Course Name	: Chemistry of Natural Waters
Course No.	: CE 519
Pre-requisites	: Environmental Science, Chemistry
Intended for	: UG/M.Tech./MS/PhD
Proposed by	: Harshad V. Kulkarni, Ph.D.
Disciplines	: Civil and Environmental Engineering, Basic Sciences (Chemistry)

Course Description

The overall objective of this course is to understand the fundamental (primarily thermodynamic) controls on the composition of natural waters and the response of natural waters to variations in various physico-chemical parameters. Additionally, this course will explore applications to environmental problems like contaminants migration in waters (groundwaters, surface waters), weathering, etc. Students will learn to solve numerical problems related to the behavior of components in natural waters and gain familiarity with simple analytical techniques for the characterization of natural waters. Examples of topics covered in this course include microbial activity, surface chemistry, redox chemistry, contaminant mobilization, treatment and remediation. This course is designed for undergraduate and graduate students in the fields of civil and environmental engineering, chemistry, biogeochemistry, contaminant hydrology, geomicrobiology.

Course Outline

1. **Hydrologic Cycle (4 hours).** This chapter will focus on various components of hydrologic cycle. The chapter discusses composition of rainwater, fundamentals of hydrology, non-meteoric types of water, and chemical terminologies used in hydrology.
2. **Chemical Thermodynamics (4 hours).** This chapter introduces chemical concepts applied to hydrology, and includes topics like units and terminologies, equilibrium thermodynamics, activity-concentration relationships and diffusion.
3. **Chemical kinetics (4 hours).** This topic discusses one of the important controls on water chemistry. The topics of discussion include mineral nucleation, dissolution and growth, and uses quantitative examples like dissolution of calcite in seawater, dissolution of silicates etc.
4. **Carbonate System and pH Control (4 hours).** This chapter discusses one of the most important systems relevant to water quality. The topics of discussion include carbonic acid system, alkalinity and titration curves, calcium carbonate solubility, dolomite solubility, high-magnesium calcite solubility, ground and surface water in carbonate terrains, carbonate chemistry in oceans, and acid water chemistry.
5. **Organic Compounds in Natural Waters (4 hours).** This chapter focuses on structure of natural organic solutes, functional groups, humic substances, and dissolved organic carbon in natural environments.
6. **Redox Conditions in Natural Waters (4 hours).** This chapter will introduce fundamental ideas such as standard hydrogen electrode and thermodynamic conversions, measurement of Eh, pe-pH and Eh-pH diagrams construction and interpretation, partial pressure or fugacity diagrams and interpretation. This chapter will also discuss processes controlling redox equilibrium in natural water such as photosynthesis, respiration and decay, redox buffering, and use specific case studies of lakes, oceans, and groundwater chemistry to illustrate the concepts.
7. **Ion exchange and Sorption (4 hours).** This topic focuses on an important phenomenon of ion exchange that occurs naturally especially with clay minerals and widely used in environmental engineering applications for water and wastewater treatment. The topics of discussion include mineralogy and composition of ion exchange material, colloid properties, and retardation of

pollutant cations in groundwater. Concepts of adsorption – desorption, adsorption isotherms etc. will be discussed in the context of natural and engineered water chemistry.

8. **Weathering and Water Chemistry (5 hours).** First part of this chapter will focus on fundamental principles such as soil formation, mass balance, thermodynamic, and statistical approaches to study weathering and water chemistry. The second part of this chapter will focus on specific case studies including river and groundwater systems and their evolution in terms of water chemistry due to weathering.
9. **Surface and Groundwater Chemistry (5 hours).** This chapter will overview chemistry of surface waters including rivers, lakes, oceans, role of environmental factors affecting their chemistry, effects of climate change, and combining the ideas learnt earlier to understand and model surface water chemistry. This chapter will also overview chemistry of groundwater in variety of aquifers worldwide and controlling factors. Ideas about the sediment-water interactions will be introduced in this chapter. Various data visualization techniques will be used to interpret groundwater chemistry.
10. **Contaminants in Natural Waters (4 hours).** Many of the trace elements are of human health concern. This chapter will focus on understanding sources of trace elements (metals or metalloids), their speciation (pH and redox dependent), controls on solubility, adsorption and coprecipitation controls important for remediation, and their uptake by organisms important for bioremediation. Other topics such as organic contaminants, emerging contaminants, acid rain and drainage, eutrophication etc. and more will also be discussed in this chapter.

Textbooks / Reference Books

- Drever, J.I., 1988. The geochemistry of natural waters. Englewood Cliffs: Prentice hall.
- Baird, C. and Cann, M., 2012. Environmental Chemistry. W. H. Freeman and Company.
- Masters, G.M., 1996. Introduction to Environmental Engineering and Science. Prentice-Hall, Inc.
- Faure, G., 1991. Principles and Applications of Geochemistry. Prentice-Hall, Inc.
- D. Langmuir. Aqueous Environmental Geochemistry.
- Appelo and Postma. Geochemistry, Groundwater, and Pollution.
- Stummn and Morgan. Aquatic Chemistry.

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