WATER TREATMENT

SKAA 2912

WATER QUALITY PARAMETERS (PHYSICAL)

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Solids

- Sources (mixture of inorganic and organic compounds)
  - Soil erosion
  - Urban runoff
  - Decaying plants and animals
  - Wastewater and septic effluent
- Effects
  - Aesthetic and health aspects
  - Adsorption point/centre for chemicals and microorganisms
  - Stain textiles
  - May contain elevated levels of ions such as nitrate, arsenic, lead, copper, calcium, magnesium etc
  - Corrosive to plumbing fixtures/Scale formation due to dissolved ions

Solids

Total Solids

Residue of water sample that has been evaporated and dried at 103 to 105°C

Total Suspended Solids

Filter through 0.45–2.0 µm glass fiber filter → Dried filter at 105°C → Measure the weight of the filter

Total Dissolved solids

Solids that passed through 0.45–2.0 µm glass fiber filter → Dried at 180°C → Measure the weight

Volatile Suspended Solids

Fixed Suspended Solids

Volatile Dissolved Solids

Fixed Dissolved Solids

Total Volatile Solids

Dried at 500±50°C

Volatize solids are burned off

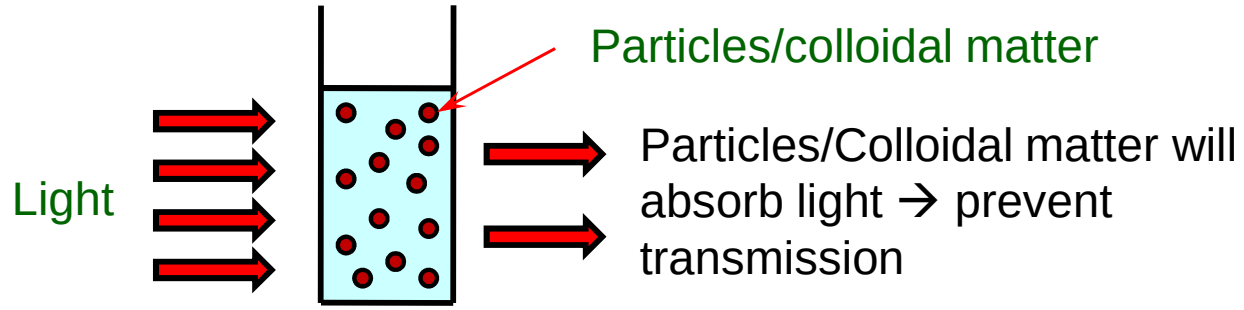
Total Fixed Solids

Dried at 500±50°C

Remaining solids after ignition

Turbidity

- Turbidity - the amount of cloudiness in water.
- Measure light-transmitting properties of water with respect to particles/colloidal matter



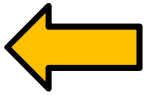
- Unit: nephelometric turbidity unit (NTU)
- Measurement apparatus:
  Secchi disk, turbidity tube, turbidity meter
- For drinking water, turbidity < 5 NTU.
- For chlorination to be effective, it is best to achieve < 1 NTU

Color

- Color is closely related to turbidity.
- Colloidal matter in the water gives color to surface waters
- Generally, pH ↑ , color intensity ↑
- Source:
  - Decomposed organic debris in the form of humic acids, tannins, lignins
  - Dye wastes
  - Wastewater (domestic and industrial)
  - Minerals
- Effects:
  - Aesthetics
  - Some are toxic for human consumption
  - Stain textiles
  - High consumption of energy in industrial boilers, equipment and tools due to the insulation caused by minerals – reduce efficiency and life of an equipment

Color

- Two types:
  - Apparent color: Color due to both dissolved and suspended matters.
  - True color: Color of a water sample that consists only dissolved matter (suspended material is already removed)
- Measurements:
  - Visual comparison method (dilution)
  - Spectrometric method (light transmission)

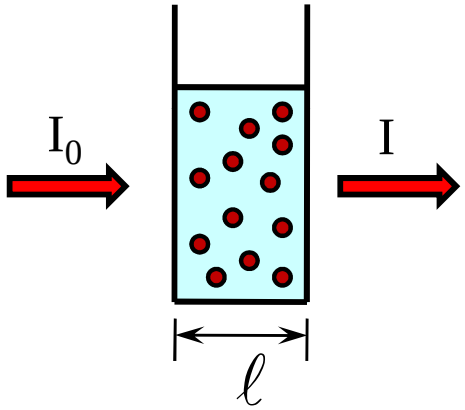


Most commonly used

Principles of Spectrometric Method

- Beers-Lambert Law

$$A = \log \frac{I_0}{I} = \varepsilon c \ell$$



where

A = absorbance, unit/cm

I_0 = intensity of light entering the solution

I = intensity of light leaving the solution

ε = molar absorptivity, mol^{-1} L cm^{-1}

c = concentration, mol L^{-1}

ℓ = length of absorbing layer, cm

Taste & Odor

- Taste reflects inorganic constituents and odor reflects organic constituents
- Temperature and pH can affect taste
- Sources:
  - Specific metals (Fe, Cu, Mn, Zn) - Taste
  - $MgSO_4$ and $CaCO_3$ - Taste

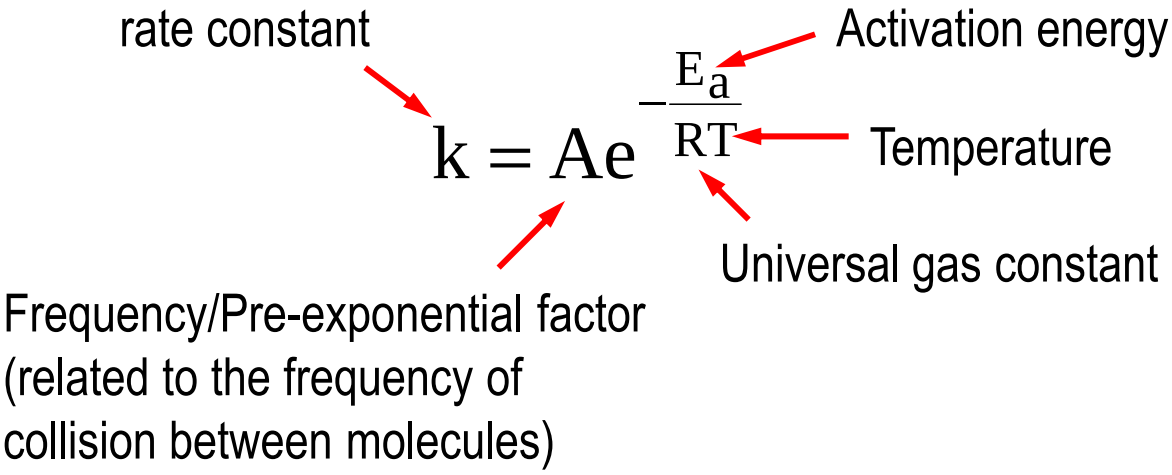
  } **Inorganic compounds**
  - Chlorine (when reacts with organic compounds especially phenols), monochloramine – Taste & Odor
  - Microorganisms (Geosmin, 2-methylisoborneol (MIB), hydrogen sulfide normally happen in distribution system) – Taste & Odor
  - Organic compounds from petroleum and/or degradation of organic matter
- Effects:
  - Aesthetics
  - Some are toxic at elevated concentrations (e.g. H_2S, reaction from sources and other chemicals such as chlorine)
  - Produce psychological stress (poor appetite for food, lower water consumption, nausea and vomitting)
  - Impaired respiration

Temperature

- The most common physical assessment of a water quality
- Sources:
  - Warmer water discharge into the environment → thermal pollution (normally by industrial boilers)
  - Absorption of heat from sunlight by sediments in water (Erosion)
- Effects:
  - Affect chemical reactions and properties (e.g. gas solubility, density and viscosity)
  - Disturb biological (microorganisms and aquatic life) activities (↓ temperature, ↓ biological activity)

Temperature

- The relationship between rate constant and temperature is represented by Arrhenius equation



- Rate constant, k, will change with temperature but activation energy does not. The increase of **10°C** will **double** the k.

Conductivity

- Measurement of the ability of a solution to conduct an electrical current
- Dependent on the concentration and mobility of ions (↑ ion concentration, ↑ conductivity)
- Can be used as a surrogate measure of total dissolved solids (TDS) concentration.

$$\mathrm{TDS} \cong \mathrm{EC}\,(\mu\mathrm{mho/cm}) \times (0.55 - 0.90)$$

- Unit: millisiemens per meter (mS/m), micromhos per centimeter (µmho/cm)

Conductivity

- Electrical conductivity can be estimated if the concentration and mobility of the ions in a solution are known
- For this estimation, we need
  - concentration of the ions
  - equivalence conductance of the ions
  - ionic strength of a solution
  - activity coefficient of the ions in a solution

Ionic Strength

- Quantification of the effect of all ions in a solution
- Chemical interactions between the ions depend strongly on the ionic charge
- ↑ ionic charge, ↑ ionic strength

$$I = \frac{1}{2} \sum_{\text{all ions}} c_i z_i^2$$

where

c_i = the concentration of i in mol/L

z_i = the charge on species i (diamensionless)

Activity Coefficient

- A factor that considers the deviation of a chemical reaction from its ideal behavior.

$$\gamma = \frac{\text{Actual reactivity of a substance}}{\text{Reactivity of a substance in the standard state}}$$

- ↑ ionic charge, ↑ attraction and shielding effect, ↓ the activity coefficient
- To predict the activity coefficients, three equations used are:
  - Debye-Huckel limiting law
  - Extended Debye-Huckel
  - Davies

Activity Coefficient

- For water at 25°C,

Debye-Huckel limiting law (I<0.005 M)	$\log \gamma_{D-H} = -0.51 z^2 I^{1/2}$
Extended Debye-Huckel (I<0.1 M) Appropriate in solution where only one salt dominates the ionic strength	$\log \gamma_{\text{Ext.D-H}} = -0.51 z^2 \frac{I^{1/2}}{1 + 0.33 a I^{1/2}}$ a = ion size, Ångstroms
Davies (I<0.5 M)	$\log \gamma_{\text{Davies}} = -0.51 z^2 \left(\frac{I^{1/2}}{1 + I^{1/2}} - 0.3 I \right)$

Ionic Strength and Activity Coefficient

- Example:

Part 1

A solution contains 10^{-3} M NaCl, 10^{-3} of $NaHCO_3$ and 10^{-4} of $CaCl_2$. Calculate the

a. ionic strength

b. activity coefficient (Debye-Huckle)

of the solution.

Part 2

If NaCl concentration becomes 0.1 M, what changes do you observe in the ionic strength and activity coefficient?

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