CornellEngineering
Civil and Environmental Engineering

CEE 4540

Sustainable municipal drinking water treatment

Instruction: YuJung Chang
YuJung.Chang@cornell.edu

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Water Quality Regulations

Primacy Enforcement Responsibility for Public Water Systems

- The Safe Drinking Water Act (SDWA) requires EPA to establish and enforce standards that public drinking water systems must follow, including:
- Maximum contaminant levels (MCLs) and Best Available Technologies are recommended for water treatment
- Stipulates monitoring and reporting requirements
- EPA delegates primary enforcement responsibility (also called primacy) for public water systems to states and Indian Tribes if they meet certain requirements. EPA recently released revisions to the primacy requirements.

USEPA Primary & Secondary Drinking Water MCLs
https://www.epa.gov/dwstandardsregulations

EPA Website

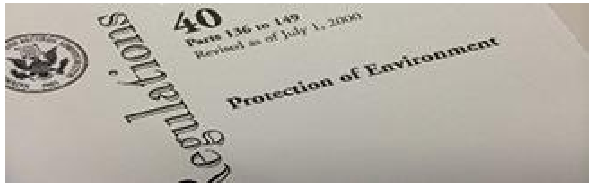
Drinking Water Contaminants – Standards and Regulations

EPA identifies contaminants to regulate in drinking water to protect public health. The Agency sets regulatory limits for the amounts of certain contaminants in water provided by public water systems. These contaminant standards are required by the Safe Drinking Water Act (SDWA). EPA works with states, tribes, and many other partners to implement these SDWA provisions.

Regulated Contaminants

- National Primary Drinking Water Regulations (NPDWRs) - table of contaminants
- Secondary drinking water standards
- Drinking water requirements for states and public water systems

Developing and Reviewing Standards



- Regulation development process
- Regulations under development or review
- Six-year review of drinking water standards

Related Information

- Background on drinking water standards
- Community water system survey
- CCR annual water quality reports of water systems
- Drinking water distribution systems
- Ground water and drinking water home page
- Health effects information for contaminants
- Optimization program for water systems
- Private well information

Goals for Drinking Water Treatment: Provide safe & affordable drinking water to the public

- Requires health impact studies
- Economic analyses on potential cost impacts
- Solicit public comments
- Set the standards that meet both goals

Drinking Water Quality Requirements for Public Health

- US Environmental Protection Agency (USEPA) set water quality standards based on impacts to public health and cost implications
- Primary Maximum Contaminant Level (MCL) is enforceable
- Secondary MCL is “recommended” but not enforceable; but most utilities follow the guidance
- State can institute more stringent MCLs
- When microbial contaminants exceed standards a Boil-Water Advisory/Order will be issued

Steps of Drinking Water Treatment Process Design

- Analyze raw water quality data
  - Historical long-term water quality monitoring
- Identify Water Treatment Goals
  - Current regulated contaminants
  - Esthetics requirements
  - Emerging contaminants (e.g., endocrine disruptors; PFAS, TCP, etc.)
- Identify feasible treatment technologies
- Perform Pros & Cons analyses for identified options
- Perform bench scale testing & pilot testing for verification
- Select treatment train
- Select equipment
- Detail design

Design Project: 40 MGD Green Field Drinking Water Plant

– Project Location: Northern California (Stanislaus Regional Water Supply, SRWS)

- Stanislaus County
- East Stanislaus Regional Water Management
- Turlock Irrigation Distrtict

Project Background

- Currently using groundwater supply
- Needs to expand treatment capacity to support population growth
- Client wants a “reliable and simple process” (a “Chevy” version) rather than a “Mercedes”
- Client will hire an operation company to operate plant for the first 2 – 3 years

General Water Quality Characteristics

Parameters		Max	Min	Average	Median
Alkalinity, total	mg/L $CaCO_3$	36	11	19.158	20
Bromide	µg/L	26	5	7.438	5
Calcium	mg/L	5.9	2.7	4.340	4.5
Color	ACU	50	5	18.000	10
Dissolved Oxygen (DO)	mg/L	11.67	7.66	10.243	10.325
Iron, Total	mg/L	1.4	0.032	0.361	0.24
Iron, Dissolved	mg/L	0.16	0.02	0.052	0.041
Magnesium	mg/L	2.6	0.97	1.674	1.6
Manganese, Dissolved	µg/L	14	2	4.080	2.15
Manganese, Total	µg/L	210	2	27.850	15
Nitrate (mg/L as NO3)	mg/L as NO3	2.3	0.44	1.105	0.77
Nitrite (as N)	mg/L as N	0.05	0.05	0.050	0.05
Odor-Threshold	TON	2	2	2.000	2
Organic Carbon, Dissolved (DOC)	mg/L	4	1.89	2.366	2.16
Organic Carbon, Total (TOC)	mg/L	4.2	1.92	2.419	2.23
pH	pH units	7.4	7.1	7.274	7.3
Total Dissolved Solids (TDS)	mg/L	54	25	38.000	36
Total Suspended Solids (TSS)	mg/L	10	10	10.000	10
Turbidity	NTU	25.6	0.59	4.549	2.82
UV-254, Dissolved	cm-1	0.1163	0.0408	0.064	0.061
UVT (from filtered UV-254)	%	100	0.7650679	61.352	86.297855

Inorganic Contaminants with a Primary or Secondary MCL

Parameters		Max	Min	Average	Median
Arsenic	µg/L	1.3	1	1.060	1
Chromium (Total)	µg/L	2.9	1	1.380	1
Chromium-6 (Hexavalent)	µg/L	0.052	0.028	0.038	0.036
Copper	µg/L	2.8	2	2.160	2
Cyanide	mg/L	0.025	0.025	0.025	0.025
Fluoride	mg/L	0.05	0.05	0.050	0.05
Lead	µg/L	0.5	0.5	0.500	0.5
Mercury (inorganic)	µg/L	0.2	0.2	0.200	0.2
Nickel	µg/L	5	5	5.000	5
Perchlorate	µg/L	4	4	4.000	4
Zinc	µg/L	29	20	21.800	20

Organic Contaminants with a Primary or Secondary MCL

Parameters		Max	Min	Average	Median
1,2,4-Trichlorobenzene	ug/L	0.5	0.5	0.500	0.5
1,2-Dichlorobenzene	ug/L	0.5	0.5	0.500	0.5
1,2-Dichloroethane (1,2-DCA)	ug/L	0.5	0.5	0.500	0.5
1,4-Dichlorobenzene (p-DCB)	ug/L	0.5	0.5	0.500	0.5
2,4,5-TP (Silvex)	ug/L	0.2	0.2	0.200	0.2
Alachlor	ug/L	0.05	0.05	0.050	0.05
Atrazine	ug/L	0.05	0.05	0.050	0.05
Benzene	ug/L	0.5	0.5	0.500	0.5
Carbofuran (Furadan)	ug/L	0.5	0.1	0.167	0.1
Methyl tert butyl ether (MTBE)	ug/L	0.5	0.5	0.500	0.5
Monochlorobenzene (Chlorobenzene)	ug/L	0.5	0.5	0.500	0.5
Polychlorinated Biphenyls (PCBs)	ug/L	0.1	0.1	0.100	0.1
Tetrachloroethylene (PCE)	ug/L	0.5	0.05	0.140	0.05
Toluene	ug/L	0.5	0.5	0.500	0.5
Trichloroethylene (TCE)	ug/L	0.5	0.5	0.500	0.5

Disinfection By-Products & Microbiological MCL

Disinfection By-Products	Unit	Max	Min	Average	Median
Bromate	µg/L	1	1	1.000	1
Chlorite	mg/L	0.01	0.01	0.010	0.01
Total HAA5	µg/L	2	2	2.000	2
Total THMs	µg/L	0.5	0.5	0.500	0.5
NDMA	ng/L	2	2	2.000	2

Microbiological Contaminants	Unit	Max	Min	Average	Median
Fecal Coliform & E. coli	MPN/100 mL	630	4.1	69.871	31
Cryptosporidium*	oocysts/L	0.1	0	0.018	0
Giardia*	cysts/L	0.4	0	0.083	0.093

* Refer to Long-Term 2 Enhanced Surface Water Treatment Rules

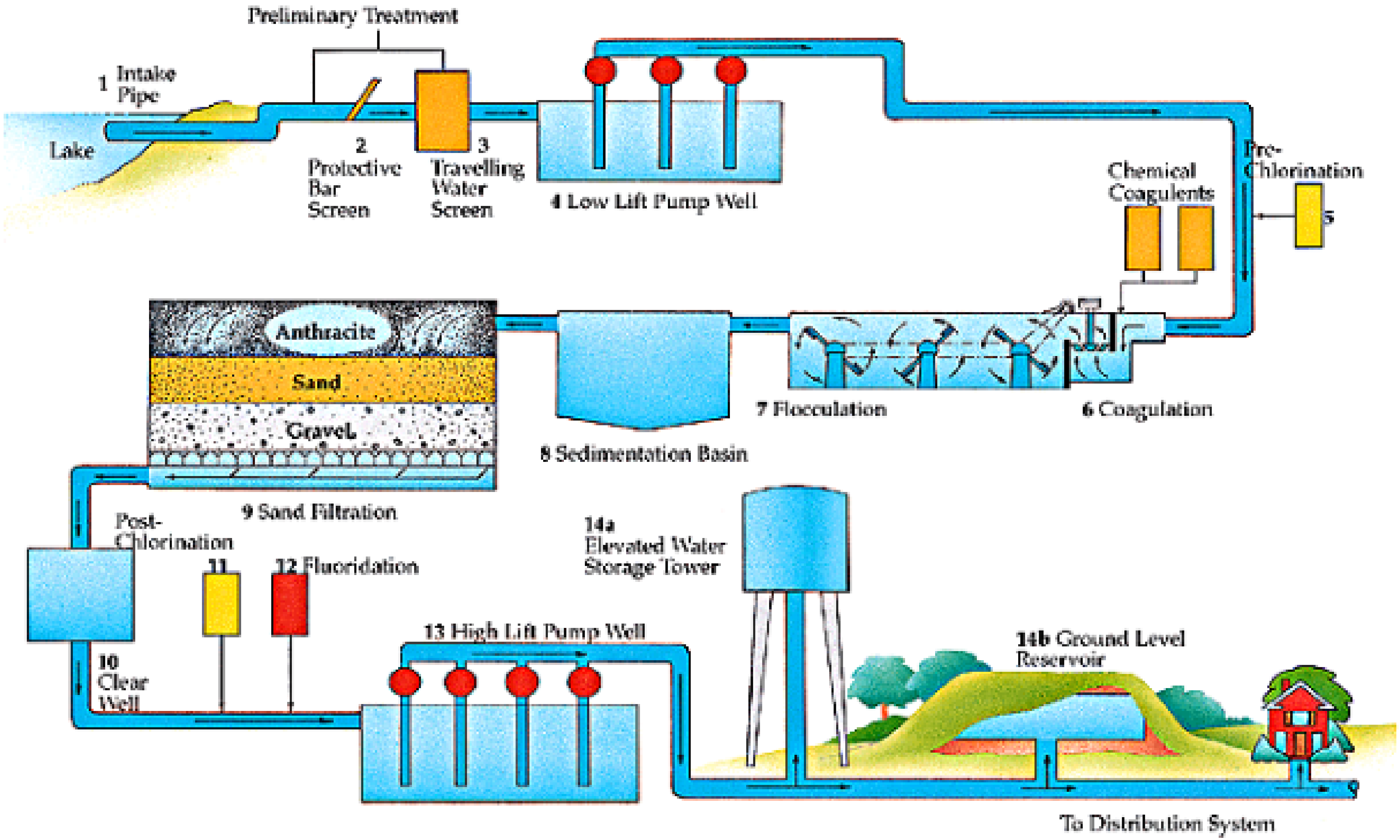
Algae Related Water Quality Parameters (No MCL)

Algae Related Water Quality	Unit	Max	Min	Average	Median
Algae Enumeration	#/mL	42	24	33.000	33
Chlorophyll A	mg/m3	2.1	1	1.300	1.05
Cyanotoxins (Anatoxin, Cylindrospermopsin)	ug/L	0.02	0.02	0.020	0.02
Cyanotoxins (Microcystins, Nodularin)	ug/L	0.1	0.1	0.100	0.1
Microcystins Screen	ng/L	0.1	0.1	0.100	0.1

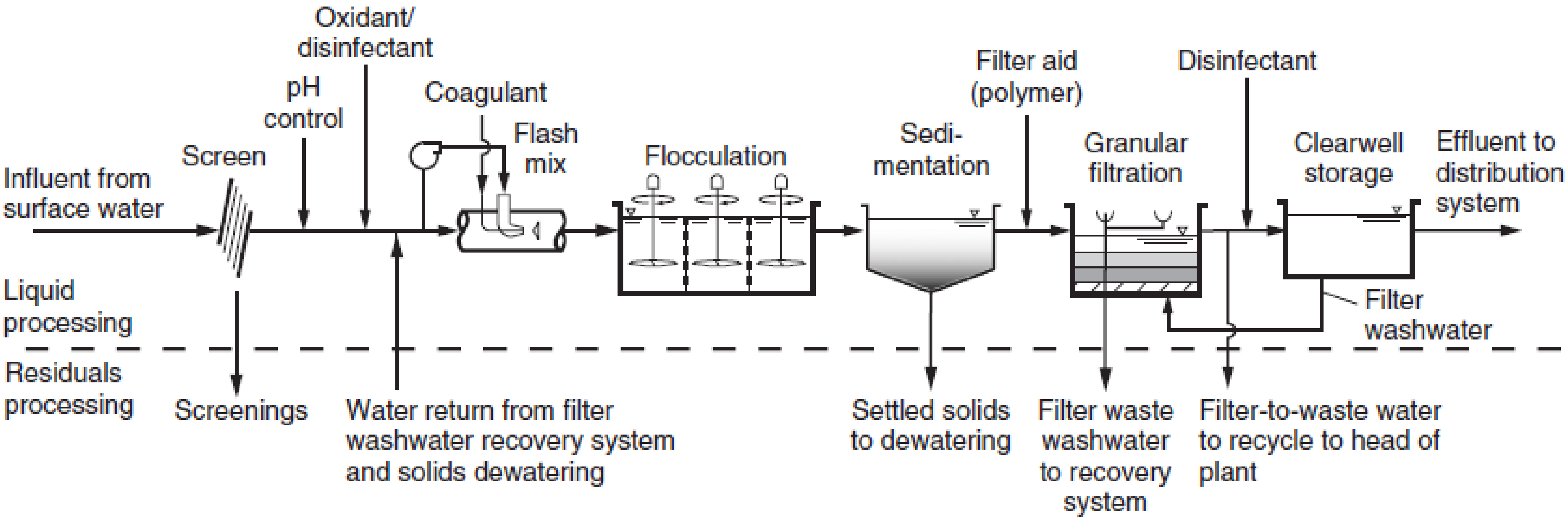
Design Project End Product

- A Process Flow Diagram (PFD) with the following elements:
  - Key unit treatment processes (from intake structure to final product pump station
  - Direction of flow
  - Flowrate to and from each treatment process
  - Chemicals to be added at appropriate locations
- A Design Report with the following elements
  - Basis of Design: Description and justification for unit processes selected
  - Calculation of Chemical dosage required (with reasonable assumptions)
  - Quantity of final waste generated

Example of WTP PFD



Example of PFD from Textbook



Basis of Design

- Treatment objectives
  - Regulations (current and/future)
  - Meeting customers’ expectation
- Reasons for the selection of each treatment unit process
  - Reliability
  - Ease of operation
  - Cost efficiency
  - Other
- Redundancy
  - How many treatment trains will be included

Chemical Dosage Requirements

– Type of Chemicals and justifications (e.g., different types of coagulants)

– Water chemistry (e.g., pH, temperature)

– Safety factor (worst case scenario); making assumptions if needed

Quantity of Final Waste Produced

- Liquid Waste
  - Type of liquid waste & quantity
  - Disposal option selected (require justifications)
- Solid Waste
  - Quantity
  - Disposal option selected (require justifications)

Redundancy

- Operation flexibility
  - Regular maintenance
  - Emergency repair
- Cost considerations
  - Treatment train redundancy
  - Key unit process redundancy
- Risk assessments
  - Balance between cost & reliability
  - Justify your decision

Chemical Concentration Expressions

- Most common term used in water treatment plants: mg/L
  - Easy to calculate & understood by operators
  - Doesn’t tell the story of water chemistry
- Concentration units used in R&D
  - Molarity
  - Normality
  - Molar Fraction

Molarity: Chemical Reaction with Mass Balance

Determine the molarity and the mole fraction of a 1-L solution containing 20 g sodium chloride (NaCl) at 20°C. From the periodic table and reference books, it can be found that the molar mass of NaCl is 58.45 g/mol and the density of a 20 g/L NaCl solution is 1.0125 kg/L.

Solution

1. The molarity of the NaCl solution is computed using Eq. 2-3

$$[\mathrm{NaCl}] = \frac{20\ \mathrm{g}}{(58.45\ \mathrm{g/mol})(1.0\ \mathrm{L})} = 0.342\ \mathrm{mol/L} = 0.342\ \mathrm{M}$$

– Molarity tells the “Molecular Concentration” of chemicals in water

Normality: Chemical Reaction with Charge Balance

6. *Normality (N):*

$$N, \text{eq/L} = \frac{\text{mass of solute, g}}{(\text{equivalent weight of solute, g/eq})(\text{volume of solution, L})} \tag{2-6}$$

where

$$\text{Equivalent weight of solute, g/eq} = \frac{\text{molecular weight of solute, g/mol}}{Z, \text{eq/mol}} \tag{2-7}$$

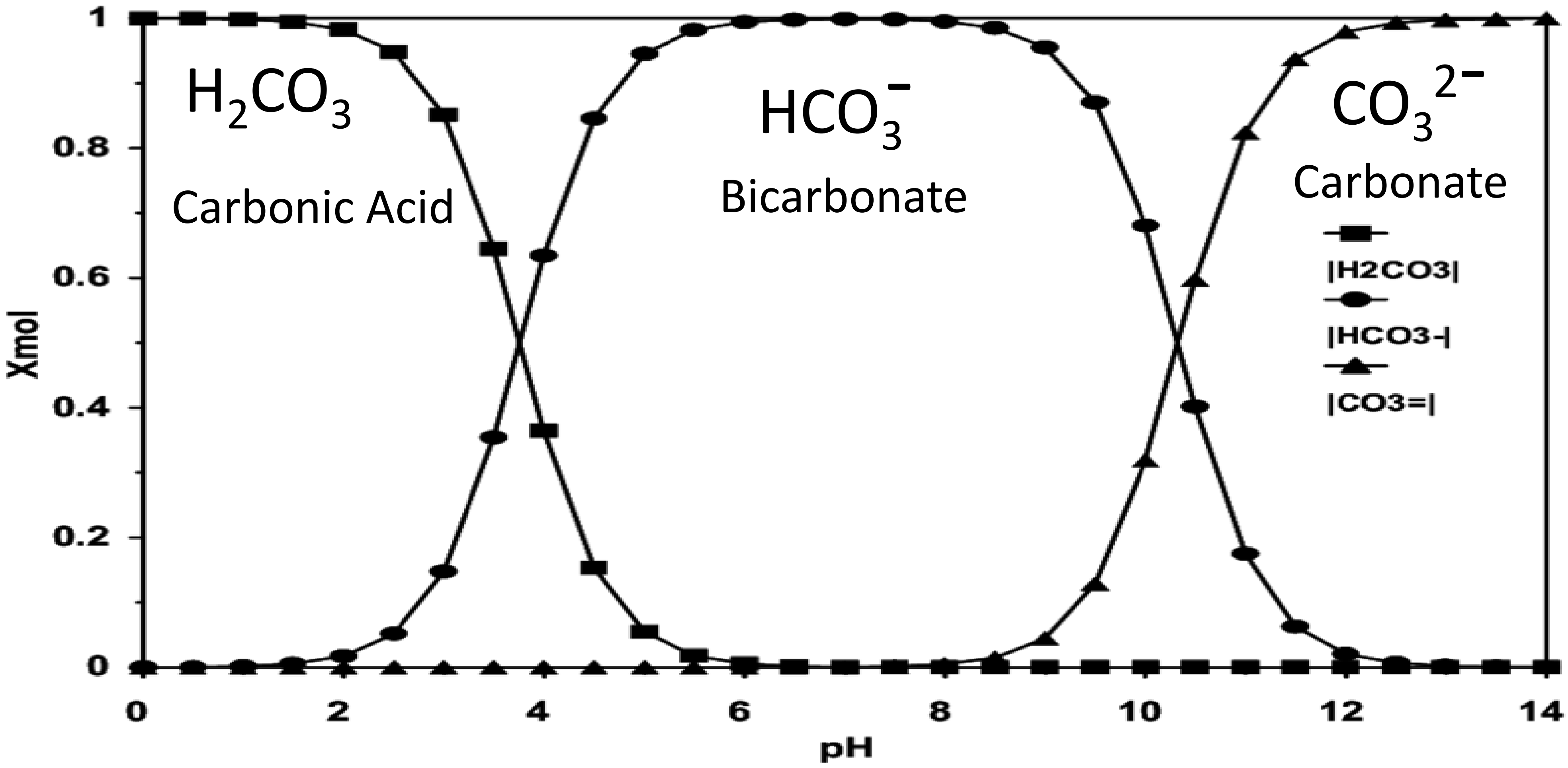
For most compounds, Z is equal to the number of replaceable hydrogen atoms or their equivalent; for oxidation–reduction reactions, Z is equal to the change in valence. Also note that $1.0\ \text{eq/m}^3 = 1.0\ \text{meq/L}$.

Importance of Normality

- Normality reflects charge density of the chemicals in the water
- All chemicals in the water will need to reach charge balance!!!!
- pH of water will shift to maintain charge balance and speciation of chemicals could change, too.

Carbonic System (CO2)

- CO2 can exist in water in 3 forms; depending on the pH of water



Mass Concentration: mg/L

5. *Mass concentration:*

$$\text{Concentration, g/m}^3 = \frac{\text{mass of solute, g}}{\text{volume of solution, m}^3}$$

Note that $1.0\,\text{g/m}^3 = 1.0\,\text{mg/L}$.

– Once you smart engineer figured out mass balance and charge balance required for the water chemistry, you provide required chemical dosages in mg/L or ppm that is easy to calculate and understood by the operators

Home Work #1

- Assign Primary or Secondary MCL to the regulated water quality parameters for the Design Project; microbial parameters can be ignored.
- Identify treatment requirements for Cryptosporidium and Giardia according to the Long-term 2 Enhanced Surface Water Treatment Rule (LT2 ESWTR)
- Problem 2-4 and 2-10 in Textbook
- Homework #1 Due on 9/04/2018 Wednesday

Reading Assignments

- Chapter 1 & Chapter 2