ENVR 710
ENVIRONMENTAL PROCESS BIOTECHNOLOGY

Syllabus, Spring 2017

This course is designed to be accessible to students with backgrounds in either engineering or physical science (see General Course Objectives below). All students are assumed to have had at least one year of calculus; some simple calculus is used in the course, including in assignments.

Class Hours and Location: MWF, 9:05–9:55, 1305 McGavran-Greenberg

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Office Hours: after class or by appointment

Suggested Texts:
(1) Metcalf and Eddy, Inc., *Wastewater Engineering*, McGraw-Hill, N.Y., 5th edition, 2014 (ISBN 978-0-07-340118-8).
(2) Grady JR., C.P.L., G.T. Daigger, N.G. Love and C.D.M. Filipe, *Biological Wastewater Treatment*, IWA Publishing and CRC Press, 3rd edition, 2011 (ISBN 978-0-8493-9679-3)

Note: My lecture material does not closely follow either of these books. However, the books do cover most of the lecture topics in more detail than can be covered in class. Any student who anticipates entering a career in environmental engineering practice is encouraged to obtain one of these books. Metcalf & Eddy, Inc. covers wastewater engineering broadly and comprehensively. Grady *et al.* is oriented to quantitative concepts in biological treatment systems, and it is a basis for understanding and applying commercially available simulation models of these systems.

Course Scope. Biological processes are used in a variety of situations in environmental engineering practice, including the treatment of wastewater (both municipal and industrial), bioremediation of contaminated soil and groundwater, and biofiltration of contaminated air. The primary focus of the course will be on biological processes used in wastewater treatment, although concepts relevant to the biodegradation of specific organic chemicals that could be found in a variety of environmental systems will be dispersed throughout the course. Students will be introduced to the phenomena underlying microbial transformation and degradation of biodegradable organic matter, and to the principles that form the basis for quantifying the microbial removal of organic matter as well as the design of biological treatment systems. There is a substantial emphasis on quantitative analysis of the biological systems covered in the course.

The course begins with a general overview of biological processes and some relevant concepts in microbiology, including microbial ecology and microbial physiology. We then cover fundamentals of stoichiometry, energetics (thermodynamics), and kinetics, followed by the application of stoichiometric and kinetic principles to ideal reactors; these fundamentals form the basis for a quantitative understanding of all biological treatment processes. The remainder of the course focuses on applications of these processes.

General Course Objectives. Graduate students from a variety of academic backgrounds in science or engineering may be interested in learning about engineered biological processes. One objective of this course is to present the material in such a way that each student learns the key features of biological processes, regardless of background. I hope that a diversity of student backgrounds in the classroom will lead to a mutually beneficial learning experience for everyone.

Some of the topics to be covered in class will be more familiar to some students than to others. For example, every student needs to understand basic principles of reactor theory and the formulation of mass balance equations before we can discuss their application to biological process design and analysis. Students who have taken ENVR 451, Elements of Chemical Reaction Engineering, will have learned these principles, while other students may be less familiar with them. We will review these principles in class but I will also provide more detailed information and example applications in supplementary materials. Similarly, understanding the biodegradation of organic chemicals by microorganisms requires knowledge in chemistry, microbial physiology and microbial ecology that some students might be more familiar with than others.

Every student will be expected to demonstrate knowledge of the basic quantitative elements, the underlying science, and the general concepts of biological treatment by completing periodic written assignments. New this year, I plan to distribute one assignment question (intended to be relatively simple) in advance of each lecture period, along with the upcoming lecture slides, for students to complete and turn in on the day of the lecture itself; this approach is meant to engage students with the lecture material before class and to provide opportunities to identify difficulties in grasping key concepts. Longer assignments will be given periodically, which will include questions or problems that cover a range of difficulty; problems intended to be quantitatively challenging (requiring synthesis and/or an extension of kinetic and stoichiometric concepts covered in class) will be identified as such. Students are encouraged to begin the solution to each assignment individually, but it is acceptable to discuss problems on the assignment with other students. Assignments will generally be due on Fridays. If one or more problems on an assignment are particularly challenging for any student, we may discuss the problem in that Friday class session (see below).

Later in the semester, I will present a problem for which each student will be required to prepare a written report; the problem will be designed to be more qualitative than quantitative. More detail on the problem and the expected scope of the report will be provided at a later date. The final written report will be due on the date and time that the final exam would have been scheduled for this course (8:00 am, Monday, May 8 in the regular room for the course).

Specific Objectives. Students should leave the course with an understanding of fundamental concepts, such as:

- How reactor design and/or the reaction environment influence the selection of certain microorganisms within a microbial community;
- That microbial selection has a direct impact on the performance of the reactor or system, and that such selection is often controllable;
- Why organic chemicals are biodegraded in some situations and not in others; and
- How the biodegradation of chemicals that cannot serve as growth substrates is fundamentally different than the degradation of chemicals which *can* serve as growth substrates.

Students completing this course should also understand how to:

- Size a biological reactor based on loading information and loading rates;
- Size a bioreactor based on loading information, the relevant kinetic expression(s), and mass balance equations;
- Determine the quantity of oxygen required for an aerobic process, and size the aeration equipment;
- Determine the quantity of electron donor required to remove an electron acceptor that is a target contaminant (and understand what these terms mean);
- Estimate the requirements, if any, for supplemental inorganic nutrients in a given system; and
- Estimate yields of biosolids (waste biomass), methane from anaerobic processes, and other products.

Lecture Schedule. The lecture schedule for the semester is provided below. For each topic on the schedule, the relevant section(s) (if any) from the two suggested texts are provided as a guide; in some cases, my written notes provide the primary means of covering the topic. My notes will be posted on the Sakai site. The PowerPoint slides for each lecture will also be posted prior to the lecture period. Students should review the slides before class, which will provide more opportunity for discussion of unclear topics (see above as well).

On most Fridays the topic is designated “Freewheeling Friday.” Most of these are meant to be periods of small-group discussion, essentially brainstorming a topic that I will introduce at the beginning of the class period. The purpose of these discussions is to mimic discussions that often take place in professional settings when a new subject is first introduced to an individual or project team. After discussions in small groups, we will collectively discuss the ideas brought up by each group. It is not intended that there will be “right” or “wrong” answers; the main point is to see how well students are obtaining a conceptual understanding of the topics we are covering (or extensions of those topics). In some cases these periods may be used to discuss approaches to solving one or more problems on a homework assignment. In a few cases we may also cover a reading from the literature that will be provided a week in advance. Friday periods will be used to make up classes canceled because of weather and/or to complete a specific lecture topic if we are running behind schedule.

Student Evaluation. Grading will be weighted as follows:

Written assignments: 50%
Class participation: 30%
Final written report: 20%

Assignments. Although written assignments can be discussed with other students, every student must turn in an individual solution to each assignment. Solutions should be in the student's own words and should demonstrate an understanding of how the solution was obtained. For quantitative problems, the more work you show the more I can understand how you obtained a particular solution and can identify mistakes. The approach should be logical and the solution easy to find (*i.e.*, organized) - I am not interested in trying to evaluate scrap paper.

Rather than providing numerical grades, I use a "check" system to evaluate solutions to assignments. A "check" (√) indicates that a significant effort was made by the student. If the effort appeared to be cursory or if most answers are unsatisfactory, a "check minus" (√-) is given, and if the solution is essentially perfect a "check plus" (√+) is given. These marks are converted to numerical scores at the end of the semester for purposes of weighting the effort on assignments. Anyone who turns in their solution to the assignment on the Friday it is due is *eligible* for a √+. If anyone has particular difficulty with one or more problems on an assignment, we can discuss a general approach to the solution on the Friday it is due. It is acceptable for a student to turn in their solution to the assignment in class the following Monday, but it will not be eligible for a √+ grade.

I will post my own solutions to the assignments on the Sakai site shortly after the final due date (after the Monday following the initial due date). Solutions to assignments will not be accepted after my solutions are posted.

Questions on Readings. For every reading, I provide notes and study questions that are intended both to ensure that each student reads the assigned paper and to stimulate class discussion. Written answers should be turned in for each reading, for which I will check the answers as described above for the written assignments.

Final Report. The topic and scope of the final report will be provided later in the semester.

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Lecture Schedule

		Text Chapter (pages)	
Date	**Lecture Topic**	**M&E** [a]	**Grady *et al.*** [b]
1/11	Introduction	1 (4-9)	1 (3-9)
	MICROBIOLOGY PRINCIPLES		
1/13	General Concepts in Microbiology	7 (555-573)	2 (33-38)
1/16	**Holiday**		
1/18	Concepts in Microbial Physiology/ Biodegradation	notes	
1/20	Molecular Tools in Microbial Ecology	7 (568-571)	
1/23	Anaerobic Microbiology	7 (655-659)	4 (46-50)
	QUANTITATIVE FUNDAMENTALS		
1/25	Stoichiometry (electron equivalents and electron acceptors)	7 (573-588); notes	2,3 (51-88; 116-118)
1/27	Freewheeling Friday		
1/30	Stoichiometry		
2/1	Stoichiometry and Energetics (biomass yield)		
2/3	Freewheeling Friday		
2/6	Stoichiometry and Energetics		
2/8	Kinetics of Growth and Substrate Removal	7 (588-596); notes	3 (90-116; 118-125)
2/10	Freewheeling Friday		
2/13	Kinetics of Growth and Substrate Removal		
2/15	Kinetics of Growth and Substrate Removal		
2/17	Freewheeling Friday		
2/20	Reactor Theory (ideal reactor models)	notes	4 (137-149)
2/22	Reactor Engineering and Modeling (coupling rate expressions and reactor models)	7 (597-610)	5 (all); 6 (195-201)
2/24	Freewheeling Friday		
2/27	Reactor Engineering and Modeling		
3/1	Reactor Engineering and Modeling	8 (742-751)	
3/3	Freewheeling Friday		
	PROCESS ENGINEERING IN WASTEWATER TREATMENT		
3/6	Introduction	2 (60-65); notes	
3/8	Design Concepts	3 (185-200; 208-215); 4 (265-297); notes	10 (353-376)
3/10	Freewheeling Friday		
3/13	**Spring Break**		
3/15	**Spring Break**		
3/17	**Spring Break**		
3/20	Aerobic Suspended Culture Processes	7 (615-618); 8 (697-742; 752-795)	11 (all)
3/22	Aerobic Suspended Culture Processes		
3/24	Freewheeling Friday		
3/27	Aerobic Suspended Culture Processes		
3/29	Aeration	5 (411-440)	

Date	Lecture Topic	Text Chapter (pages) M&E [a]	Text Chapter (pages) Grady *et al.*[b]
3/31	Freewheeling Friday		
4/3	Nitrification	7 (618-628)	3 (88-90); 6 (210-216)
4/5	Denitrification	7 (631-640); 8 (795-861)	3 (86-88); 6 (216-220); 12 (489-509)
4/7	Freewheeling Friday		
4/10	Anaerobic Ammonium Oxidation	7 (640-645)	
4/12	Biological Phosphorus Removal	7 (648-655); 8 (861-884)	2 (62-66); 12 (471-489; 510-519)
4/14	**Holiday**		
4/17	Anaerobic Processes	10 (1059-1109)	14 (561-610)
4/19	Biodegradation of Specific Chemicals	7 (663-674); notes	22 (895-912)
4/21	Freewheeling Friday		
4/24	Biodegradation of Specific Chemicals		
4/26	Reading		
4/28	Freewheeling Friday		
5/8[c]	**Final report due date and discussion**		

[a] Metcalf and Eddy, Inc., *Wastewater Engineering*, 5th edition (McGraw-Hill, 2014)

[b] C.P.L Grady Jr., G.T. Daigger, N.G. Love, and C.D.M. Filipe, Biological Wastewater Treatment, 3rd edition (IWA Publishing and CRC Press, 2011)

[c] 8:00 am (final exam period for this course)