CIVE/CBE 540 Advanced Biological Wastewater Processing

Instructor:
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Office hours: M, W 11:00 am – 12:30 pm

Course description:
The purpose of this course is to educate students in biological process engineering. Students will be introduced to fundamentals of biotechnology and design and operation of biological processes. Fundamental biotechnology concepts will include basic environmental microbiology and microbial ecology; microbial metabolism, energetics and kinetics; applications of molecular biology; and an introduction to bioreactor design. Biological wastewater process engineering will also be introduced. Both aerobic and anaerobic biological waste treatment will be covered.

Course objective
To gain a fundamental understanding of microbial processes necessary for the design and optimization of biological processing unit operations.

Learning Objectives
By the end of CIVE students will:
1. Have a basic understanding of microbial processes governing environmental systems.
2. Understand relationships between stoichiometry and bacterial energetics.
3. Understand the fundamentals of bacterial kinetics.
4. Be able to conceptualize and mathematically express biological mass balances in environmental systems based on the above concepts.
5. Design an Activated Sludge treatment plant appropriate to the influent wastewater conditions.
6. Design Attached Growth bioreactors appropriate to the treatment conditions.
7. Design processes for specialized treatment, such as removal of nitrogen and phosphorus.
8. Design an anaerobic digester
9. Consider alternative treatment approaches based on appropriate criteria.

Prerequisites:
CIVE 437 (also acceptable as co-req); A course in general microbiology is recommended. The course involves quantitative analysis of microbial systems and thus familiarity with differential equations is assumed.

Textbook and Course Materials
Supplemental materials (journal articles and instructors’ notes) will be distributed in class or on Ram CT

Grading:
Homework 20%
Exam I 25%
Exam II 25%
Design Project 30%
Term grades will be assigned as follows:

- **A**: 90% or better
- **B**: 80-89%
- **C**: 70-79%
- **D**: 60-69%
- **F**: 59% or below

However, a curve may be applied depending on the overall performance of the class as a whole. Term grades for this course will use the +/- grading system as described in the CSU catalog.

**Late Submissions:**
All assignments must be submitted at the start of class on the due date. Homeworks received on the due date after the start of class will receive a 25% reduction. No assignments will be accepted after the due date. While discussion is encouraged on assignments, your submission must reflect your own individual work.

**Additional course information available on RamCT.**

**Course Schedule [approximate number of lecture hours]**

1. **Introduction [1]**
2. **Basics of Environmental Microbiology [2]**
   a. Taxonomy and phylogeny
      i. Eukaryotes and prokaryotes (bacteria and archaea), viruses
      ii. Morphology
      iii. Trophic classifications
   b. Physiology of the cell
   c. Microbial replication and growth
3. **Biochemistry and Metabolism [4]**
   a. Anabolism/catabolism
   b. Central metabolism: glycolysis and the TCA cycle
   c. Metabolic pathways of contaminant biodegradation
   d. Metabolic regulation
4. **Microbial Ecology [1]**
   a. Types of microbial communities and interactions
   b. Enrichment cultures and other selection procedures
   c. Horizontal gene transfer
5. **Detection, Enumeration, and Characterization of Microorganisms in the Environment**
   **Methods for detection and enumeration [1]**
   a. Methods for characterization of microbial communities
      i. Traditional
      ii. Molecular microbial ecology
6. **Stoichiometry and Bacterial Energetics [4]**
   a. Mass balances
   b. Redox reactions: electron donor/electron acceptor
   c. Redox half-reactions
   d. Energy balances ($\Delta G$)
      i. Growth
      ii. Substrate Partitioning and theoretical yield
iii. Electron acceptors, fermentation

e. Nitrogen source

f. BOD/COD

7. **Enzyme and Microbial Kinetics [4]**
   a. Michaelis-Menten kinetics
   b. Monod kinetics
   c. Inhibition kinetics
   d. Alternate Rate Expressions
   e. Growth on multiple substrates
   f. Cometabolism
   g. Mixed culture kinetics

8. **Bioremediation [2]**

9. **Wastewater Treatment [6]**
   a. Wastewater Treatment Plant Configuration
   b. Reactor Types
   c. Activated Sludge

Exam II [1]
Field Trips [2]

10. **The Activated Sludge Process (Chapters 5 & 6) [4]**
    a. Aeration
    b. Analysis and design of settling
       i. Type I, II, III “zone settling” (M&E chapter 6)
       ii. Loading criteria
       iii. Basics of flux theory
       iv. Sludge-settling problems (bulking, foaming, etc.)

    a. Nitrification
       i. Biochem and physiology of nitrifying bacteria
       ii. Activated Sludge versus Biofilm nitrification
       iii. Role of BOD₅ : TKN ratio
    b. Denitrification
       i. Physiology of denitrifying bacteria
       ii. Tertiary denitrification
       iii. One-Sludge Denitrification
    c. Phosphorous Removal
       i. Phosphate uptake (normal and luxury uptake)
       ii. Precipitation by metal-salts addition
       iii. Enhanced biological P removal, and Barden-Pho process

12. **Anaerobic Treatment** (Chapter 13) – [3]
    a. Applications of anaerobic treatment
    b. Reactor configurations
    c. Chemistry and microbiology
    d. Kinetics of methanogenesis
    e. Factors for design consideration
13. Aerobic Biofilm Processes (Chapters 4 & 8) [3]
   a. Properties of microbial aggregation
   b. Idealized biofilm
   c. Estimating kinetic parameters in a biofilm
   d. SRT in a biofilm
   e. Biofilm process considerations
   f. Trickling filters/ biological towers
   g. RBCs
   h. Fluidized-bed reactors