The University of Zambia
School of Engineering
Dept. of Civil & Environmental Engineering

CEE 4412: Environmental Engineering I

Water Supply

JMT
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Factors affecting Demand (Consumption)

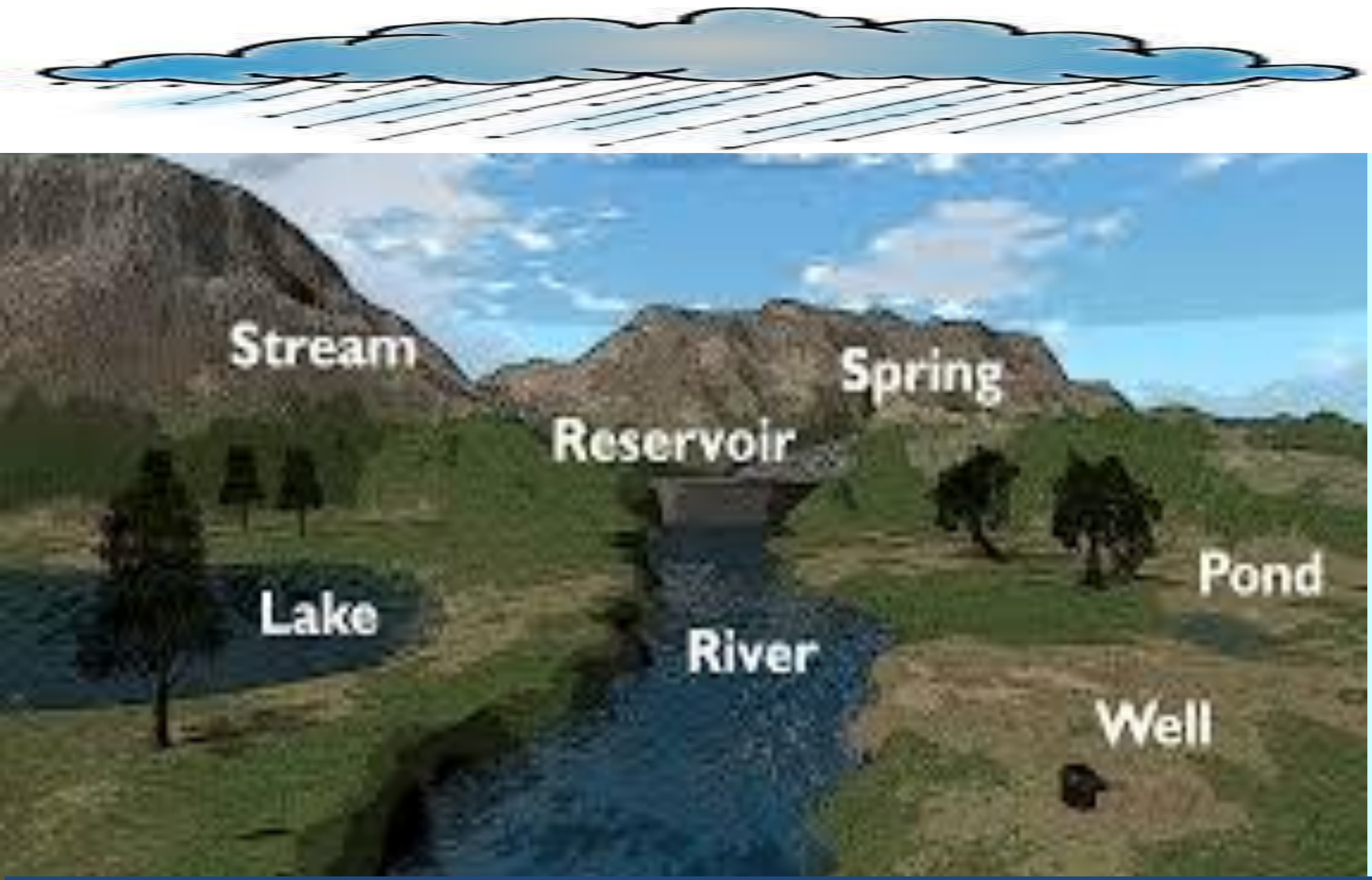
- Size of the city (e.g. Small = unsewered = low)
- Characteristic of the population (rich/poor)
- Presence of industries (Yes = high)
- Quality of the water (poor = low)
- Cost (high = low)
- Pressure in the system (low =low)
- Climate (hot = high)
- Cultural background of the community
- Whether supplies are metered (Not = high)

Factors affecting Demand (Consumption)

❖ Level of Service

- ❖ Public standpipe (In peri-urban areas)
- ❖ Yard connection (Low cost areas)
- ❖ House or in-house connections (medium and high cost areas)

WATER SOURCES



Source: Google images

Water Sources: Comparisons

- Groundwater is usually of a better quality
- Can be supplied directly without treatment

Water Sources: Characteristics

- Good water source is always wrt the purpose for which it is to be used. For domestic purposes it should:
  - be free from pathogenic bacteria;
  - have low concentrations of compounds that are acutely toxic or that have serious long term effects such as lead (guidelines to be observed);
  - Aesthetically acceptable (clear and free from compounds that cause offensive odour and taste;
  - Not saline; and
  - Neither corrosive nor scale forming in piping or staining of clothes.

Water quality considerations in Design – Source Characterisation

Parameter characterisation	Excellent source	Good source	Poor source	Rejectable source
Average BOD_5 (mg/l)	0.75- 1.5	1.5 - 2.5	2.5 - 4.0	>4
Average coliforms (MPN)/100ml	50 - 100	100 – 5000	5000 - 20000	>20000
pH	6 - 8.5	5 - 6, 8.5 – 9	3.8-5, 9-10.3	<3.8, >10.3
Chlorides (mg/l)	<50	50 – 250	250 - 600	>600
Flourides (mg/l)	<1.5	1.5 – 3	>3	-

- Why do we use the above parameters in characterising source? Why not suspended solids?

Choice of a Water Source

Some Factors to Consider

- Adequacy
- Reliability
- Quality
- Location (defines energy requirements which can affect recurrent operational costs)

- In most cases, water quality will not meet guideline values.
- As it is not practical to abandon all polluted sources, water is subjected to treatment!!

Water Treatment

- Virtually possible to treat water of whatever quality to required specifications
- Therefore, in a treatment system, economic and operational considerations become the limiting constraints in the selection of treatment process. Most important considerations are:
  - Treated water specifications
  - Raw water quality and its variations
  - Local constraints (e.g. Skilled Manpower)
  - Relative costs of different treatment processes

Water Treatment

❖ Treatment process selection

How do we address problem of contamination

- On a small scale (usually aiming at addressing microbiological contamination) by boiling/chlorination
- Large scale through water treatment which is through unit operations like Coagulation/flocculation, sedimentation, filtration, disinfection, etc.
- **Unit operation** is a process for the physical, chemical or biological treatment of water.
- The system of integrated unit processes or unit operations used to treat water or wastewater is called a **treatment train**.

Objectives of water treatment

❖ Removal of unwanted constituents

❖ Addition of wanted constituents

❖ Stabilisation

❖ Disinfection

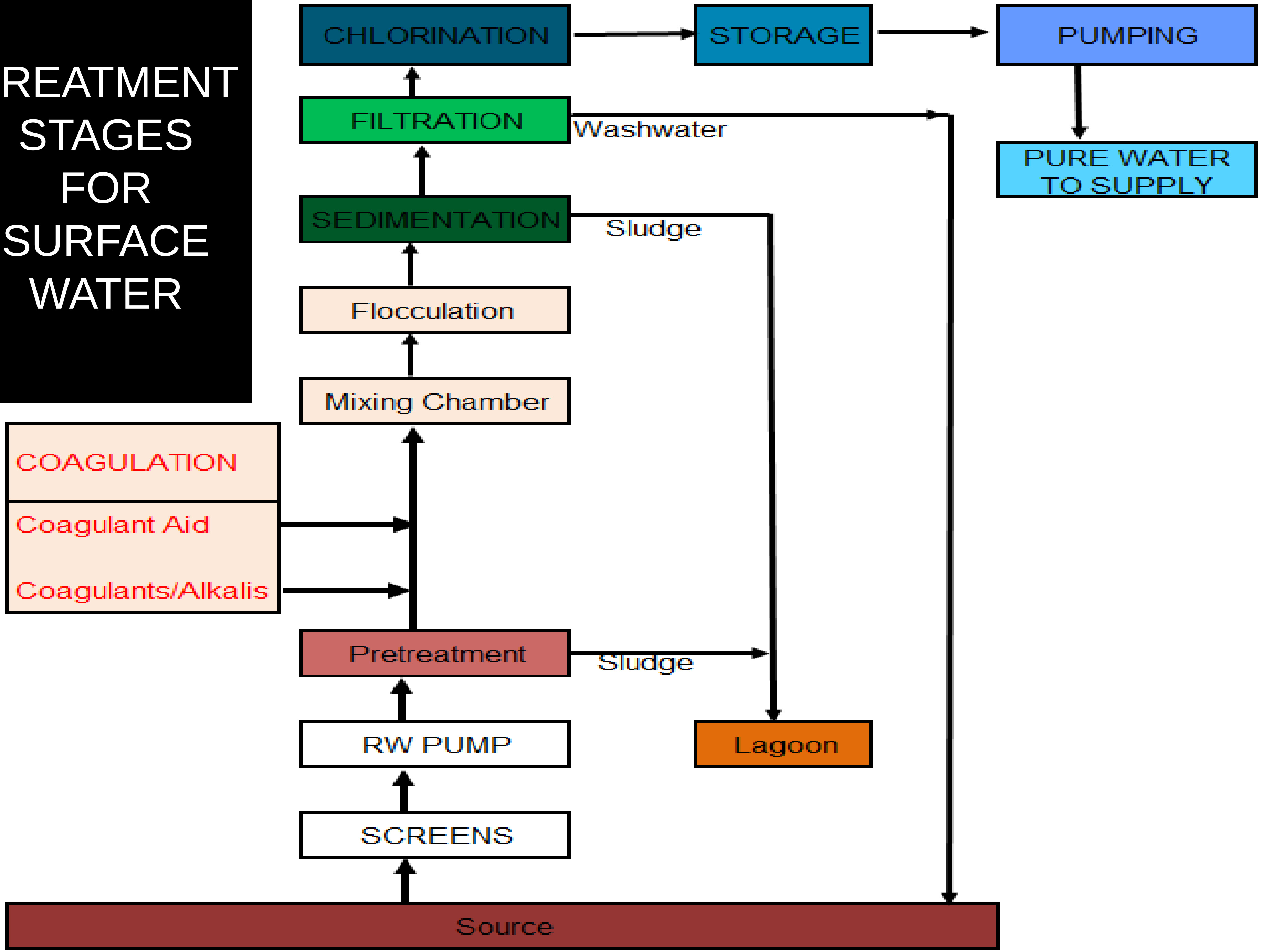
Examples of what can easily be treated

- ❖ Suspended matter
- ❖ Colloidal matter
- ❖ Iron
- ❖ Manganese
- ❖ Excessive hardness

Examples of what cannot easily be treated

- ❖ Chemical parameters like chlorides, nitrates, flourides
- ❖ Removal of odour and taste causing substances

TREATMENT STAGES FOR SURFACE WATER



Pretreatment

Examples:

- ❖ Screening
- ❖ Pre-conditioning
- ❖ Storage

- ❖ Screening
  - Typically the first step in water purification plants, especially those treating surface water.
  - Screens are used to remove large debris that could adversely impact the remaining water purification process and equipment

Pretreatment –Cont'

- Preconditioning
  - Step in which water is treated to alter characteristics that may impact on downstream treatment processes.
    - ✓ Where water is acidic, lime is often added to raise the pH
    - ✓ Water rich in hardness is often treated with sodium carbonate to precipitate out calcium carbonate.

Pretreatment

- Storage. Serves several purposes in water treatment as follows:
  - It reduces turbidity by natural sedimentation
  - It attenuates sudden fluctuations in raw water quality
  - Improves microbiological quality of water especially if it is protected;
  - Improves reliability of water supply
  - Can be drawn upon during short periods of exceedingly high turbidity, during which river water is not fed into the storage basin.

Coagulation/Flocculation

- Unit operation for the removal of colloids which are usually responsible for turbidity and colour of natural waters.
- Coagulation = distabilisation of the charge on the surface of colloidal particles which cannot aggregate under normal circumstances due to charges (-ve charge = ZETA potential)
- How to tell: Look at separation characteristics between solid-liquid phases of the suspension

Coagulation/Flocculation

What happens during Coagulation?

- Charge neutralized
- Destabilised colloids come together
- The required type of mixing in coagulation = Rapid for just about 1minute
- Why? Avoid hydrolysis before coagulation
- $Al^{3+} + 3H_2O \longrightarrow Al(OH)_3 + 3H^+$

Flocculation Step

- Upon complete neutralisation of charge on colloids, surplus coagulant undergoes hydrolysis
  - $Al^{3+} + 3H_2O \longrightarrow Al(OH)_3 + 3H^+$
  - $Fe^{3+} + 3H_2O \longrightarrow Fe(OH)_3 + 3H^+$
  - Type of Mixing = Gentle

- Why do we normally use trivalent ions? They are more potent in neutralizing the charges on the colloids

Flocculation step cont'

❖ The Al and Fe hydroxides are not discrete (stand-alone) molecules. They are polymerized. Very large molecules are formed leading eventually to a visible floc. This floc will entrap the coagulated colloids. This is what is called FLOCCULATION

pH and Alkalinity in C/F

- Alkalinity represents buffering capacity of water which is important for both microbiological and chemical reactions
- It constitute the following species

$$CO_2/HCO_3^-/CO_3^{2-}$$

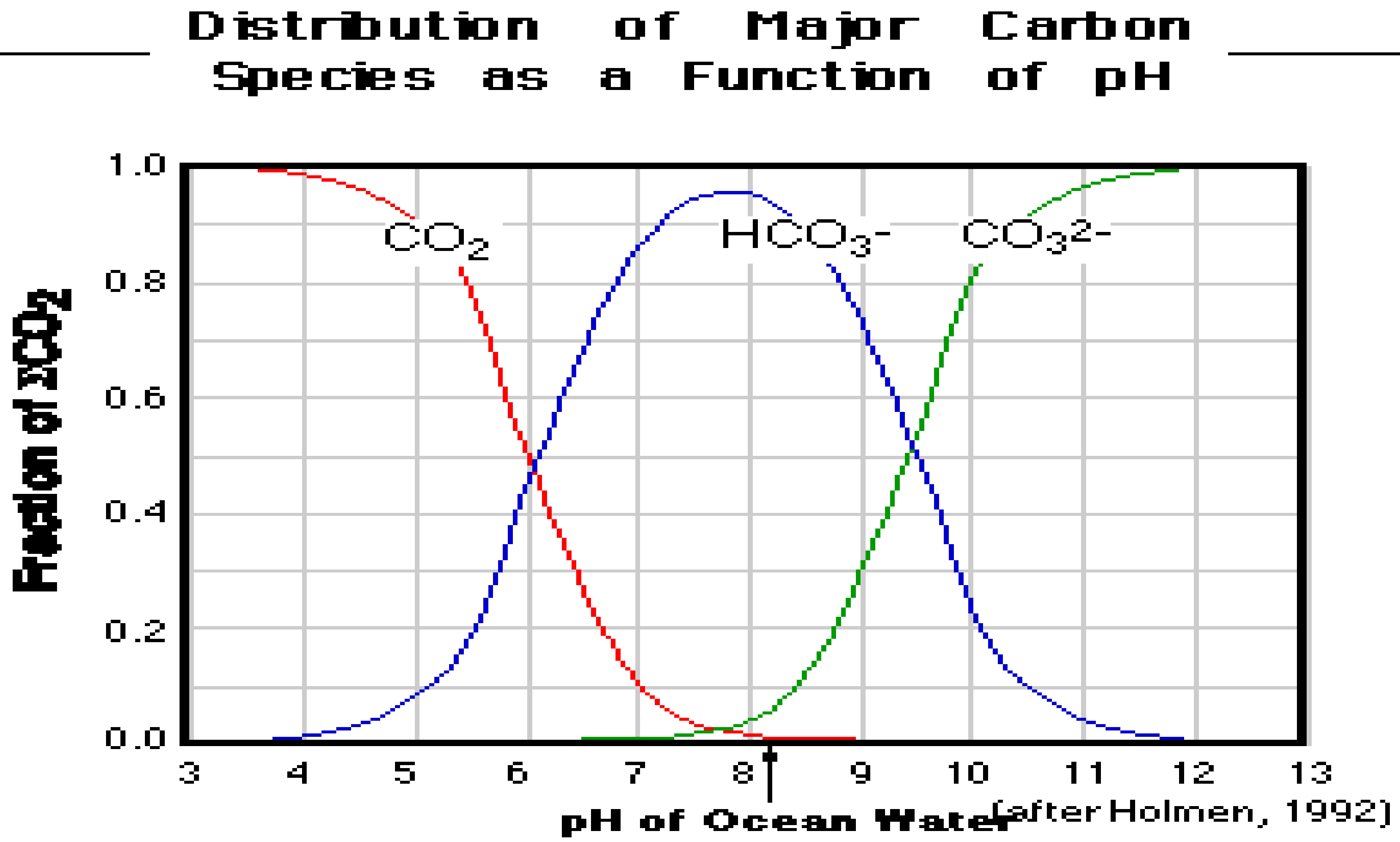
$$H^+ + CO_3^{2-} \longrightarrow HCO_3^-$$

$$H^+ + HCO_3^- \longrightarrow H_2O + CO_2$$

$$OH^- + CO_2 \longrightarrow HCO_3^-$$

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

pH and Alkalinity in C/F



pH and Alkalinity in C/F

- Alkalinity improves buffering
- Helps capture liberated H^+ which would otherwise lower pH leading to dissolution of the floc

- $3Al^{3+} + 3HCO^-_3 \longrightarrow 3Al\ (OH) \quad + \ 3\ CO_2\uparrow$

- $2Al^{3+} + 3\ CO^{2-}_3 \ + 3H_2O \longrightarrow 2Al\ (OH)_3 + 3CO_2\uparrow$

pH and Alkalinity in C/F CONT'

- If alkalinity is low, it is important to add an alkali (e.g. Calcium hydroxide) together with the coagulant to increase the buffering capacity of the water. However, if too much alkali is added, the pH will increase and impair floc formation (re-dissolving).

How to determine required amount of coagulant

- Through Jar Test

- APPARATUS
- 1 to 6 l liter jars
- various amounts of coagulants
- a stirring device

COAGULANT AIDS

Polymerized substances with long-chain molecules

Improves flocculation in small doses by:

- ❖ Forming floc more rapidly
- ❖ Forming larger or/and heavier floc
- ❖ Reducing coagulant dose

Coagulation/Flocculation in practice

Materials needed

- A jar test kit
- Solution storage tank (they should be of corrosive resistant materials)
- Chemical feeder (constant head or other types e.g. dry feed equipment)
- Mixing chamber (Create turbulence e.g. by plunging/cascading or hydraulic jump)
- Flocculation tank (baffles, mechanical agitators, upflow sedimentation tanks E.T.C.)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END

THANK YOU