Water Quality Parameters

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Water Quality

Q: When is dirty water?

Answer: of course depends on what we mean by dirty.

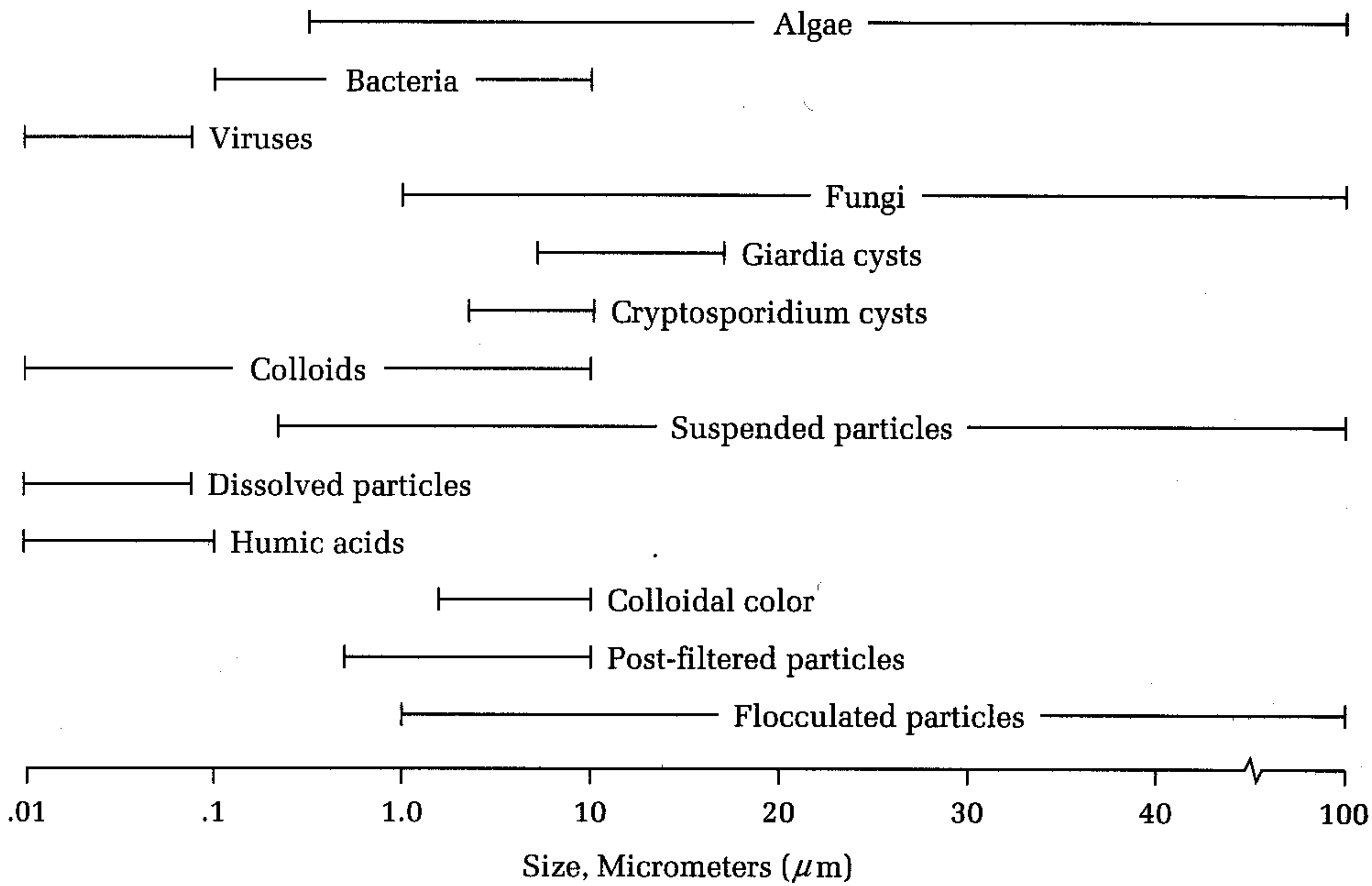
Water Quality Parameters

- **Physical**
- **Chemical**
- **Biological**
- **Radiological**

Physical Parameters

1. **Suspended solids (big particles)**
2. **Turbidity (tiny particles)**
3. **Odor and Taste**
4. **Color**
5. **Temperature**

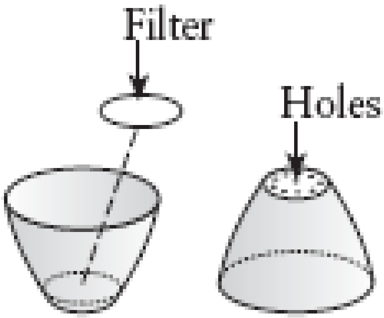
Sizes of Particles in Water



Solids by Size

Classification	Diameter (mm)
Dissolved	< 0.000 001
Colloidal	0.000 001 – 0.001
Suspended	0.001 -0.1
Particulate	> 0.1

SS Separation from Water



Imhoff cone

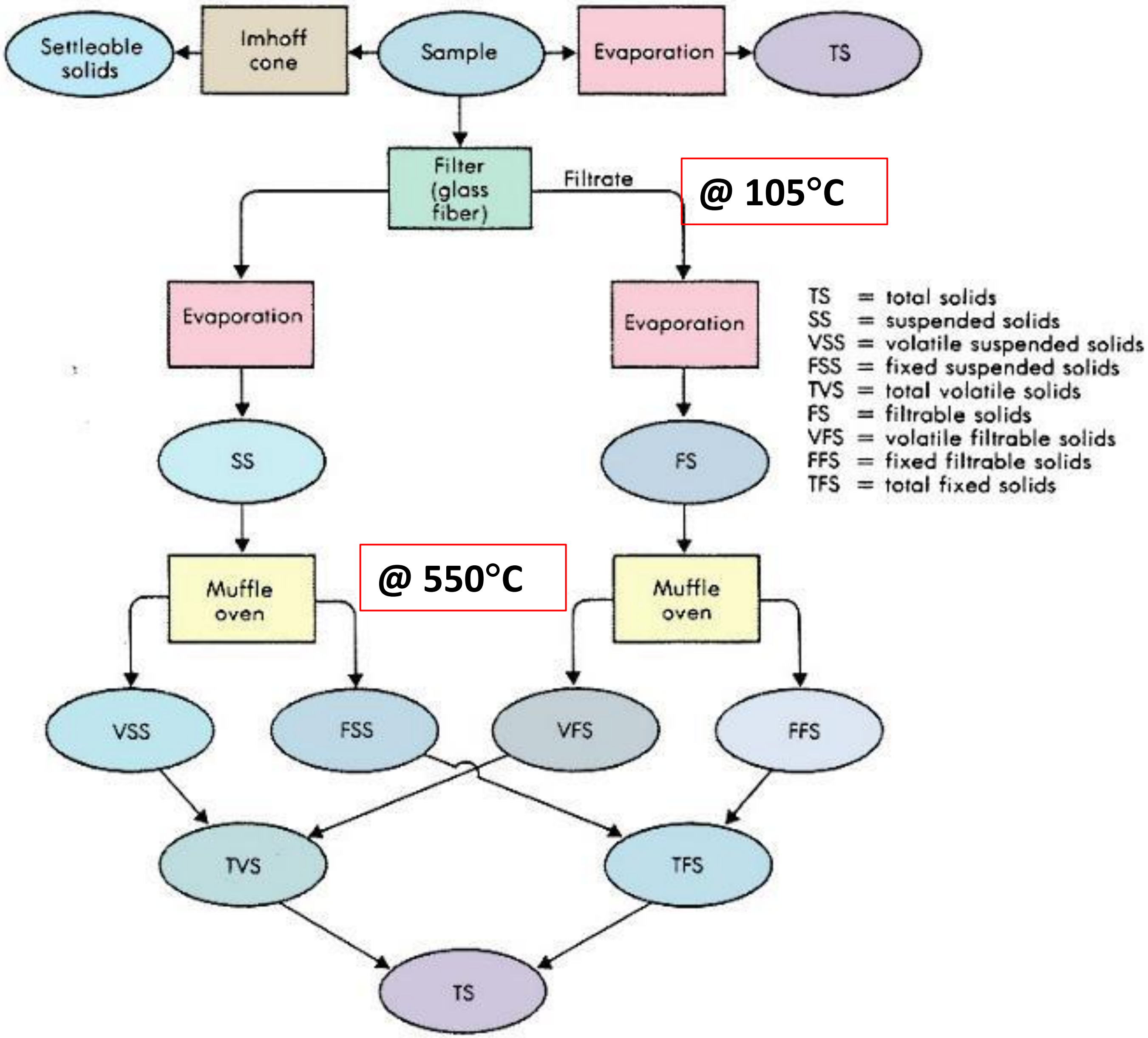


FIGURE 2.7

Interrelationships of solids found in water and wastewater. In much of the water quality literature, the solids passing through the filter are called dissolved solids.

TS & SS

$$TS = \frac{W_{ds} - W_d}{V} \times 10^6$$

where,

TS = total solids, mg/L
W_{ds} = weight of dish plus the dry solids after evaporation, g
W_d = weight of the clean dish, g
V = volume of sample, mL

$$SS = \frac{W_{df} - W_d}{V} \times 10^6$$

where,

SS = suspended solids, mg/L
W_{df} = weight of dish plus dry filtered solids, g
W_d = weight of clean crucible and filter, g
V = volume of sample, mL

- **Total solids =** ***dissolved solids*** + ***suspended solids***.

- A ***Gooch crucible*** is used to separate suspended solids from dissolved solids

Solids: FS & VS

$$FS = \frac{W_{du} - W_d}{V} \times 10^6$$

Where,

FS = fixed solids, mg/L
W_{du} = weight of dish plus unburned solids, g
W_d = weight of clean crucible and filter, g
V = volume of sample, mL.

$$VS = TS - FS$$

Where,

VS = volatile solids, mg/L.

Although volatile solids are considered to be organic, some of the inorganics are decomposed and volatilized as well at the 550°C - 600°C used for the test. However, this is not considered a serious drawback.

Turbidity

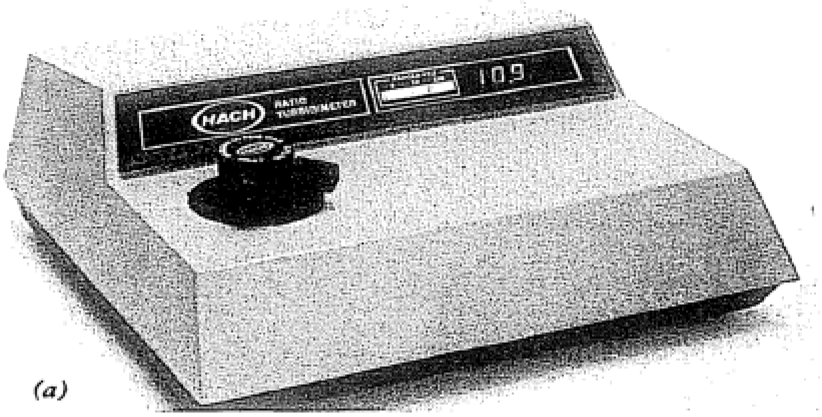
- It is the muddy or cloudy appearance of clay or such other particles that presents hindrance to the path of light .

- The turbidity is measured by a turbidity rod or a turbidity meter with physical observations and is expressed as the suspended matter in mg/l or ppm (part per million).

- Colloids, clay, silt, tiny fragments of organic matter and microscopic organisms (bacteria, algae) are some of the substances that cause turbidity.

Units of turbidity

- The standard unit of turbidity is that which is produced by 1 mg of finely divided silica in one liter of distilled water
- The interference in the passage of light caused by a suspension of 1 mg/l of silica is equivalent to one **turbidity units** (TU).



(a)

Measurement methods:

Nephelometers (NTU),
Jackson candle turbidimeter (JTU)

Taste and Odor

- A physical characteristics of drinking water that is important for aesthetic reasons.
- The dissolved inorganic salts or organic matter or the dissolved gases may impart taste and odor to the water.
- Inorganics (e.g. soil components) are usually odorless and may only be responsible for taste.
- T & O are most commonly caused by: algae, decomposed organic matter, and dissolved gases.
- Oxidants (Chlorine, potassium permanganate) are used to oxidize the materials causing the taste and odor. Or Activated carbon filters can be used.

T & O measurement

- The extent of taste or odor is measured by a term called **odor intensity** which is related with threshold odor, which represents the dilution ratio at which the odor is hardly detectible.

- The water to be tested is gradually diluted with odor free water and the mixture at which the detection of taste and odor is *just lost* is determined.

- The odor is measured (by human nose) and expressed in terms of a **threshold odor number** (TON)= (Vt+Vd)/Vt.

Vt: volume tested, Vd: volume added.

TON=1 is the lowest value possible.

Example: 50 ml is diluted to vol. of 200 ml. The dilution no. equals 200/50 = 4 = TON

Color

- It is a physical characteristic of drinking water that are important for aesthetic reasons.

- It may be caused by dissolved (*true color*) or suspended colloidal particles (*apparent color*) or by dissolved organic matters from decaying vegetation.

- It is measured in the labs by Nessler's tubes by comparing the sample with the known color intensities. More precisely tintometer measures it.

- One color unit is equivalent to the color produced by a 1 mg/l solution of platinum.

Temperature

- Warm water tastes flat.
- Cooling water suppresses odors and tastes and makes it more palatable.
- Temperature also affects the chlorination and purification of water.
- Disinfection takes longer when water is colder, and purification capacity is reduced with reverse osmosis treatment equipment.
- An average temperature of 15°C is generally suitable.

Chemical Parameters

1. Total dissolved solids:

- Hardness
- Alkalinity
- Fluoride
- Metal ions
- Organics
- Nutrients

Hardness

- **Hardness** is caused by multivalent cations (or minerals)—such as calcium, magnesium, and iron—that dissolve from soil and rocks (particularly limestone).

➢ While hardness does not cause health problems, it does reduce the effectiveness of soaps, and cause scale formation especially in heat transfer equipment.

- **Total hardness (TH)** is defined as the sum of the multivalent cations in the water. Mainly, Calcium (Ca^{2+}) and Magnesium (Mg^{2+}).

$$\mathrm{TH} = \sum (\text{Multivalent cations}) \cong \mathrm{Ca}^{2+} + \mathrm{Mg}^{2+}$$

➢ Typical units for hardness are mg/L as $CaCO_3$ and meq/L

Hardness Classification

Hardness

- Soft < 50 mg/L
- Moderate = 50 -150 mg/L
- Hard = 150 -300 mg/L
- Very Hard > 300 mg/L

➢ Treatment usually left to consumer (domestic, industrial, etc.) depending on needs

Hardness Classification

Classification	Hardness: meq/L	Hardness: mg/L as $CaCO_3$
Extremely soft to soft	0–0.9	0–45
Soft to moderately hard	0.9–1.8	46–90
Moderately hard to hard	1.8–2.6	91–130
Hard to very hard	2.6–3.4	131–170
Very hard to excessively hard	3.4–5	171–250
Too hard for ordinary domestic use	>5	>250

Source: L.A. Lipe and M. D. Curry, "Ion Exchange Water Softening," a discussion for water treatment plant operators, 1974–75 seminar series sponsored by Illinois Environmental Protection Agency.

Hardness Calculations

$$C_q = \frac{C}{\text{EW}}$$

where C_q = concentration in meq/L
C = concentration in mg/L
EW = equivalent weight in g/eq or mg/meq

$$\text{EW} = \frac{\text{AW or MW}}{n}$$

where, atomic weight (AW) and molecular weight (MW), valence or ionic charge (n, which is always positive):

To convert to the standard unit mg/L as $CaCO_3$, the meq/L concentration is multiplied by the equivalent weight of $CaCO_3$, which is 50.0 mg/meq (100 g/mol/ 2 eq/mol):

$$\boldsymbol{C_{CaCO3} = C_q \times 50.0}$$

where C_{CaCO3} = concentration in mg/L as CaCO3
C_q = concentration in meq/L

Example

Problem The concentration of calcium in a water sample is 100 mg/L. What is the concentration in (a) meq/L and (b) mg/L as $CaCO_3$?

Solution The valence or ionic charge of calcium is +2, so n is 2 eq/mol. Calcium's atomic weight is 40.1 g/mol. Therefore, its equivalent weight is (Equation 10.5):

$$EW = \frac{AW}{n} = \frac{40.1 \text{ g/mol}}{2 \text{ eq/mol}} = 20.0 \text{ g/eq} = 20.0 \text{ mg/meq}$$

a. The concentration in meq/L is then simply obtained through unit conversion (Equation 10.4):

$$C_q = \frac{C}{EW} = \frac{100 \text{ mg/L}}{20.0 \text{ mg/meq}} = 5.0 \text{ meq/L}$$

b. Again, the concentration in mg/L as $CaCO_3$ is simply obtained through unit conversion (Equation 10.6):

$$\begin{aligned} C_{CaCO_3} &= C_q \times 50 \\ &= (5.0 \text{ meq/L})(50 \text{ mg/meq}) \\ &= 250 \text{ mg/L as } CaCO_3 \end{aligned}$$

Note that the *correct* unit includes "as $CaCO_3$."

Alkalinity

- **Alkalinity** is a measure of the buffering capacity of water (or the capacity of the water to neutralize acid, or H^+).

- It is not the same as pH; water does not have to be basic to have high alkalinity.

- The natural sources of alkalinity in water are the **atmosphere** and **limestone**.

  - Atmospheric carbon dioxide dissolved in water forms carbonic acid (H_2CO_3), which can dissociate into bicarbonate (HCO_3^-) and carbonate (CO_3^{-2}).
  - Limestone formations ($CaCO_3$) can also dissolve in water and produce HCO_3^- and CO_3^{-2}. Both HCO_3^- and CO_3^{-2} can "grab" (or neutralize) H^+ that is added to the water. Notice that carbonate can grab two H^+ while bicarbonate can grab only one.

Alkalinity Calculations (mol/L)

$$\text{Alkalinity (mol/L)} = \left(\frac{\text{mol } HCO_3^-}{\text{L}}\right)\left(\frac{1 \text{ mol ALK}}{\text{mol } HCO_3^-}\right)$$
$$+ \left(\frac{\text{mol } CO_3^{2-}}{\text{L}}\right)\left(\frac{2 \text{ mol ALK}}{\text{mol } CO_3^{2-}}\right)$$
$$+ \left(\frac{\text{mol } OH^-}{\text{L}}\right)\left(\frac{1 \text{ mol ALK}}{\text{mol } OH^-}\right)$$
$$- \left(\frac{\text{mol } H^+}{\text{L}}\right)\left(\frac{1 \text{ mol ALK}}{\text{mol } H^+}\right)$$

or simply

$$\text{Alkalinity (mol/L)} = [HCO_3^-] + 2[CO_3^{2-}] + [OH^-] - [H^+]$$

Alkalinity Calculations (meq/L)

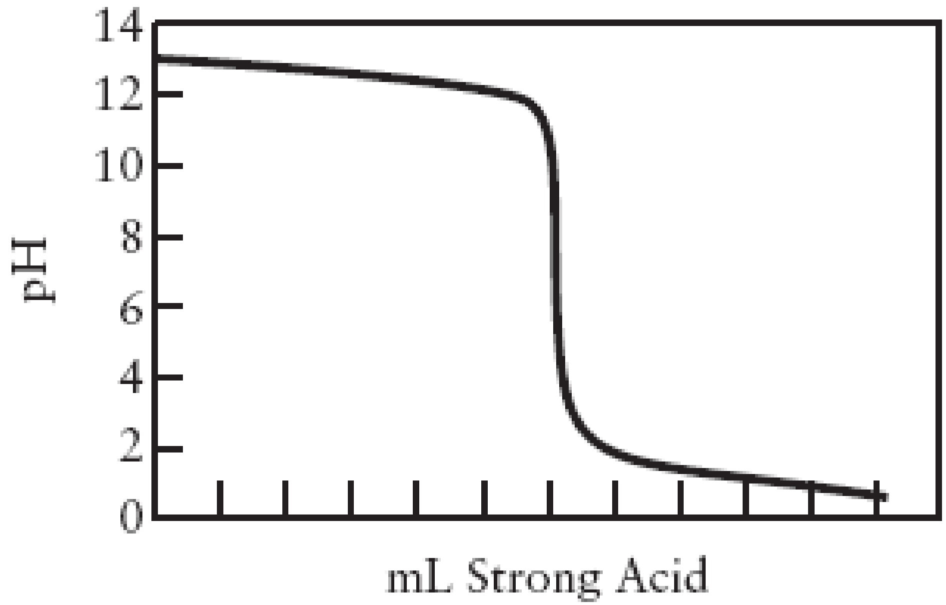
$$CO_3^{2-}\ (\text{eq/L}) = \left(\frac{\text{mol } CO_3^{2-}}{\text{L}}\right)\left(\frac{2\text{ eq}}{\text{mol}}\right)$$

$$\begin{aligned}\text{Alkalinity (meq/L)} &= \left(\frac{1\text{ meq } HCO_3^-}{\text{L}}\right)\left(\frac{1\text{ meq ALK}}{\text{meq } HCO_3^-}\right)\\ &+ \left(\frac{1\text{ meq } CO_3^{2-}}{\text{L}}\right)\left(\frac{1\text{ meq ALK}}{\text{meq } CO_3^{2-}}\right)\\ &+ \left(\frac{1\text{ meq } OH^-}{\text{L}}\right)\left(\frac{1\text{ meq ALK}}{\text{meq } OH^-}\right)\\ &- \left(\frac{1\text{ meq } H^+}{\text{L}}\right)\left(\frac{1\text{ meq ALK}}{\text{meq } H^+}\right)\end{aligned}$$

or simply

$$\text{Alkalinity (meq/L)} = (HCO_3^-) + (CO_3^{2-}) + (OH^-) - (H^+)$$

Alkalinity: Titration curve



At pH less than 7.3, the carbonate concentration is much less than the bicarbonate concentration, and around neutral pH, [H+] ≈ [OH−]. Therefore, for most potable water sources:

$$\text{Alkalinity} \cong (HCO_3^-)$$

Carbonate hardness & Noncarbonate hardness

TH = carbonate hardness (**CH**) + noncarbonate hardness (**NCH**)

- Carbonate hardness is the component of total hardness associated with the anions carbonate (CO_3^{-2}) and bicarbonate (HCO_3^{-});
- Carbonate hardness (total alkalinity) is a temporary hardness that is removed by heat.
- Noncarbonate hardness is equal to the difference between total hardness and carbonate hardness;
- If the alkalinity is equal to or greater than the total hardness, then the noncarbonate hardness is zero.

Example

Problem From the following water analysis, determine the total hardness, carbonate hardness, and noncarbonate hardness in (a) milliequivalents per liter (meq/L) and (b) milligrams per liter (mg/L) as $CaCO_3$.

Component	Concentration (mg/L)
CO_2	6.0
Ca^{2+}	50.0
Mg^{2+}	20.0
Na^{+}	5.0
Alkalinity	120 as $CaCO_3$
SO_4^{2-}	94.0
pH	7.3

Component	EW (mg/meq)	Concentration		
		mg/L	meq/L	mg/L as $CaCO_3$
Ca^{2+}	20.0	50	2.5	125
Mg^{2+}	12.2	20	1.6	82
Alkalinity	50.0	120	2.4	120

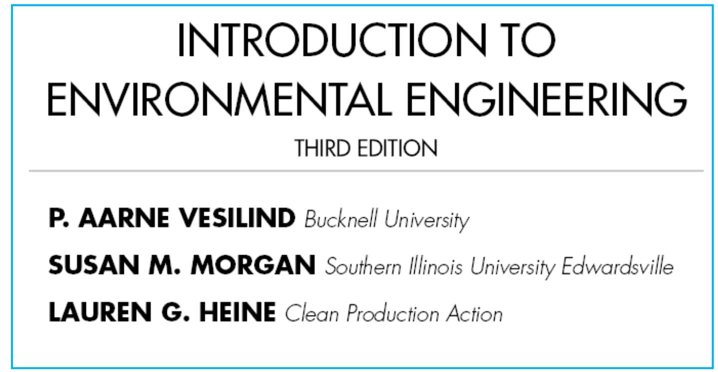
$$TH = (2.5 \text{ meq/L}) + (1.6 \text{ meq/L}) = 4.1 \text{ meq/L}$$

or

$$TH = (125 \text{ mg/L as } CaCO_3) + (82 \text{ mg/L as } CaCO_3) = 207 \text{ mg/L as } CaCO_3$$

Examples

- Ex 10.4
- Ex 10.5
- Ex10.6



INTRODUCTION TO
ENVIRONMENTAL ENGINEERING
THIRD EDITION

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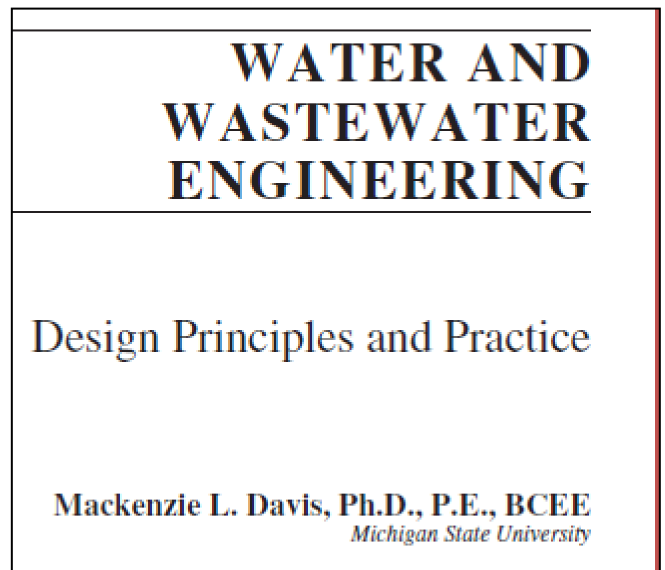
LAUREN G. HEINE *Clean Production Action*

- All Examples in Chapter 7



WATER AND WASTEWATER ENGINEERING

Design Principles and Practice

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Biological Parameters

Microorganisms:

- Bacteria
- Protozoa
- Parasitic Worms
- Viruses
- Algae
- Fungi
- **Pollution indicators:** Coliform bacteria

Microorganisms

- ✓ Looking for pathogens in most surface waters is a perfect example of the proverbial needle in a haystack!

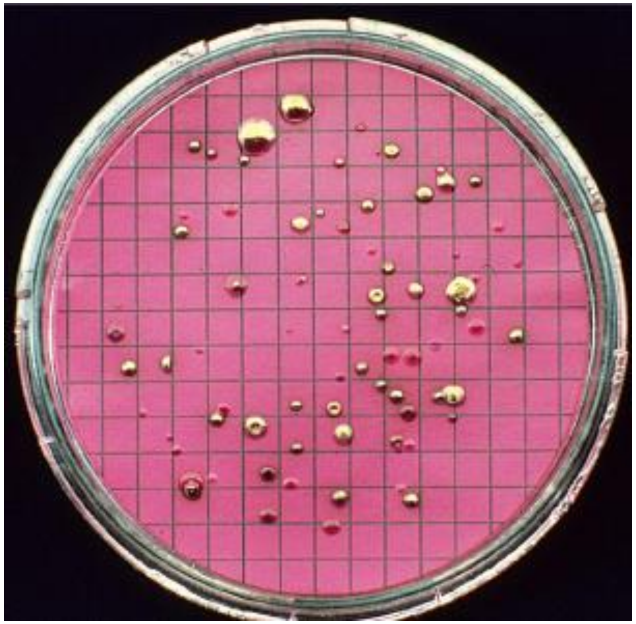
- E. coli used as an indicator of water quality: normal inhabitant of intestines of many animals

- *Indicator organisms*: the indicator most often used is a group of microbes called coliforms (which includes the 150 strains of *E. coli*).

Coliform test:

- Membrane filtration and 24 or 48 hours of incubation.
- Results reported as Most Probable Number (MPN) per 100 mL
- Incubation at moderate temperature (35°C) for 48 hr

A fecal coliform bacteria test is used to indicate the likely presence of disease-causing bacteria in water.



- ✓ a high coliform count is suspicious, and although the water may in fact be perfectly safe to drink, it should not be consumed.
- ✓ The opposite is also true!

Radiological Parameters

Radioactive substances

Primary MCLs

Disinfection By-Products (interim)			
Total trihalomethanes	0.10		

Radionuclides			
Radium 226	20 pCi/L	Beta particle and photon radioactivity	4 mrem/yr
Radium 228	20 pCi/L	Radon	300 pCi/L
Gross alpha particle activity	15 pCi/L	Uranium	20 μg/L

- The *rem*, or roentgen equivalent man, takes into account the biological effect of absorbed nuclear radiation, so it measures the extent of biological injury.
- One Sv is numerically equal to 100 rem.
- pCi/L (pico Curies of radon per liter of air)

HW

10.19

10.20

10.21