University of North Carolina at Chapel Hill
ENVR 890-002 Science and Technology of Membranes for Water Purification
Fall 2016

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

Meeting Time: M 10:00 am-12:45 pm **Room:** McGavran-Greenberg 1302

Office Hours: TTh 10:00 am-11:00 pm and whenever else available

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

Required Text: None

Recommended texts: MWH's Water Treatment: Principles and Design, 3rd edition, John Wiley (2012)

Cheryan, M., *Ultrafiltration and microfiltration handbook*. 2nd ed.; CRC Press: United States of America, 1998; p 527.

Schäfer, A. I.; Fane, A. G.; Waite, T. D., *Nanofiltration–Principles and Applications*. Elsevier: United Kingdom, 2005; p 560.

Course Description: This is an advanced course on membrane processes for water purification. The course will be divided in three distinct sections: (i) microfiltration and ultrafiltration; (ii) nanofiltration, reverse osmosis, and forward osmosis; and (iii) electrodialysis and electro-deionization. The reason to divide the course in these three sections is that the physico-chemical phenomena controlling water and solute transport is the same in the membranes within each section, and different between membranes from different sections. For each of the section, the course covers: (1) the transport phenomena controlling water and solute permeation; (2) fouling phenomena; (3) characterization of membrane materials; (4) characterization of membrane performance; and to a lesser degree (5) chemistry of membrane materials. While this is not a design course, basic design principles of membrane processes are also covered.

Target Audience: Graduate students, either engineers or scientists, who wish to become familiar with the science and technology associated with membrane processes for water purification.

Course Goal: The goal of this course is to provide the student with scientific and engineering concepts and skills on membranes processes for water treatment that are useful for engaging in membrane-related work both as a researcher and as a practitioner.

Learning Objectives: Students who take this course will: (1) become familiar with the processes of microfiltration, ultrafiltration, nanofiltration, reverse osmosis, forward osmosis, electrodialysis, and electro-deionization and their applications for water treatment; (2) understand the transport phenomena controlling water and solute permeation in membrane-based processes for water purification; (3) become familiar with techniques used for the characterization of membrane materials and performance; (4) understand the mechanisms behind the phenomena of membrane fouling; (5) understand the basic concepts used in the design of membrane systems.

Course Format: This course includes lectures, laboratory activities, and a tour of a membrane treatment plant.

- Lectures: 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 transport phenomena or design principles. Assigned readings will be from the recommended textbooks or from research or review papers chosen by the instructor.
- Laboratory activities: Various laboratory activities will be performed throughout this course. The laboratory activities are meant to be demonstrations with guided participation by the students as opposed to laboratory assignments. The activities are intended to familiarize the students with practical aspects of membrane processes, performance measurements, and membrane characterization techniques. A report about the laboratory activities must be submitted by each student.
- Membrane treatment plant tour: at the end of the semester a tour of the Groundwater Nanofiltration Treatment Plant operated by the Cape Fear Public Utility Authority (CFPUA) in Wilmington, North Carolina will be offered.

Course Pre-requisites: None.

Useful Background Concepts:

- Fundamentals of water chemistry
  - Acid-base chemistry
  - Complexation
  - Solubility
  - Alkalinity
  - Charge balance
- Mass transfer principles
  - Partitioning
  - Diffusion
  - Film theory
  - Pore flow
- Differential calculus
  - Single variable
- Basic electrochemistry

Student Evaluation: Student evaluation will consist of four 10-min quizzes, four 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 Philosophy on Assignment of Final Grade:
Assignment of High Pass (H) and Pass (P) 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 either take-home assignments to be submitted to the instructor 24 hours after received by the students, or in-class exams to be completed in a 2-hour period. Exams typically include all of the following types of questions in increasing order of weigh for the exam grade: very short-answer questions to be answered in one or a few words, short-answer questions to be answered in one or two lines, conceptual questions to be answered in less than a page (typically half a page) (e.g., draw a schematic and describe in detail what concentration polarization is), and questions that require calculations (so always bring your calculators!).

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:

TOPIC	Lecture hours
Introduction to membrane processes	3
Labor day (Monday Sep 5)	
Low-pressure (LP) membrane processes description and fundamentals	3
Fouling in LP membranes	3
Characterization of LP membranes and associated fouling	1.5
Mathematical description of LP membrane and system performance	1.5
Laboratory experience (setting up a bench-scale LP membrane system and characterizing water flux, contaminant rejection, and fouling)	3
Exam 1: Low-pressure membranes	
High-pressure (HP) membrane processes description and fundamentals	3
Concentration polarization	1
Fouling in HP membranes	2
Characterization of HP membranes and associated fouling	3
The solution-diffusion and pore flow models	3
HP membrane process design	3
Laboratory experience (setting up a laboratory-scale, crossflow HP membrane system, and characterizing water flux, salt rejection, and fouling)	3
Exam 2: High-pressure membranes	
Ion-exchange (IX) membrane processes description and fundamentals	3
Thanksgiving (Thursday Nov 24 through Sunday Nov 27)	
Characterization of IX membranes and associated fouling	3
Mathematical description of IX membrane and system performance	3
Optional: Laboratory experience (setting up a bench-scale electrodialysis cell, and characterizing system performance)	2
Class evaluation (last day of classes – Dec 5)	15 min
Exam 3: Ion-exchange membranes (Friday Dec 16, 8:00am)	
Nanofiltration treatment plant tour (Date to be announced)	