University of North Carolina at Chapel Hill
ENVR 756 Physical/Chemical Processes for Water Treatment
Spring 2019

Instructor: Orlando Coronell (coronell@unc.edu, 163B Rosenau, 919-966-9010)

Meeting Time: Tu, Th 2:00-3:15 pm **Room:** McGavran-Greenberg 2303

Course website: http://coronell.web.unc.edu/teaching **Course Credits:** 3

Office Hours: Tu, Th 3:15-4:45 pm and whenever else available

Required Text: MWH's Water Treatment: Principles and Design, 3rd edition, John Wiley (2012) (Note: The 2nd edition also works)

References: Water Quality and Treatment, 5th edition, R. Letterman, Editor American Water Works Association, Denver, CO (1999)
Process Dynamics in Environmental Systems, W. J. Weber, Jr. and F. A. DiGiano, Wiley-Interscience (1996)

Course Description: This is an introductory course on physical and chemical processes used for the purification of water. The physical and/or chemical principles at work behind the processes covered are also discussed, e.g., adsorption phenomena occurring during water treatment with granular activated carbon. The course covers conventional processes such as alum coagulation and media filtration as well as advanced processes such as ion exchange and membrane filtration. The course starts with general background information on water contaminants, after which topics are taught in the order in which treatment processes are used in conventional treatment plants (i.e., coagulation, flocculation, sedimentation, filtration, disinfection, and advanced processes). While this is not a design course, basic design principles are also covered.

Target Audience: Senior undergraduate students and graduate students, either engineers or scientists, who wish to become familiar with the principles, processes and technologies applied in water purification.

Learning Objectives: Students who take ENVR 756 will: (1) become familiar with conventional and advanced physical and chemical processes used to purify water; (2) understand how physical and chemical phenomena are at work during application of water treatment technologies; (3) understand and be able to use the basic principles of design and operation of a variety of water treatment processes; (4) be able to calculate basic process parameters such as needed disinfection contact times, sizing of sedimentation basins, filter flow rates, number of membrane modules needed for treatment of a given feed flow rate, etc.

Course Format: A large portion of the course material is delivered through lectures by the instructor; however, the students are expected to do assigned readings and bring questions to the lectures. Not all material in the assigned readings is covered during the lectures. Instead, lectures focus on the most important aspects of the topics covered, on answering questions that result from reading the assigned material, and on in-class exercises that help consolidate the understanding of physico-chemical principles or process design.

Course Pre-requisites: It is highly recommended, though not required, that students have taken one of the two following courses or an equivalent course: ENVR 419-Chemical Equilibria in Natural Waters or ENVR 451-Elements of Chemical Reaction Engineering. While ENVR 419 and ENVR 451 are two entirely different courses, the instructor understands that due to the wide variety of interests within the Environmental Sciences and Engineering Department, students interested in becoming familiar with water treatment processes may not have taken both ENVR 419 and ENVR 451. Non-compliance with these pre-requisites should be discussed with the instructor.

Useful Background Concepts:

- Fundamentals of water chemistry
  - Acid-base chemistry
  - Oxidation-reduction (redox)
  - Complexation
  - Solubility
  - Others: alkalinity, charge balance, etc.
- Principles of reactor engineering
  - Plug flow reactors
  - Completely-stirred tank reactors (CSTR)
- Mass transfer principles
  - Partitioning
  - Diffusion
  - Film theory

Bring to Class: Yourself (highly recommended), paper, pen(cil), calculator, questions and a good attitude.

Student Evaluation: Student evaluation will consist of 4 quizzes, 5 homework sets, and three exams, all of which will be graded out of 100% and weighed as follows:

Exam 1:	20%
Exam 2:	20%
Exam 3:	20%
Homeworks:	20%
Quizzes:	20%

Final grades will be assigned as High Pass (H), Pass (P), Low Pass (L) or Fail (F).

Instructor Approach on Assignment of Final Grade:
Assignment of grades will occur as follows:

- H: students with a final average grade above 90%

- P: students with a final average grade between 70% and 90%
- L: students who obtain a final average grade between 50% and 70% AND this grade is at least 6 percentage points lower than the lowest P
- F: students who obtain a final average grade below 50% AND this grade is at least 6 percentage points lower than the lowest L grade

Exams Format: Exams will be in-class exams to be completed in a 75 minute period. A typical exam will consist of conceptual questions (i.e., no need for calculator to answer the question) and design/calculation questions for which formulas and a calculator will likely be required. Each the theory section and the design/calculation section will be worth *approximately* 50% of the grade of the exam.

Quizzes Format: Quizzes will consist of one or two questions to be answered in 10 minutes. Only material covered in class (unless otherwise specified in advance) will be evaluated in quizzes, i.e., the student should be able to answer the questions in the quizzes by studying from the class notes.

Honor Code: I invite the students to visit the webpage dedicated to the Honor Code of UNC-Chapel Hill students (http://honor.unc.edu/). While in these matters there is no better steering wheel than honesty and good will, the Honor Code and what is referred to as The Instrument of Student Judicial Governance (http:// http://instrument.unc.edu/) serve as a guideline to students in matters related to the good exercise of their freedom at UNC. For what directly concerns this class, students should not lie, cheat or steal and should be aware of what constitutes academic dishonesty as defined in Section IIB of The Instrument of Student Judicial Governance of which an excerpt is reproduced below (taken from http://instrument.unc.edu/instrument.text.html#academicdishonesty):

"…**(Section II)B. Academic Dishonesty.**

…

> 1. **Plagiarism** in the form of deliberate or reckless representation of another's words, thoughts, or ideas as one's own without attribution in connection with submission of academic work, whether graded or otherwise.
> 2. **Falsification, fabrication, or misrepresentation** of data, other information, or citations in connection with an academic assignment, whether graded or otherwise.
> 3. **Unauthorized assistance or unauthorized collaboration** in connection with academic work, whether graded or otherwise.
> 4. **Cheating** on examinations or other academic assignments, whether graded or otherwise, including but not limited to the following:
> a. Using unauthorized materials and methods (notes, books, electronic information, telephonic or other forms of electronic communication, or other sources or methods), or
> b. Representing another's work as one's own.

…"

Schedule of Lectures (29):

Week	**TOPIC**	**MWH 2nd Ed[¥]**	**MHW 3rd Ed[€]**
1	Introduction to Physical/Chemical Water Treatment Processes: objectives of water treatment, water sources, water contaminants, overview of methods used to treat water	1.5, 1.6, 2.1, 2.4-2.7, 4.1, 4.4-4.6	1.3, 1.5, 2.1, 2.4-2.7, 4.1, 4.4-4.6
2	Particles in Water: types of particles in water, characteristics of particles, aggregate measurements of particles, Natural Organic Material (NOM)	2.3, 9.2	2.3
3	Particle Charge (Double Layer and DLVO Theory) and Particle Size Distributions	9.2	2.3, 9.2
4	Coagulation: particle destabilization, hydrolyzing metals, polymers, mechanisms, jar tests, enhanced coagulation	9.1, 9.3-9.4	9.1, 9.3-9.5
5	Flocculation and Mixing: basics, theory, practice	9.5-9.7[Ŧ]	6.10, 9.6-9.7[Ŧ]
6	Sedimentation: discrete particle behavior, flocculent settling, sedimentation basins	10.1-10.6	10.1-10.8
7	Design of sedimentation basins	10.1-10.6	10.1-10.8
	EXAM 1		
8	Depth Filtration: history, hydraulics, particle capture Mechanisms, types of filters	11.1-11.6	11.1-11.8
9	Depth filtration (continuation) and design of deep filters	11.1-11.6	11.1-11.8
10	Disinfection: pathogens, disinfectants, inactivation kinetics, CT concept, reactors, regulations, disinfection by-products	13.1-13.3, 13.5, 13.7-13.8	13.1-13.3, 13.5, 13.7, 13.9
11	**SPRING BREAK**		
12	Chemical Oxidation: oxidants, advanced oxidation processes (AOPs), thermodynamics, kinetics	8.1-8.5	8.1-8.4, 18.1
	EXAM 2		
13	Adsorption: equilibrium, kinetics, activated carbon, IAST, EBC, biologically-active activated carbon (BAC)	15.1-15.7[Ŧ]	15.1-15.6[Ŧ]
14	Adsorption (continuation)	15.1-15.7[Ŧ]	15.1-15.6[Ŧ]
15	Ion Exchange: softening, demineralization, NOM removal, selectivity, kinetics, MIEX	16.1-16.5	16.1-16.4, 16.6
16	Ion Exchange (continuation)	16.1-16.5	16.1-16. 4, 16.6
17	Membrane Processes: microfiltration, ultrafiltration, nanofiltration, reverse osmosis, forward osmosis, fouling	12.1-12.5	12.1-12.7
18	Review and online Class evaluation (T)		
	EXAM 3 (Monday May 6, 2019 12:00 p.m.)		

[¥] Sections from: Water Treatment Principles and Design, MWH, 2nd edition, John Wiley (2005)
[€]Sections from: MWH's Water Treatment: Principles and Design, 3rd edition, John Wiley (2012)
[Ŧ]As covered, unless otherwise specified during class.