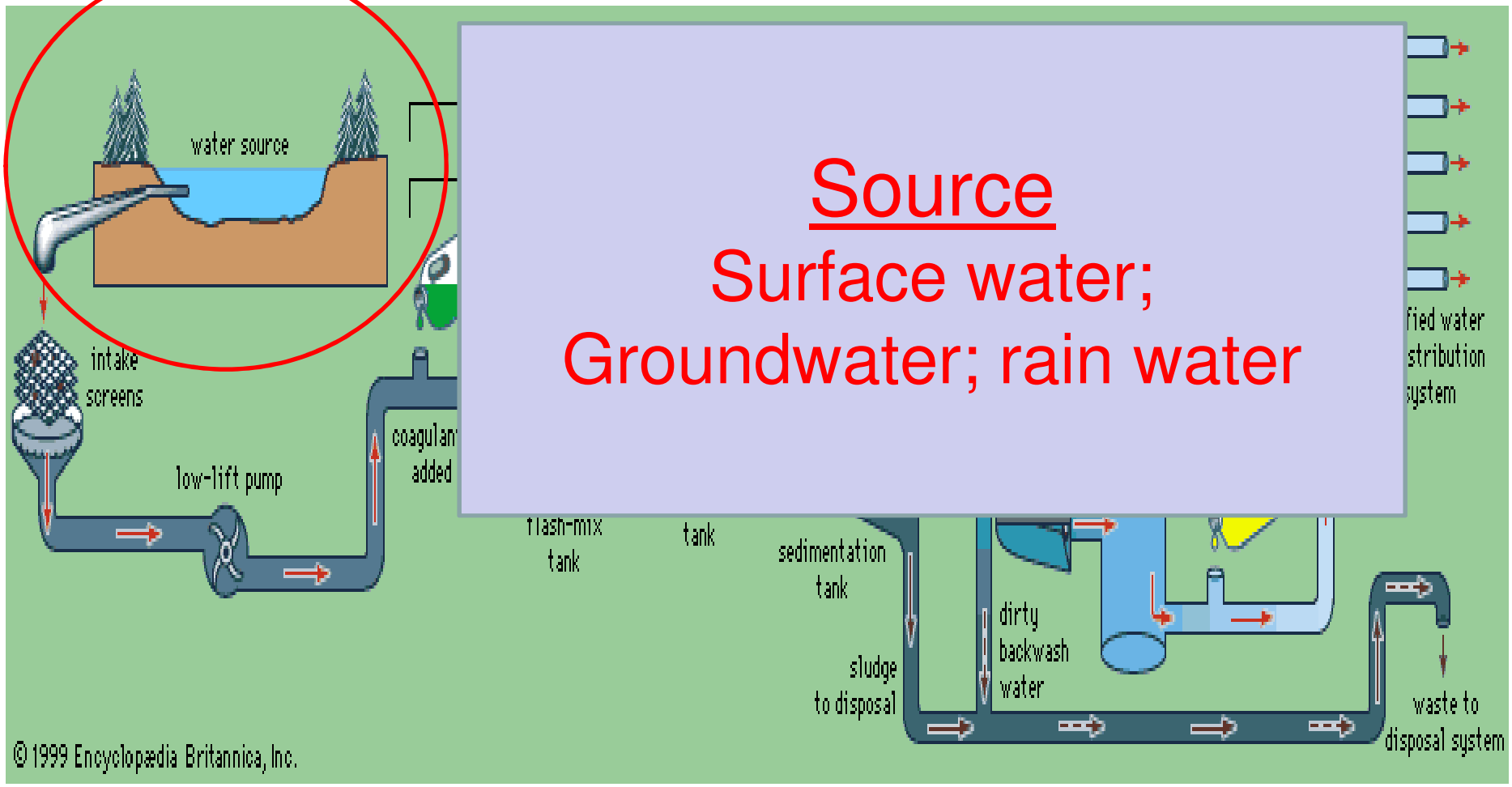
Overall Parameters

Constituents	Parameters
Ions	Hardness; alkalinity; acidity; conductivity
Solids	Turbidity; total solids; total suspended solids; dissolved solids; volatile solids; fixed solids
Organic compounds	ThOD; biological oxygen demand; chemical oxygen demand; total organic carbon
Nutrients	Ammonium ions; phosphates
pathogens	Indicators (bacterial; viral); pathogen

Water Treatment Plant Schematic

Objective: To introduce water treatment plant schematic and need for different unit processes

Water: Source



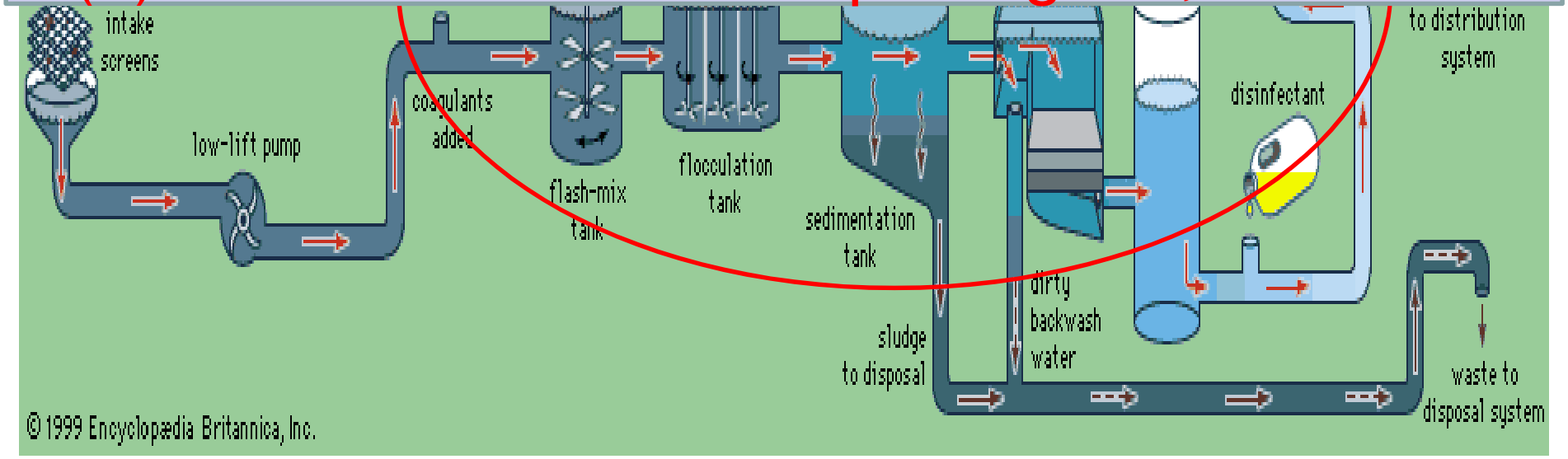
Source

Surface water;

Groundwater; rain water

Water: Treatment train of unit processes

(1)Coagulation: increases particle size
(2)Sedimentation: settles particles
(3)Filtration: removes solids
(4)Disinfection: removes pathogens; oxidation



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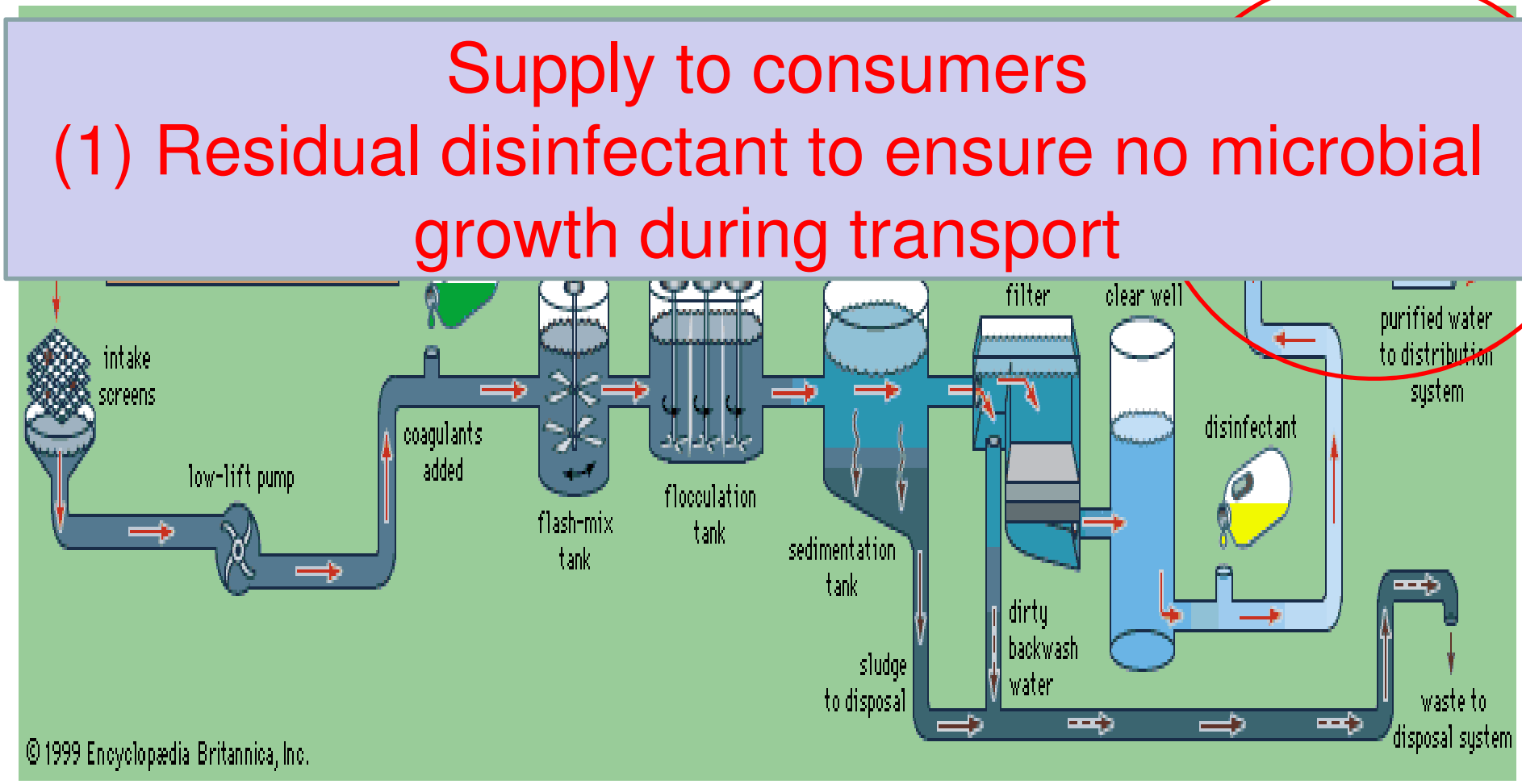
Water: Supply part

Supply to consumers
(1) Residual disinfectant to ensure no microbial growth during transport



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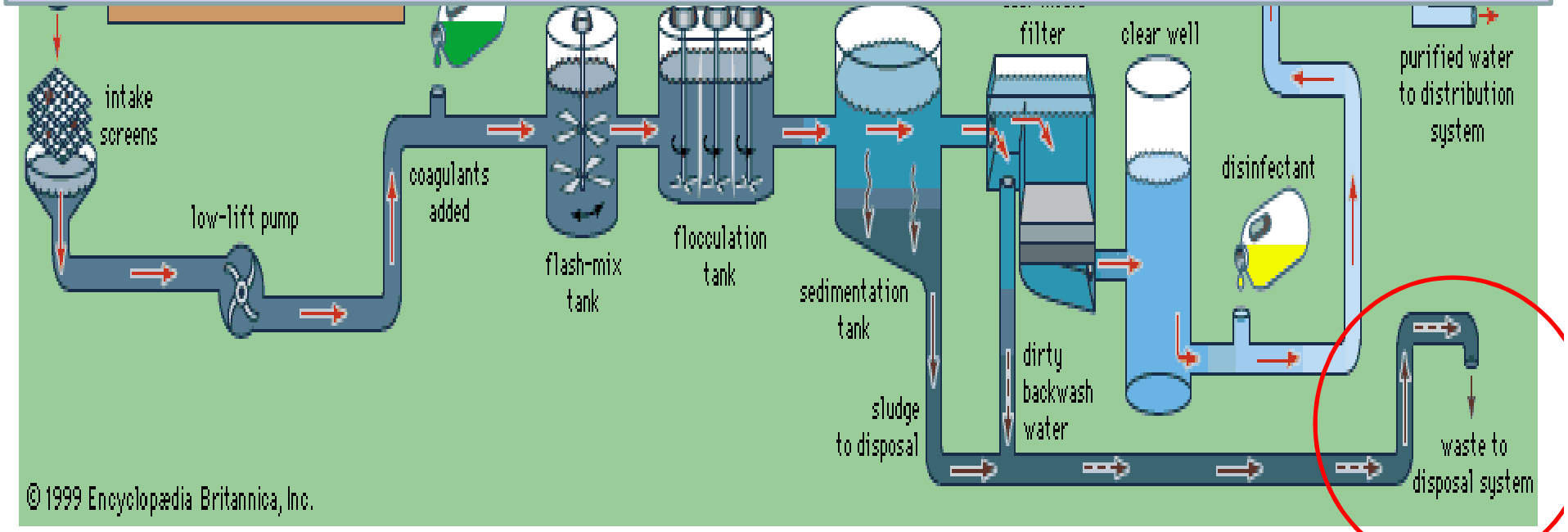
Water: Disposal part (solids waste)

1)Chemical sludge
2) Disposal to municipal landfill
3)Reuse in brick making; pavement material, etc.



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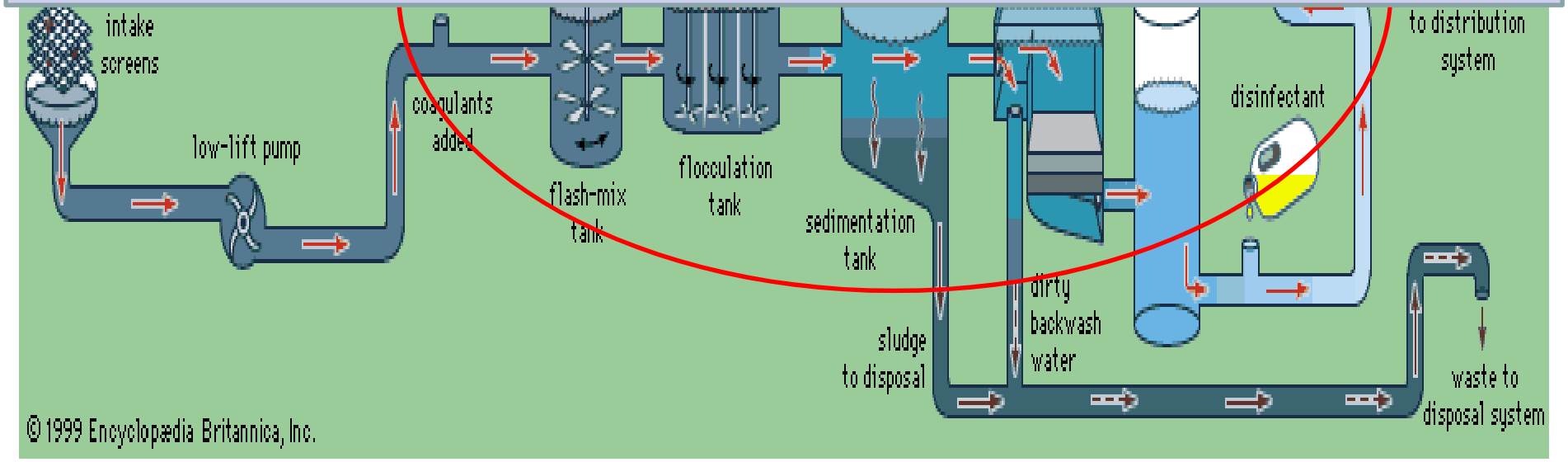
Water: Order of constituents removal

Source: Dissolved gases →solids→ions →reduced substances→pathogens →supply



Step 1. List water quality characteristics which need to be removed

- Nutrients
- Ions (arsenate; chromate ions; nitrate)
- Organic compounds (pesticides, etc.)
- Pathogens (viruses, if we have human fecal pollution)
- Solids (depends if there is a fracturing in subsurface)
- Gases(methane, etc.)

Step 2. Identify unit(s) which can remove at least one type of contamination

- Ions (removal by: adsorption; coagulation-flocculation; chemical precipitation; bio-adsorption; membrane process)

Step 2 contd.

- Organic compounds (degradation/removal by: oxidation; adsorption; biodegradation; reduction-oxidation; irradiation; membrane process)

Step 2 contd.

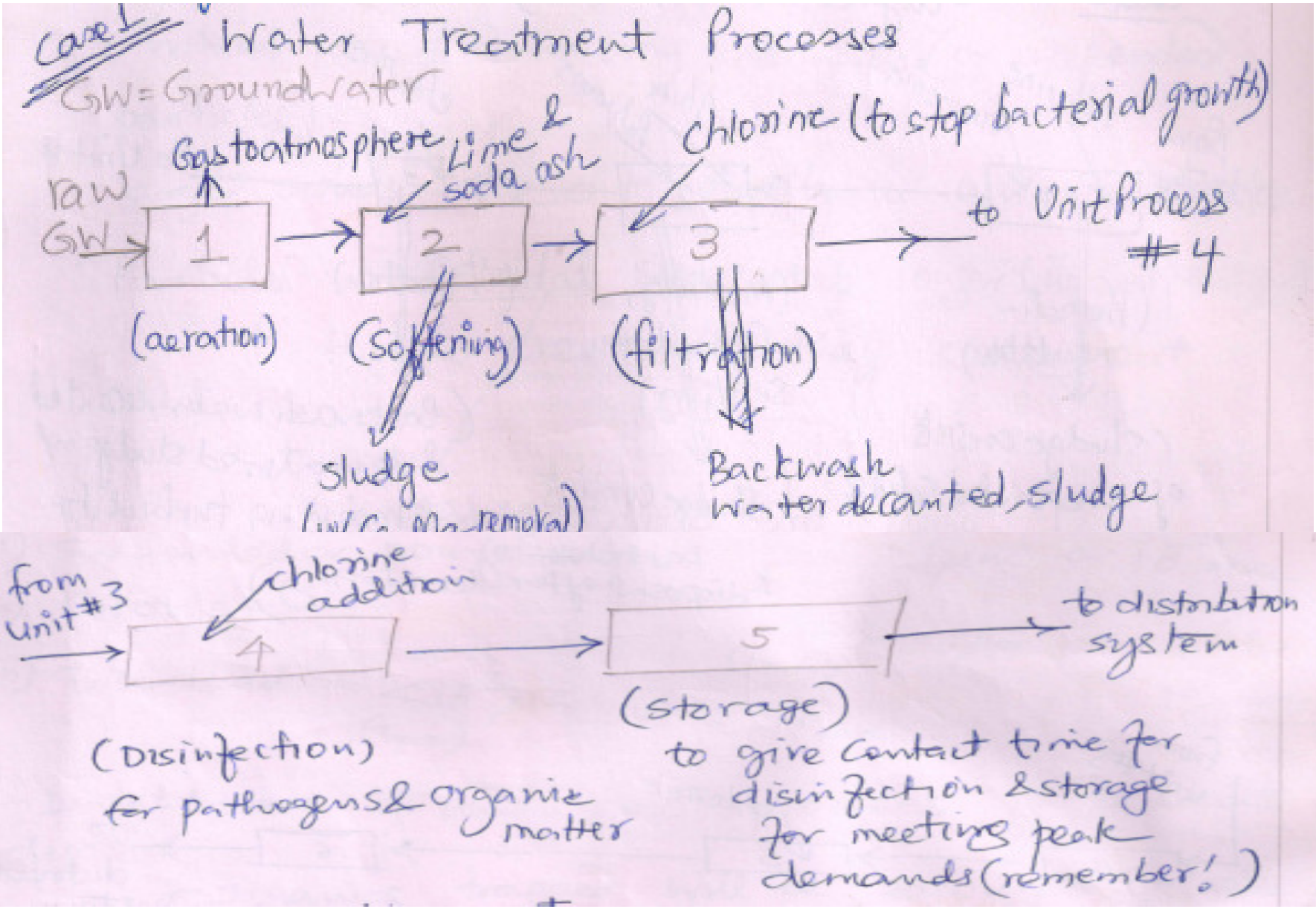
- Pathogens (killed by : adsorption; coagulation-flocculation; chemical precipitation; disinfection; boiling; irradiation; membrane process)

Step 2 contd.

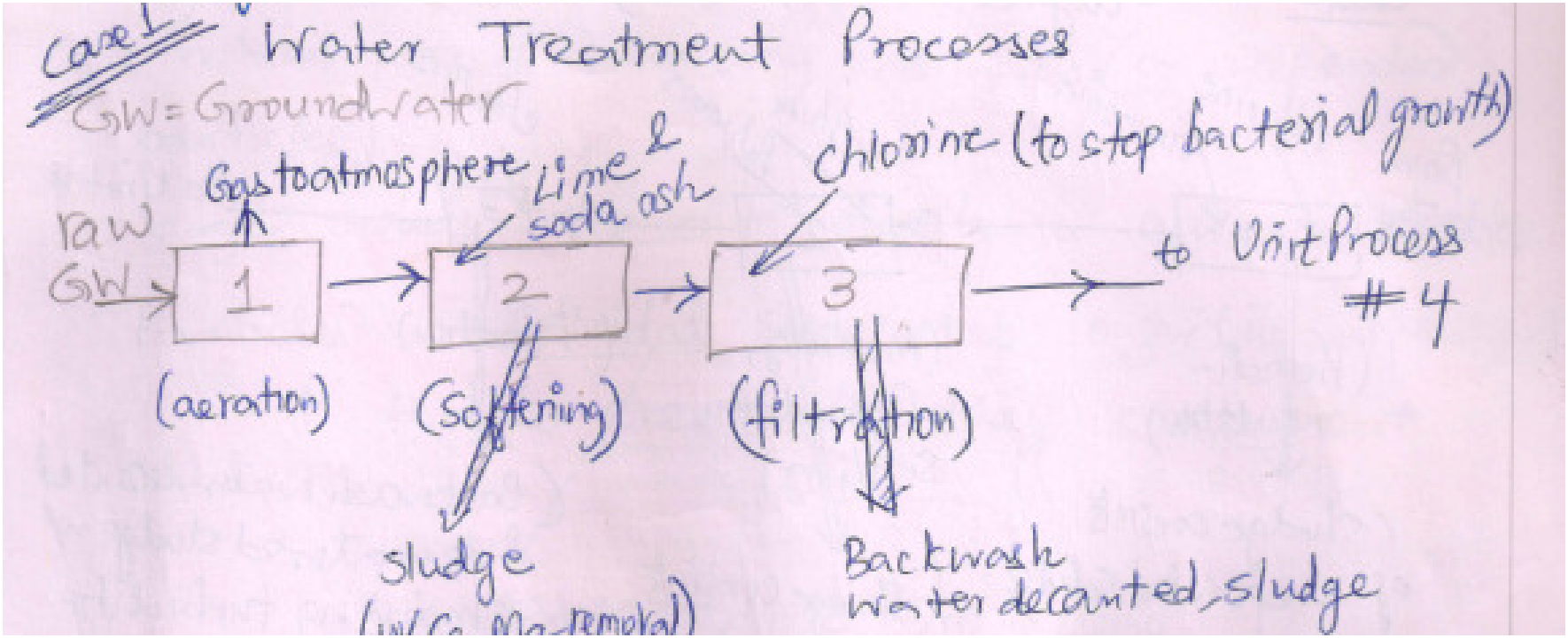
- Solids (removal by : settling; filtration; membrane process)

- Gases (removal by) : aeration; adsorption; solubilization)

Case:Groundwater →produce drinking water



Exercise: Groundwater →Drinking water



Name: constituents to be removed; unit processes; their role; their sequence; solid waste generation

Treatment schematic (GW→ Potable drinking water)

- Raw Ground water → aeration chamber → Softening unit → Filtration with chlorination →Disinfection → Storage
- See sequence of units used
- Chemical is required to be added
- Water is treated
- Chemical sludge is produced

Units used for (GW→ Potable drinking water

- Aeration chamber (to remove gases; using air)
- Softening unit (to remove cations; using softener and/or cation exchangers)

Treatment schematic (GW→ Potable drinking water)

- Filtration with chlorination (to remove solids; to kill microbial growth on filter unit surface)
- Disinfection (to kill microorganisms before water is supplied for public consumption)
- Storage

Exercise 2: Yamuna River Water →produce drinking water

- Think for 5 minutes for two steps.
- Step 1: water quality characteristics determination
- Step 2: selection of units, their order

Exercise 2: Yamuna River Water →Drinking water