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Water Quality, Definitions, and Characteristics

By

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Water Quality

The availability of a water supply adequate in terms of both quantity and quality is essential to human existence. Early people recognized the importance of water from a quantity viewpoint. Civilization developed around water bodies that could support agriculture and transportation as well as provide drinking water. Recognition of the importance of water quality developed more slowly. Early humans could judge water quality only through the physical senses of sight, taste, and smell. Not until the biological, chemical, and medical sciences developed were methods available to measure water quality and to determine its effects on human health and well-being.

Water Quality

Like all sciences, the science of water quality has developed its own terminology and the means of quantifying these terms. The purpose of this lecture is to introduce the students and readers to the modern concepts of water quality. The means by which the nature and extent of contaminants in water are measured and expressed are presented along with the sources of various contaminants that find their way into water. An understanding of the material in this lecture will be essential in subsequent lectures dealing with water quality changes in both natural and engineered systems.

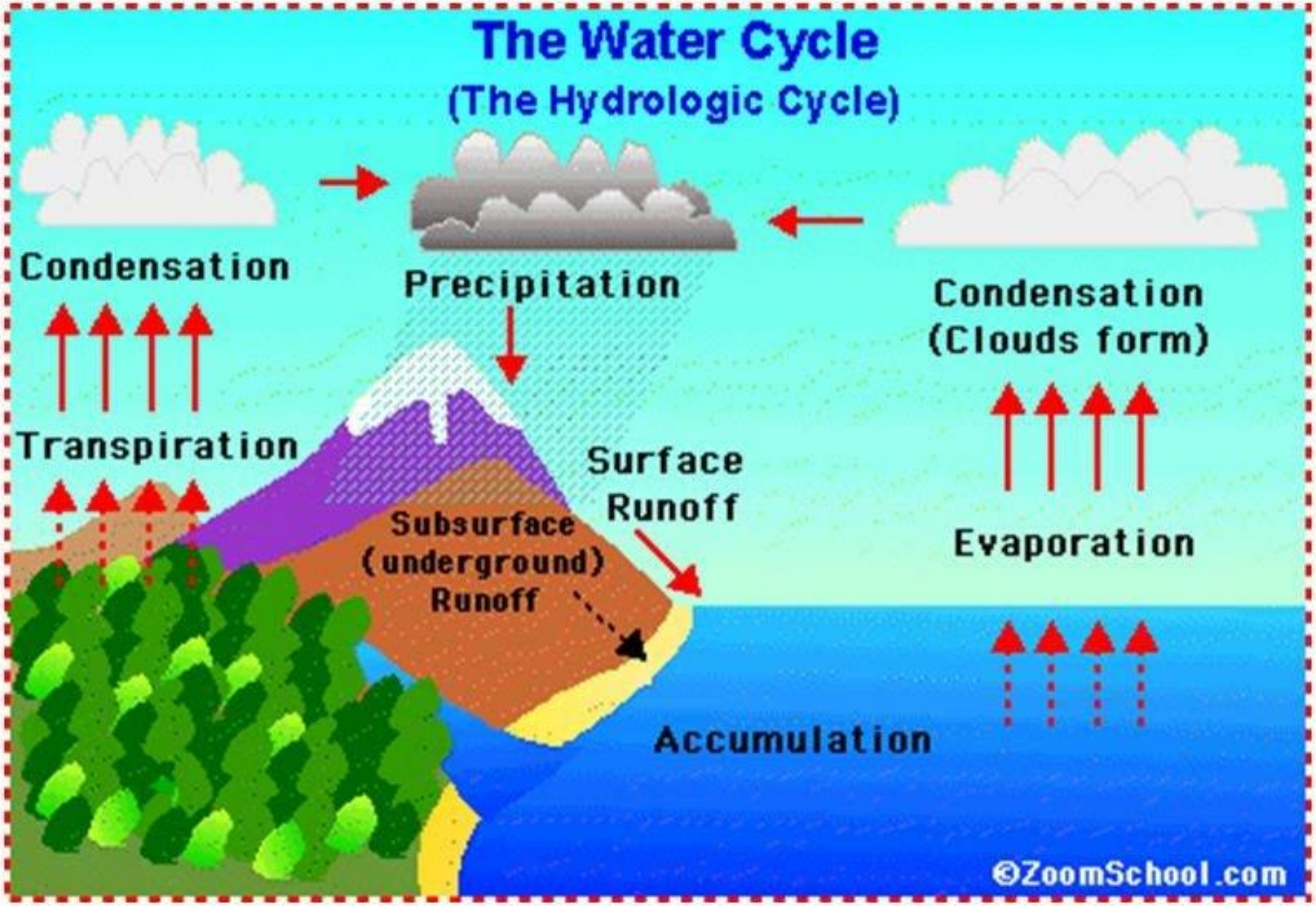
Contents

- 1- The Hydraulic cycle water and water quality
- 2- physical water – Quality parameters
- A- suspended solids
- B-Turbidity
- C- Color
- D- Taste and odor
- E- Temperature
- 3- Chemical water – Quality parameters
- Chemistry of solutions
- Total dissolved solids
- Alkalinity
- Hardness,

- Fluorides
- Metals
- Organic
- Nutrients , Nitrogen , phosphorus
- 4- Biological water – Quality parameters

2.1 - The Hydrologic cycle and water quality

The Water Cycle (also known as the hydrologic cycle) is the journey water takes as it circulates from the land to the sky and back again.



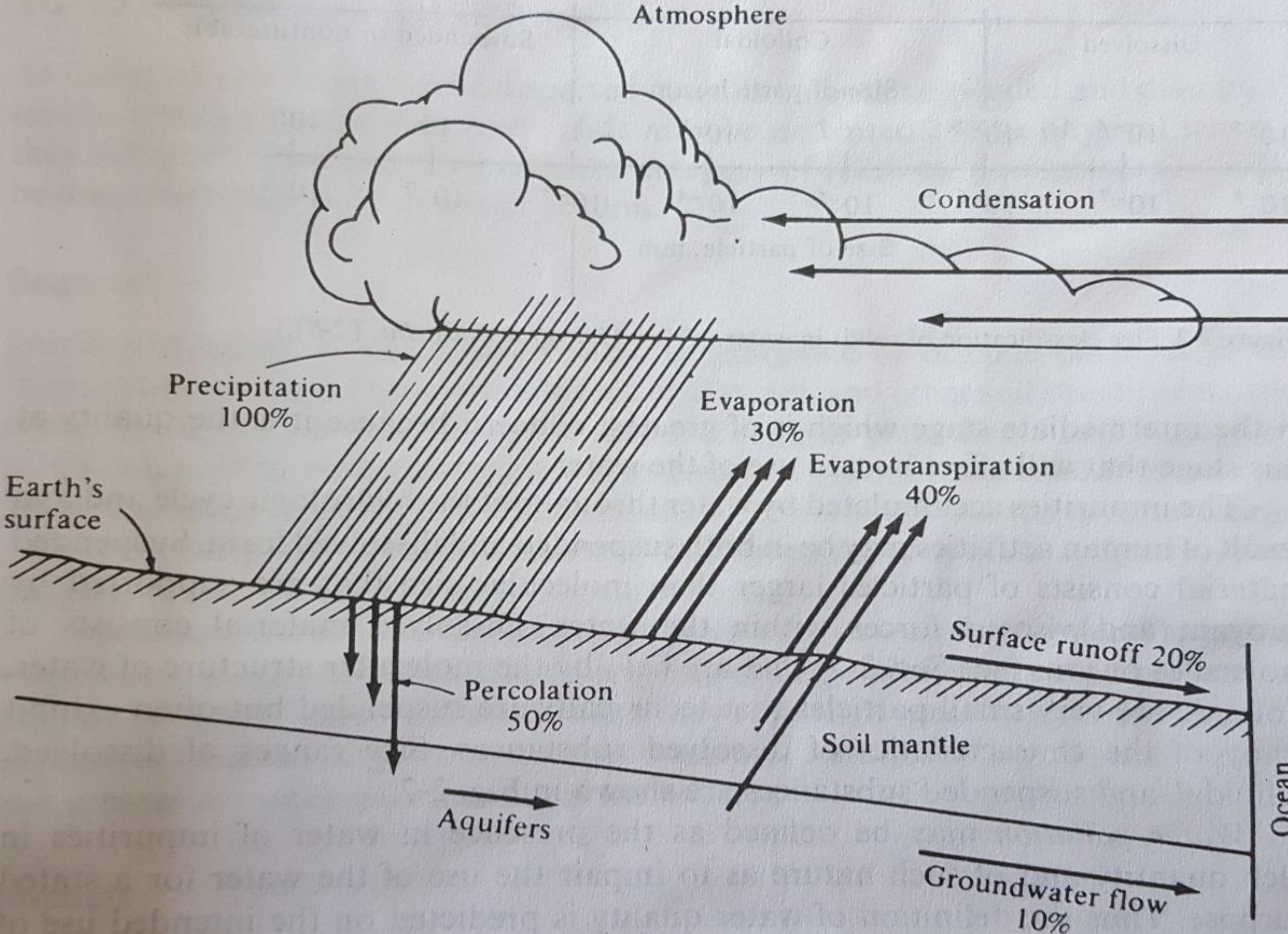
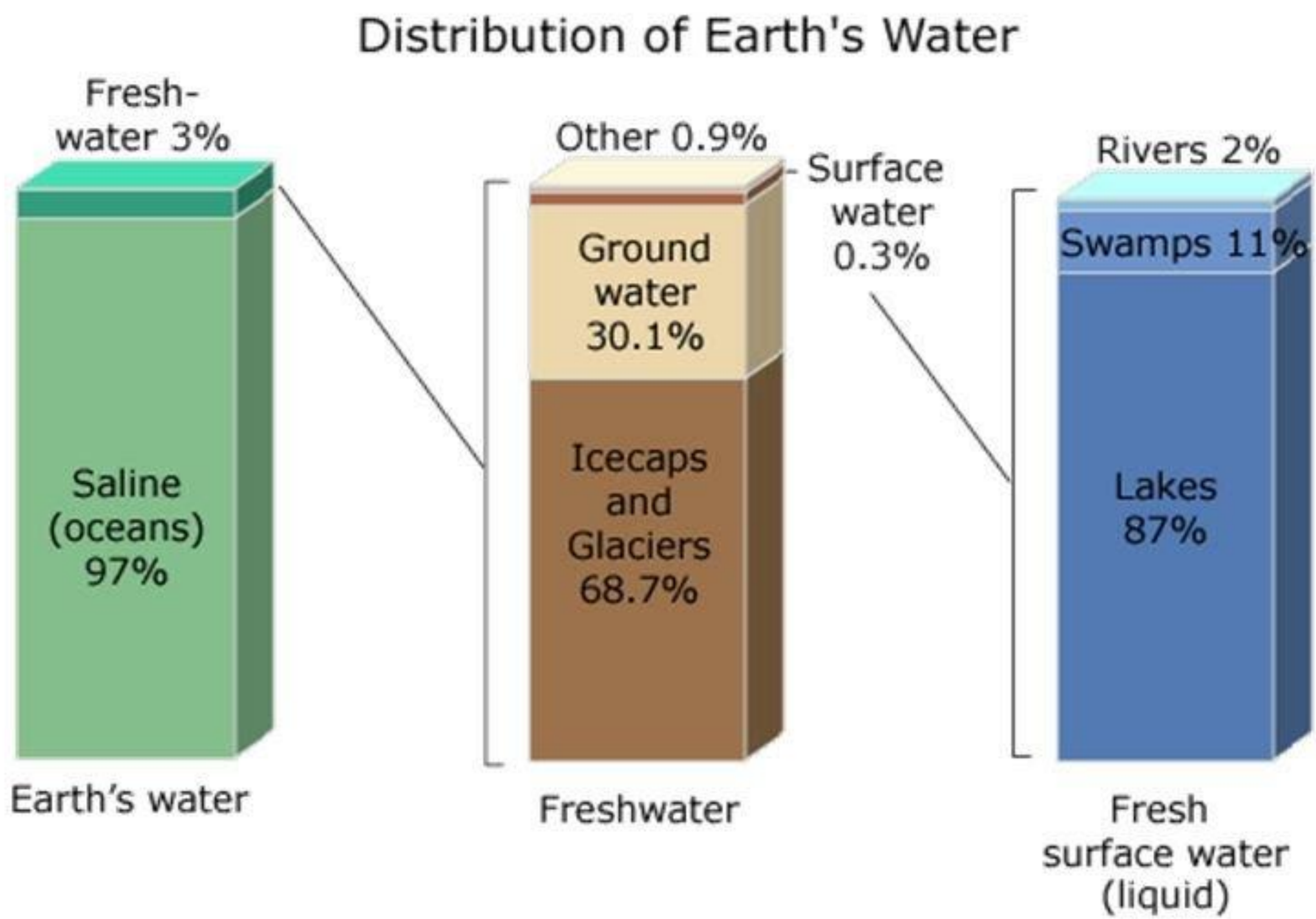


Figure 2-1 Hydrologic cycle.

World Water Distribution



Size classification of solids in water

Type	Description	Size (mm)
Dissolved	Material consists of molecules or irons that are held by molecular structure of water.	$< 10^{-6}$
Colloidal	Very small particles that technically are suspended but often exhibit many of the characteristics of dissolved substances	$10^{-6} - 10^{-3}$
Suspended	Suspended material consists of particles that are supported by buoyant and viscous forces within water	$> 10^{-3}$

Physical water–quality parameters

- **Physical parameters …** characteristics of water that respond to the senses of sight, tough, taste or smell.

2-2 Suspended Solids

- **Sources**

1. **Inorganic** solids such as clay, silt, other soil constituents.
2. **Organic** material such as plant fibers, biological solids (alge, bacteria) ……

   - natural contaminants from erosive action of flowing surface water,

   - domestic wastewater
3. **Immiscible liquids** such as oils

- **Impacts**

1. It is displeasing and provides adsorption sites for chemical and biological agents.
2. May be degraded biologically resulting in objectionable by-products.
3. May include disease causing organisms

Measurement

- **Total Solid Test**:

  - Quantifies **all the solids** in the water (suspended and dissolved),

  - Measured by evaporating a sample at a temp. of 104°C to dryness and weighing the residue,

  - Expressed as (mg/l) based on a dry mass of solids per volume,

- **Suspended Solid Test**

  fraction of the solids in water sample can be approximated by filtering the water, and drying the residue at 104°C and determining the mass of the residue retained on the filter.

- The amount of **dissolved solids** passing through the filters, is the difference between the total-solids and the suspended solids of a water sample.

- **Note:**

  - Some colloids may pass through the filter and then it is measured with the dissolved fraction while some of the dissolves solids adsorb to the filter material.

  - It depends on the size and natural of solids and on the pore size and surface characteristics of the filter material.

- The total **organic content** of both total and suspended solids can be determined by firing the residues at 600 ^{o}C for 1hr. The organic material will be converted to carbon dioxide, water and vapor. The remaining material will represent the inorganic residue

- **Use:**
- Suspended Solid is an important parameter of wastewater in measuring the quality of the wastewater influent and monitor several treatment processes.

- **EPA** set a max. SS of **30 mg/l** for most treated wastewater discharge.

Example 2.1

- The tare mass of the pair = 54.352 g
- Volume of sample = 250 ml drawn through a filter pad, then placed in a drying oven at 104 °C, a constant mass of 54.389 g is reached.
- Determine the suspended solids concentration of the sample.

Solution

- Determine the mass of solids removed.
- Tare mass + solids = 54.389 g
- -Tare mass = 54.352g
- ____________________________
- Mass of solids = 0.037g
- = 37 mg
- Determine the concentration of the solids

$$\frac{\text{mg solids x 1000 mL /L}}{\text{mL of sample}} = \text{conc. in mg /L}$$

$$\frac{37 \text{x } 1000}{250} = 148 \text{ mg /L}$$

- Example :
- 100 mL of water
- Dry filter = 0.254 gm
- After 104 c = 0.263 gm
- After 600 c = 0.258 gm
- Sol.
- S.S = 0.263 – 0.254 /0.1 L = 0.09 g/L = 90 mg/L
- V.S.S = 0.263 - 0.258 / 0.1 = 0.05 g/L = 50 ppm

F.S.S = 40 mg/L

2.3 Turbidity

- **What is Turbidity?**

  A measure of the extent to which light is either absorbed or scattered by suspended material in water.

- Turbidity is not a quantitative measurement of suspended solids … why? (small pebble of glass)

- Test of turbidity is commonly for natural bodies of water or potable (drinking) water where the nature and effects of the solids are more important than quantity.

Source

- Erosion of colloidal material such as clay, silt, rock fragments, oxides from the soil.
- Vegetable fibers and microorganisms,
- Soap, detergents.

Impacts

- Turbid water is displeasing
- Provide adsorption sites for chemicals that may be harmful or cause undesirable taste and odor.
- the presence of tiny colloidal particles makes it more difficult to remove,
- Disinfection of turbid water is difficult (adsorption)
- Accumulation of turbidity causing particles in streambeds result in sediment depositions…surface water bodeis

Measurement

- Generally, turbidity is measured by determining the percentage of light of a given intensity that is either absorbed or scattered.
- Jackson turbid-meter.
- Turbidity is measured using a **turbidity meter**.
- Formazin, a chemical compound, is currently used as the primary standard for calibrating turbid meters,
- Turbidity meter readings are expressed as a formazin turbidity units (FTU) and the results are reported as nephelometric turbidity units (NTU).

Use

- Natural waters have turbidity ranging from few FTUs to several hundred.

- **EPA** … maximum **1 FTU** for drinking water.

2.4 Color

- Pure water is colorless.
- Foreign substances in water cause color.

- **Apparent color** : due to suspended matter,
- **True color**: due to dissolved solids after removal of suspended matter.

Source

- Industrial wastes, food processing, chemical production…etc
- Reddish water …. Iron oxides
- Yellowish-brown …..organic debris, leaves, wood
- Brown or blackish water …. Manganese oxides

Impacts

- Not acceptable to the public
- Unsuitable in industrial use
- Reduce the effectiveness of disinfection process
- (some organic compounds with chlorine result in cancer-causing agents)

Measurement

- Color can be measured visually by comparison with potassium chloroplatinate standards …. True color unit **(TCU),**
- or by scanning at different spectro-photo-metric wavelengths.

Use

- Color is an indirect measurement of foreign substances in water.

Impacts

- Not acceptable to the public
- Unsuitable in industrial use
- Reduce the effectiveness of disinfection process
- (some organic compounds with chlorine result in cancer-causing agents)

Measurement

- Color can be measured visually by comparison with potassium chloroplatinate standards …. True color unit **(TCU),**
- or by scanning at different spectro-photo-metric wavelengths.

Use

- Color is an indirect measurement of foreign substances in water.

2.5 Taste and Odor

Source

- Inorganic substances produce tastes; alkaline material ….bitter taste, metallic material …. Salty or bitter taste.
- Organic material produce both taste and odor
- Biological decomposition of organics result in taste and odor.

Impacts

- displeasing (water is odorless and tasteless), associated with contaminants
- Some organic substances which cause odor may be carcinogenic.

Measurement

Threshold odor number (TON)

- Odor-free water (B) is used for successive dilutions of the sample with odor free water (A) until the odor is no longer detectable to make 200 ml mixture.

TON = (A+B)/A

Where: A is the volume of odorous water (mL)

B is the volume of odor-free water (mL)

Use

- Taste and odor are associated with potable water and wastewater.
- EPA … max. of 3 TON

- Example
- A = 100 mL
- B = 550 mL
- TON = A + B/A
- TON = 100 + 550 / 100 = 6.5

2.6 Temperature

One of the most important parameter in natural surface water systems;

- Related to presence and activities of biological species,
- Affect chemical reactions
- Affect solubility of gases in water

Impacts

- Increasing temperature … increase biological activities … may cause problems,
- Affect physical properties of water (viscosity, density)

Chemical water – quality parameters

- Water is called a **universal Solvent**
- Chemical parameters of water are:

    1. Total dissolved solids,
    2. Alkalinity,
    3. Hardness,
    4. Fluorides,
    5. Metals,
    6. Organics,
    7. Nutrients.

Chemistry of solutions

- **Atom** the smallest unit of element
- **Molecules** of elements or compounds are constructed of atoms.

$$H + H \rightarrow H_2$$

$$H_2 + O \rightarrow H_2O$$

- **Molecular mass** is the sum of the atomic mass of all atoms in molecule

For example :

- Atomic mass of oxygen (O) = 16 , for Hydrogen (H) =1
- Molecular mass for water (H_2O) =18

- **A mole** of an element or compound is its molecular mass in gm.

For example:

one mole of oxygen (O_2) = 32, water (H_2O) =18

- One mole of a substance dissolved in sufficient water to make one liter of solution is called a **one molar solution**.
- The charged species is called **ions**. Produced when compounds dissociate in water.
- +ve ions called **cations**, -ve ions called **anions**
- **Neutrality** means the number of cations = the number of anions.

$$NaCl \Leftrightarrow Na^{+} + Cl^{-}$$

- **The valence** is the number of charges on an ion.

  The valence of (Na^{+})=1,

  The valence of (Cl^{-})=1

- **The equivalence** of an element is the number of hydrogen atoms that element can hold in combination or can replace in a reaction (= valence in most cases)

- **An equivalent** of an element is its gram molecular mass (mole) divided by its equivalence.

- **A milliequivalent** of an element is its milligrams molecular mass divided by its equivalence.

Example

How many grams of calcium will be required to combine with 90 g of carbonate to form calcium carbonate?

Solution:

1- One equivalent of Carbonate (CO_3^{2-}) $= \dfrac{\text{equivalent mass}}{\text{equivalence}} = \dfrac{12+3(16)}{2} = 30g/equiv$

2- One equivalent of Calcium(Ca^{2+}) $= \dfrac{40}{2} = 20\,g/equiv$

3- The no. of equivalents of Carbonate must equal to the no. of equivalents of calcium.

4- No. of equivalents of calcium $= \dfrac{90g}{30g/equiv} = 3\ equiv$

5- So, we need 3 equiv of carbonate = 3 equiv X 20 g/equiv = 60 g.

- The concentration of substance A can be expressed as an equivalent concentration to substance B as the following:

$$\frac{(g/L)A}{(g/equiv)A} \times (g/equiv)B = (g/L)A \quad \text{expressed as } B$$

- Generally, the constituents of dissolved solids are reported in terms of equivalent calcium carbonate concentrations

Example

What is the equivalent calcium carbonate concentration of:

- 117 mg/L of NaCl?
- $2x10^{-3}$ mol/L of NaCl?

1- One equivalent of Calcium Carbonate ($CaCO_3$)

$$= \frac{equivalent\,mass}{equivalence} = \frac{40+12+3(16)}{2} = 50\,g/equiv$$

2- One equivalent of Sodium Chloride (NaCl) $= \frac{23+35.5}{1} = 58.5\,g/equiv$

$$\frac{117(mg/L)NaCl}{58.5(g/equiv)A} \times 50(g/equiv)CaCo_3 = 100(mg/L)NaCl \quad as\ CaCo_3$$

3- One mole of a substance divided by its valence is one equivalent →

$$\frac{2\times10^{-3}mol/L}{1mol/equiv} = 2\times10^{-3}equiv/L$$

$$thus, 2\times10^{-3}equiv/L \times 50(g/equiv)CaCo_3 = 100(mg/L)NaCl \quad as\ CaCo_3$$

Total Dissolved solids

The material remaining in the water after filtration for the suspended solid analysis is considered to be **dissolved solids**.

- **Source**
- Results from the solvent action of water on solids, liquids, and gases.
- Inorganic dissolved solids; minerals, metals, gases.
- Organic ; decay products of vegetation, organic chemicals and gases.

Impacts

- Produce tastes, colors, and odor,
- Some chemicals are toxic or carcinogenic,
- Some dissolved solids may combine to form a compound of more dangerous than the original materials,
- Not all dissolved solids are undesirable.

Measurement

- See sec. 2-2 Suspended Solids
- By measuring the electrical conductivity of the water, Conductivity measures the ability of water to conduct an electrical current.

- Conductivity is a good way to determine the ionic strength of water because the ability of water to conduct a current is proportional to the number of ions in the water
- Freshwater generally has low conductivity measured in microSiemens (uS)
- Marine systems have much higher conductivity measured in milliSiemens (mS) which can easily be converted to salinity
- Humans and other terrestrial animals require fresh water for survival as do plants and animals normally found in freshwater

Use

- TDS parameter is important in the analysis of water and wastewater to know more about the composition of the solids in water

Ion Balance

The dissolved solids content of natural water is classified to:

- **Major constituents** ... (1-1000mg/L)

sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), bicarbonate ($HCO3^-$), sulfate ($SO4^{2-}$), chloride (CL^-)

- Called common ions,
- Measured individually and summed on an equivalent basis to represent the approximate TDS,
- The sum of anions must equal the sum of cations (as a check)

- **Secondary constituents** ....(0.01-10mg/L).

  Iron, potassium, carbonate, nitrate, fluoride, boron, silica

Testing for ion balance

- The results of common ions for a sample of water are shown below,
- If 10% error in the balance is acceptable, should the analysis be considered complete?

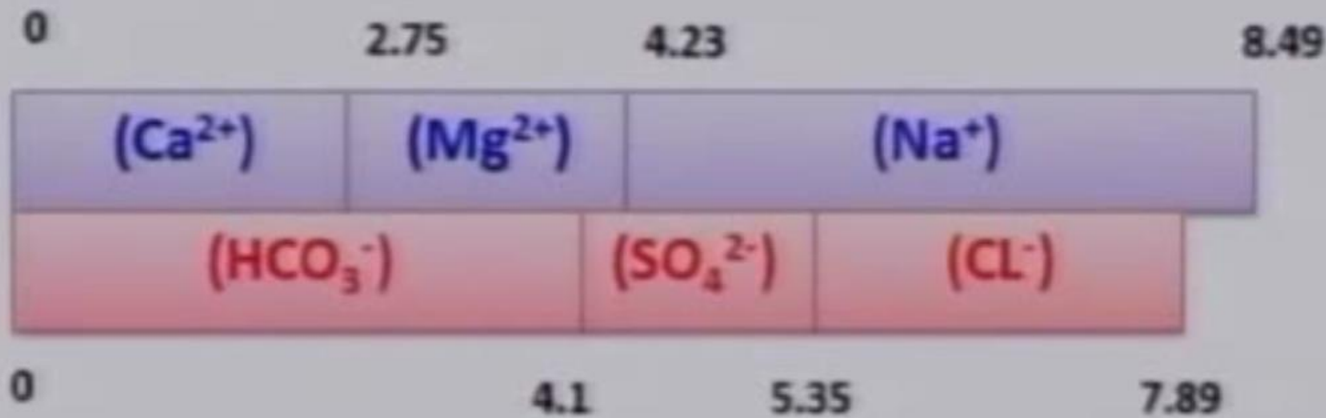
sodium (Na^+) = 98mg/L,
calcium (Ca^{2+}) =55mg/L,
magnesium (Mg^{2+})= 18mg/L,

bicarbonate ($HCO3^-$)= 250mg/L,
sulfate ($SO4^{2-}$) =60mg/L,
chloride (CL^-) = 89 mg/L

Ion	Concentration (mg/L)	Equiv, (mg/mequiv)	Equiv conc, (mequiv/L)
(Na^{+})	98	23/1	4.26
(Ca^{2+})	55	40/2	2.75
(Mg^{2+})	18	24.3/2	1.48
			8.49
(HCO_3^{-})	250	61/1	4.1
(SO_4^{2-})	60	96/2	1.25
(CL^{-})	89	35.5/1	2.51
			7.86

- Calculate the percent of error

  = (8.49-7.86)*100/7.86= 8% < 10% .... Accept analysis



Bar diagram

- CO_2 influences the carbonate system in water as follows:

Carbon dioxide dissolves in water and produces carbonic acid

$$CO_2 + H_2O \Leftrightarrow H_2CO_3 \text{ (dissolved } CO_2 \text{ and } H_2CO_3\text{)}$$

Carbonic acid dissociates producing H^+

1. $H_2CO_3 \Leftrightarrow H^+ + HCO_3^-$ (HCO_3^- can absorb another H^+ to become H_2CO_3)
2. $HCO_3^- \Leftrightarrow H^+ + CO_3^{2-}$ (CO_3^{-2} can absorb one H+ to become HCO_3^-)

- The ability of water to absorb H^+ ions (anions) without a change in pH is known as its alkalinity.
- In freshwater, **alkalinity** typically is due to the presence of excess **carbonate anion** (from the weathering of silicate or carbonate rocks) that when hydrolyzed produces OH^- (and neutralizes H^+) as follows:

  Hydrolysis of carbonate and carbonate produces OH^-

  $$CO_3^{2-} + H_2O = HCO_3^- + OH^-$$

Alkalinity

Alkalinity is a measure of the substances (ions) in water that react to neutralize acid (hydrogen ions) and resist changes in pH

Sources

- Natural water systems include CO_3^{2-}, HCO_3^-, OH^-, HPO_4^{2-}, $H_2PO_4^-$, HS^-, NH_3
- CO_3^{2-}, HCO_3^-, OH^- ....(dissolution of mineral substances, from CO_2),
- HPO_4^{2-}, $H_2PO_4^-$ .... (detergents in wastewater, fertilizers and insecticides)
- HS^-, NH_3 ....(products of microbial decomposition of organic material).
- Groundwater has higher alkalinity than surface water

- Exampal
- Alk = oH +Hco_2 + $Co_{٣}$

oH = 10 mg /L

$Co_{٣}$ = 70 mg/l

Hco_2 = 120 mg/l

Calculate alkalinity

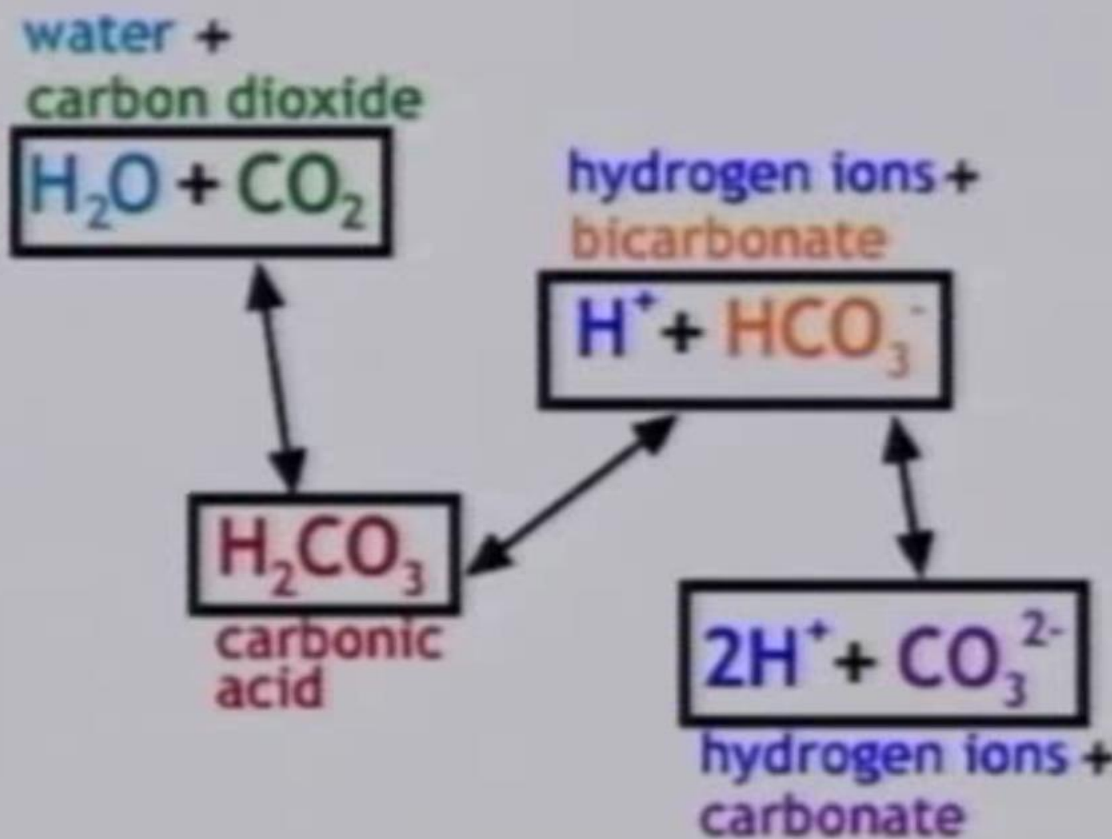
Sol.

oH = 10 /17 =0.588 meq/L

$Co_{٣}$ = 70/30 = 2.33 meq/L

Hco_2 = 120/61 = 1.967 meq/L

Alkalinity = 0.588 + 2.33 + 1.967 = 4.885 meq/l



- The relative quantities of the alkalinity species are pH dependent.
- See the next figure

Impacts

- Bitter taste to water,
- Reaction can occur between the alkalinity species and cations, resulting in precipitated substances that can foul pipes.

Measurement

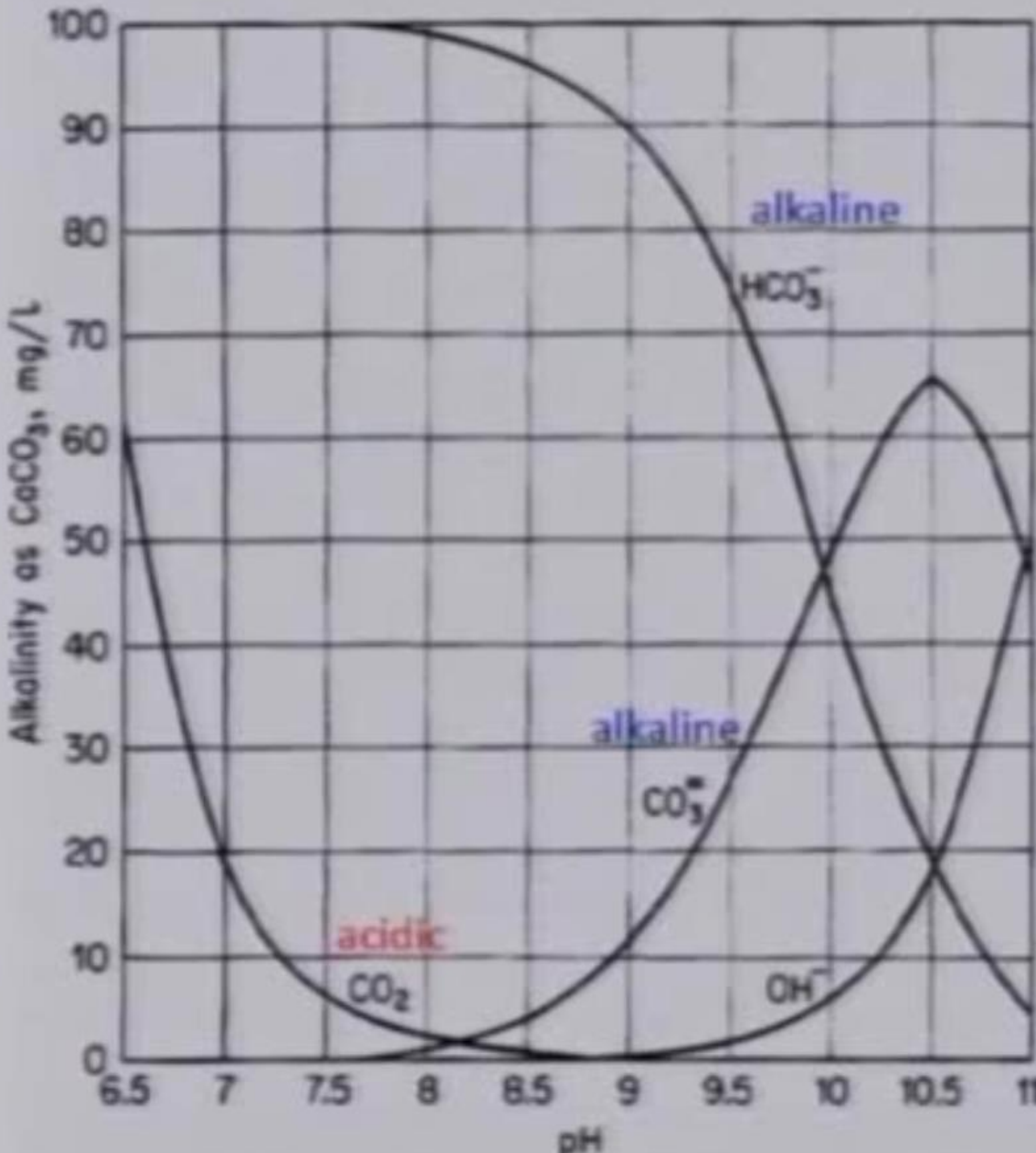
By titration the water **with an acid** and determining the hydrogen equivalent.... Expressed as mg/L of $CaCO_3$

For example:

Each mL of 0.02 N H_2SO_4 will neutralize 1mg of alkalinity as $CaCo_3$

Normality is the number of gram equivalents per liter = **nM**

Alkalinity species at various pH levels, (values calculated for water with a total alkalinity of 100 mg/l at 25°C.



- CO_2 is acidic and lowers pH as the amount of CO_2 in the water increases.
- As pH increases from 7, HCO_3^- is formed and the water becomes slightly alkaline.
- As pH continues to raise, CO_3^{2-} becomes the dominant source of alkalinity in most waters
- pH increases when CO_2 is removed from the water by photosynthesis and decreases when CO_2 is added to the water by respiration, especially at night when photosynthesis has stopped.

Hardness

- **Hardness** is the concentration of multivalent **metallic cations** in solution (mg/L), which includes mainly Ca^{2+} and Mg^{2+}
- The units are, like alkalinity, mg/L as $CaCO_3$

- Hardness is classified as carbonate hardness and non-carbonate hardness, depending upon the anion with which it associated.

- Anions of alkalinity (e.g., CO_3^-) and cations of hardness (e.g., Ca^{2+}) are normally derived from the same carbonate minerals – and this is the reason for the observed general association between alkalinity and hardness

1. **Carbonate hardness** - the portion of total hardness that is chemically equivalent to the CO32- and HCO_3^- alkalinity present in the water.

2. **Non-carbonate hardness** - that hardness which is in excess of carbonate hardness; will only occur in water where Total Hardness > alkalinity

Example

- **Ca = 70 mg/L**
- **Mg=30 mg/L**
- **CO3 = 50mg/L**
- **Calculate Total Hardnes**s (**T . H)**
- Sol.
- Ca = 70/20 = 3.5 meq/L = 3.5 * 50 = 175mg /l as caco3
- Mg = 30/12= 2.5 meq/L = 2.5*50 = 125 mg/L as caco3
- CO3 = 50/30 = 1.67 = 1.67 * 50 = 83.3 mg/L as caco3
- Hco3 = 90/61 = 1.47 = 1.47 * 50 = 73.7 mg/l as caco3
- Total Hardness = 175 + 125 = 300 mg/L as caco3
- C. H = [Co3]+ [hco3] = 83.3 + 73.7 = 157 mg/L as caco3
- N.C.H = 300 – 157 = 143 mg/L as caco3

- Carbonate hardness (C.H) = Temporary
- Non- Carbonate hardness (N.C.H) = Permanent

	Case 1 mg/l as $caco_3$	Case 2	Case 3
Ca + Mg	300	400	200
Co_3 + Hco_3	157	400	300
T . H	300	400	200
C . H	157	400	200
N. C . H	143	0	0

Sources

Caused by the presence of multivalent cations, mostly Ca^{2+} and Mg^{2+}; *(Fe^{2+}, Mn^{2+}, Sr^{2+}, Al^{3+} may be present in much smaller amounts).*

Impacts

- Hardness determines how hard or easy it is to lather soap
- **Hard water is** water that requires considerable amounts of soap to produce foam or lather; the precipitates formed by the hardness and soap adheres to surfaces of tubes, sinks and dishwashers, produces scale in hot water pipes, etc.
- Not a health concern, but have **economic concern**

Measurement

Hardness can be measured using chemical titration to determine the quantity of calcium and magnesium ions.

Use

- Analysis for hardness is commonly made on natural waters and on waters for potable supplies and for certain industrial uses.

• Soft	< 50 mg/L as $CaCO_3$
• Moderately hard	50-150 mg/L as $CaCO_3$
• Hard	150-300 mg/L as $CaCO_3$
• Very hard	>300 mg/L as $CaCO_3$

- Maximum hardness of 500 mg/L in drinking water (puplic health service standards)

Fluoride

- Associated in nature with few types of sedimentary or igneous rocks.
- Fluoride is seldom found in surface waters,
- Fluoride appears in groundwater in only few geographical regions,
- Toxic to humans and animals in large quantities,
- Beneficial with small concentrations,
- 1 mg/L concentration in drinking water help to prevent dental cavities in children … harder, stronger teeth.
- Added to water supplies for good dental formation
- Excessive fluoride can result in discoloration of teeth (< 2mg/L)

Metals

1. Nontoxic Metals

Include calcium, magnesium, sodium, iron, manganese, aluminum, copper and zinc.

Sodium: - in natural waters, earth crust.

- reactive , soluble in water.
- corrosive to metal surfaces,
- Toxic to plants in large concentrations.

Iron and manganese :

- in natural waters,
- (0.3 mg/L and 0.05 mg/L respec.) concentrations cause color problems and may cause taste and odor problems in the presence of some bacteria.

- Iron associate with chloride or bicarbonate or sulfate,
- In the presence of oxygen, Fe^{2+} is oxidized to Fe^{3+} and forms an insoluble compounds with hydroxide ($Fe(OH)_3$) .
- Manganese (Mn^{2+}) associated with chloride or nitrate or sulfate are soluble, while oxidized (Mn^{3+} , Mn^{5+}) are insoluble.

Toxic Metals

- Are harmful to humans and other organisms in small quantities
- include arsenic, barium, cadimuim, chromium, lead, mercury, and silver

ORGANICS

- **Biodegradable Organics**

Biodegradable materials consists organics that can be utilized for food by naturally occurring microorganisms within a reasonable length of time.

Source of organics

- Organics include fats, proteins, alcohols, acids, aldehydes, and esters.
- Organics are the end product of the initial microbial decomposition of plant or animal tissue.
- Result from domestic or industrial wastewater discharge.

Microbial utilization of dissolved organics can be accompanied by *oxidation* (addition of oxygen to elements of the organic molecule) or by *reduction* (addition of hydrogen).

BOD for any time period can be determined as:

- The rate at which organics are utilized by microorganisms is assumed to be a first-order reaction,
- The rate at which organics utilized is proportional to the amount available.

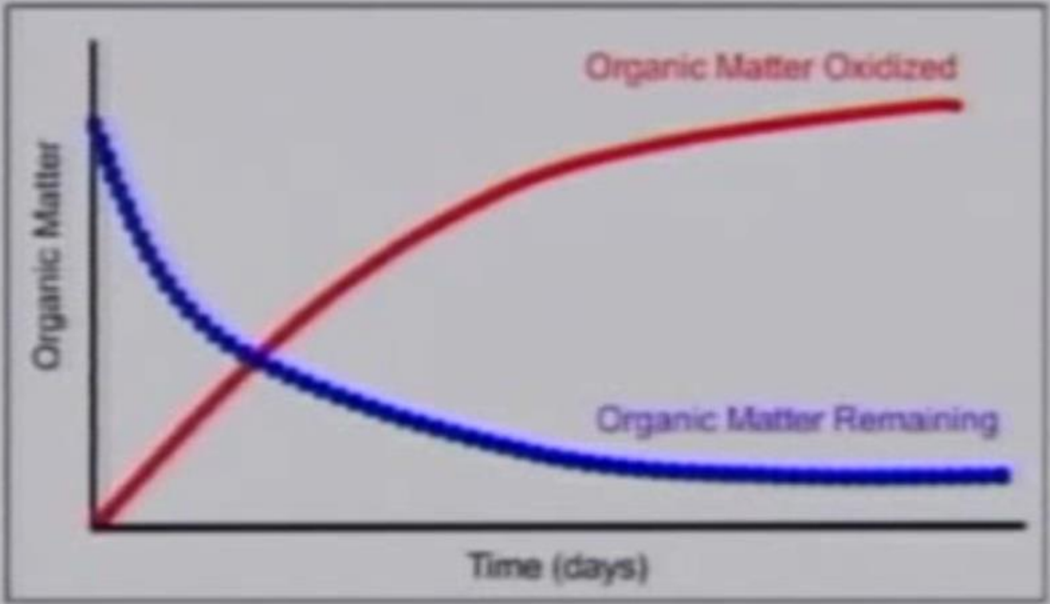
$$\frac{dL_t}{dt} = -kL_t$$

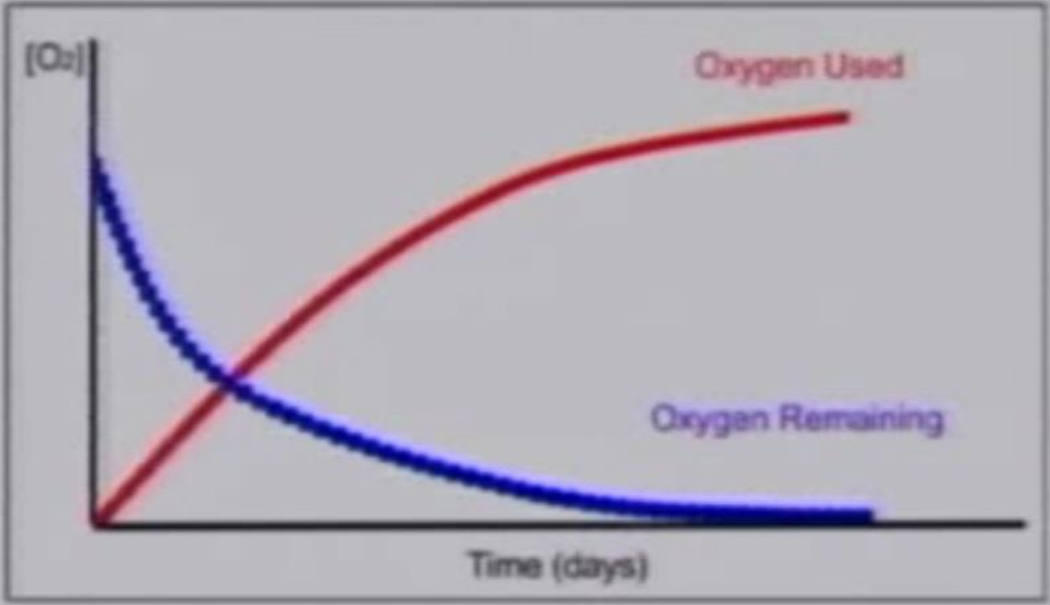
where:

- L_t is the oxygen equivalent of the organics at time t (mg/L),
- k is the reaction constant (d^{-1})

$$\int_{L_0}^{L_t} \frac{dL_t}{L_t} = -k\int_0^t dt \Rightarrow \ln\frac{L_t}{L_o} = -kt \Rightarrow L_t = L_o e^{-kt}$$

- L_o is the total oxygen equivalent of the organics at time 0 (mg/L),
- L_t is the oxygen remaining at time t (mg/L),


Organic Matter Oxidized
Organic Matter
Organic Matter Remaining
Time (days)


[O2]
Oxygen Used
Oxygen Remaining
Time (days)

The amount of oxygen used in the consumption of organics = BOD , <u>can be found</u> from the L_t value <u>as the following</u>:

<u>If</u>

- L_o is the total oxygen equivalent of the total mass organics at time 0 (mg/L),
- L_t is the oxygen remaining at time t (mg/L),

$$Y_t = L_o - L_t = L_o - L_o e^{-kt} \Rightarrow \quad Y_t = L_o(1 - e^{-kt})$$

Y_t represents the **BOD_t** of the water

<u>Note:</u>

BOD (ultimate) = the initial oxygen equivalent of the water L_o

Example : BOD conversions The BOD. Of a wastewater determined to be 150 mg/L at 20 C .The k value known to be o. 23 per day. what would the BOD_8 be if the test were run at 15 C?

- **SOLUTION**
- Determine the ultimate BOD

$$y_u = \frac{Y_5}{1- e^{-k\,t}}$$

$$= \frac{150}{1-e^{-0.23x5}}$$

$$= 220 \text{ mg/L}$$

- Correct the k value for 15 C

$$k_T = k_{20}\, 0^{T-20}$$

$$k_{15} = 0.23(1.047^{-5})$$

$$= 0.18$$

- Calculate y_8

$$y_t = y_u\,(1-e^{-kt})$$

$$y_8 = 220\,(1- e^{-0.18x8})$$

$$= 168 \text{ mg/L}$$

Notes

- The water body is considered to be very clean if its BOD_5 at $20^{\circ}C$ is less than 1 mg/litre (i.e. ppm).
- The water body is considered poor if its BOD_5 at $20^{\circ}C$ is more than 5 mg/litre.
- The BOD_5 estimate however excludes complex organics such as cellulose, and proteins, which cannot be readily biodegraded by bacteria.

COD & TOC

1. Chemical Oxygen Demand (COD):

- One problem with the BOD test is that it takes *5 days to run, if the organic compounds* were oxidized chemically instead of biologically, the test could be shortened considerably.
- Such oxidation can be accomplished with the chemical oxygen demand (COD) test.
- Since the BOD measurement includes only the readily biodegradable organics that are decomposed aerobically by simple bacteria, we use the chemical oxygen demand (COD) measurement to indicate the amount of oxidizable material present in the effluent sample that can be oxidised by a strong chemical oxidant.

Nitrogen

Source

Nitrogen occurs in five major forms in aquatic environments: organic nitrogen, ammonia, nitrite, nitrate, and dissolved nitrogen gas

1. Nitrogen gas (N_2) is the primary component of the earth's **atmosphere** and is extremely stable. N_2 Reacts with O_2 to form nitrogen oxides.
2. Nitrogen is a constituent of proteins and chlorophyll. **Decay of plants and animals (organics),** proteins are converted to amino acids and reduced to ammonia (NH_3), which may oxidized to nitrate (NO_2^-) and then to (NO_3^-) in the presence of oxygen.
3. **Animal wastes chemical fertilizers** and wastewater discharge may discharged to streams or enter groundwater .
4. Nitrogen compounds can be **oxidized to NO_3^- by soil bacteria** and may carried out into GW by percolating water.

Impact

- Nitrate can cause serious problems and even death to infant animals and humans.
- Nitrate poisoning has been referred to as "blue baby" syndrome or "methemoglobinemia'

Measurement

- Test for nitrogen forms in water include analysis for ammonia (NH_3, NH_4^+), nitrate, and organic nitrogen, expressed as mg/L as nitrogen.
- Wastewater and polluted water: NH_4^+ and organic nitrogen analysis.
- Clean water and treated wastewater: nitrate test

Phosphorus

Source

- phosphorus occurs almost as phosphate (PO_4^{3-})
- May be soluble or particulate form or may be constituents of plants or animal tissue.
- Constituents of soils , used extensively in fertilizers.
- Constituents of animal waste and municipal wastewater.
- Industrial waste.

Impact

- The tendency for phosphate to adsorb to soil particles limits its movement in soil moisture and groundwater.
- Not toxic and do not represent a direct health threat to human and other organisms.
- But, it represent indirect threat to water quality (surface water; the growth of algae in most lakes is limited by the availability of phosphorus, if phosphorus is in sufficient supply, nitrogen is usually the next limiting ***nutrient).***

Measurement

- mg/L phosphate as phosphorus.

Biological Water-Quality Parameters
Pathogens

Pathogen Indicator

- ***Pathogens = disease-causing organisms***
- From the public health standpoint, the bacteriological quality of water is as important as the chemical quality.
- A large number of pathogens may be transmitted by water, among them typhoid and cholera.
- Analysis of water for all the known pathogens is a very time consuming and expensive.
- There are many pathogens. (Next Table)
- The purity of water is checked using indicator organisms.
- The indicator most often used is ***Escherichia coli*** *(E. coli), a member of the coliform bacteria group (coliform bacteria are nonspore forming, rod-shaped bacteria* capable of fermenting lactose within 48 h at 35°C).

- Although many coliforms *occur* naturally in aquatic environments, ***E. coli***, often called ***fecal coliforms***, are associated with warm-blooded animals.
- **Fecal coliforms** are particularly **good indicator organisms** **because** they are easily detected with a simple test, generally harmless (some strains are very pathogenic, but most are not), and do not survive long outside their host.
- The presence of fecal coliforms in a water sample does not prove the presence of pathogens, nor does the absence of fecal coliforms ensure the absence of pathogens.
- However, if a large number of fecal coliforms are present, there is a good chance of recent pollution by wastes from warm-blooded animals.
- ***A high coliform count:*** *the water should not* be consumed, even though it may be safe.
- The concentration of coliforms is typically expressed as coliforms/ 100 mL of sample.

Nitrate and nitrite	NO_3, NO_2		50 mg/l total nitrogen
Turbidity			Not mentioned
pH			No guideline
Selenium	Se	<< 0,01 mg/l	0,01 mg/l
Silver	Ag	5 – 50 µg/l	No guideline
Sodium	Na	< 20 mg/l	200 mg/l
Sulfate	SO_4		500 mg/l
Inorganic tin	Sn		No guideline
TDS			No guideline
Uranium	U		1,4 mg/l
Zinc	Zn		3 mg/l

Cadmium	Cd	< 1 µg/l	0,003 mg/l
Chloride	Cl		250 mg/l
Chromium	Cr^{+3}, Cr^{+6}	< 2 µg/l	0,05 mg/l
Colour			Not mentioned
Copper	Cu		2 mg/l
Cyanide	CN^-		0,07 mg/l
Dissolved oxygen	O_2		No guideline
Fluoride	F	< 1,5 mg/l (up to 10)	1,5 mg/l
Hardness	mg/l $CaCO_3$		No guideline
Hydrogen sulfide	H_2S		No guideline
Iron	Fe	0,5 - 50 mg/l	No guideline
Lead	Pb		0,01 mg/l
Manganese	Mn		0,5 mg/l
Mercury	Hg	< 0,5 µg/l	0,001 mg/l
Molybdenum	Mb	< 0,01 mg/l	0,07 mg/l
Nickel	Ni	< 0,02 mg/l	0,02 mg/l

Standard No. 417 on Drinking Water and Analysis

Standard Specification for Drinking water

1- Natural Characteristics

Characteristic	The Maximum allowable limit
Color	10 units
Turbidity (NTU)	5 units
Taste	Accepted
Smell	Accepted
PH value	6.5-8.5

2- Chemical Characteristics

Material	The Maximum allowable limit (mg/l)
Arsenic	0.01
Cadmium	0.003
Chrome	0.05
Cyanide	0.02
Fluoride	1.0
Lead	0.01
Mercury	0.001
Nitrate $(NO_3)^-$	50
Nitrite (NO_2)	3
Selenium	0.01
Aluminum	0.2
Chloride (Cl)	250
Copper	1.0
Total Hardness (as $CaCO_3$)	500
Iron	0.3

Water Quality

Total Hardness (as $CaCO_3$)	500
Iron	0.3
Manganese	0.1
Sodium	200
T.D.S	1000
Sulphate $(SO4)^{-2}$	250
Zinc	3.0
Calcium	50
Magnesium	50
Barium	0.7
Nickel	0.02
Dissolved H.C	0.01
Carbon-chloroform Extracted	0.3
Industrial Detergents	0.3
Phenolic compounds	0.002

3-Biological Characteristics

Bacteria type	The Maximum allowable limit
Coliform (100 ml after 24hr at 35°C)	<1.1
E.coli (100 ml after 24hr at 44°C)	<1.1
Escherichia coli (250 ml after 24hr at 35°C)	Zero
Plate count (1ml after 24hr at 35°C)	Zero

Water Quality

4-Pesticides

Pesticide	The Maximum allowable limit (mg/l)
Organic chloro (chlorinated)	0.7
Organic Phosphorous	0.000005
Multi chloro-diphenolic	0.001

5-Radiation

Radiation	The maximum limit (Becquerel/liter)
Total Alfa radiation	0.1
Total Beta radiation	1

Water Quality

Profile on Environmental and Social Considerations in Iraq

ANNEX

September 2011

TABLE Q-3
EUROPEAN STANDARDS FOR SURFACE WATER QUALITY USED AS RAW WATER FOR DRINKING WATER SUPPLY

Treatment type[a]	*A1*		*A2*		*A3*	
Parameter (mg/l unless noted)	*GL*	*MAC*	*GL*	*MAC*	*GL*	*MAC*
pH units	6.5–8.5		5.5–9.0		5.5–9.0	
Colour units	10	20	50	100	50	200
SS	25					
Temp (°C)	22	25	22	25	22	25
Conductivity (μS/cm)	1000		1000		1000	
Odour (TON)	3		10		20	
Nitrate (NO_3)	25	50		50		50
Fluoride	0.7–1.0	1.5	0.7–1.7		0.7–1.7	
Iron (soluble)	0.1	0.3	1.0	2.0	1.0	
Manganese	0.05		0.1		1.0	
Copper	0.02	0.05	0.05		1.0	
Zinc	0.5	3.0	1.0	5.0	1.0	5.0
Boron	1.0		1.0		1.0	
Arsenic	0.01	0.05		0.05	0.05	0.1
Cadmium	0.001	0.005	0.001	0.005		0.005
Chromium (total)		0.05		0.05		0.05
Lead		0.05		0.05		0.05
Selenium	0.01		0.01		0.01	
Mercury	0.0005	0.001	0.0005	0.001	0.0005	0.001
Barium		0.1		1.0		1.0
Cyanide		0.05		0.05		0.05
Sulphate	150	250	150	250	150	250
Chloride	200		200		200	
MBAS	0.2		0.2		0.5	
Phosphate (P_2O_5)	0.4		0.7		0.7	
Phenol		0.001	0.001	0.005	0.01	0.1
Hydrocarbons		0.05		0.2	0.5	1.0
PAH		0.0002		0.0002		0.001
Pesticides		0.001		0.0025		0.005
COD					30	
BOD (ATU)	<3		<5		<7	
DO (% satn)	>70		>50		>30	
Kjeldahl nitrogen	1		2		3	
Ammonium (NH_4)	0.05		1	1.5	2	4
Total coliforms/100 ml	50		5000		50 000	
Faecal coliforms/100 ml	20		2000		20 000	
Faecal streptococci/100 ml	20		1000		10 000	
Salmonella	Absent in 5 litres		Absent in 1 litre			

Water Quality

A1: Simple physical treatment and disinfection,

A2: Normal full physical and chemical treatment with disinfection,

A3: Intensive physical and chemical treatment with disinfection.

GL: Guide level

MAC: maximum allowable concentration

ATU : allylthiourea

MBAS : methylene blue active substance

TON = threshold odour number

DRINKING WATER QUALITY STANDARDS

Drinking water quality standards describes the quality parameters set for drinking water. Various standards and guidelines which are used to specify water quality for drinking purpose.

1- In Europe: the European Drinking Water standards (EU)
2- In the USA: the United States Environmental Protection Agency (EPA) establishes standards as required by the Safe Drinking Water Act.
3- For countries without a legislative or administrative framework for such standards: the World Health Organization (WHO) publishes guidelines on the standards that should be achieved.
4- China: adopted its own drinking water standard enacted by Ministry of Environmental Protection.
5- Iraq drinking water standard IQS 417/2001 ICS, Council of Minsters-Central Agency for Meteorology and Quality Control.
6- Others

Table Q-2 provides drinking water quality standards by different committees

QUALITY INDICATORS FOR VARIOUS TYPES OF WATER

Characteristic	*River water*	*Drinking water*	*Raw sewage*	*Sewage effluent*
pH	x	x	x	x
Temperature	x	x	x	
Colour	x	x		
Turbidity	x	x		
Taste		x		
Odour	x	x		
Total solids	x	x		
Settleable solids			x	
Suspended solids			x	x
Conductivity	x	x		
Radioactivity	x	x		
Alkalinity	x	x	x	x
Acidity	x	x	x	x
Hardness	x	x		
Dissolved oxygen (DO)	x	x		x
Biochemical oxygen demand (BOD)	x		x	x
Chemical oxygen demand (COD)	x		x	x
Total organic carbon (TOC)	x		x	x
Volatile organic carbon (VOC)	x	x		
Assimilable organic carbon (AOC)		x		
Organic nitrogen			x	x
Ammonia nitrogen	x		x	x
Nitrite nitrogen	x	x	x	x
Nitrate nitrogen	x	x	x	x
Chloride	x	x		
Phosphate	x		x	x
Synthetic detergent	x		x	x
Bacteriological counts	x	x		

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For listening