COURSE OUTLINE

COURSE INFORMATION

Course Name: Biological Aspects of Wastewater Treatment — Course Code: CIV ENG 4V04 (CIV ENG 6V04)
Class Scheduled: Mo 12:30 – 2:20pm; Th 1:30 – 2:20pm — Location: PGCLL B131
Instructor: Younggy Kim (JHE 334; ext. 24802; younggy@mcmaster.ca; No Avenue-to-Learn email)
Office Hours/Location: Th 2:30-3:30pm at JHE 334
Lab instructor: Monica Han (JHE 201; ext. 27074; hanm7@mcmaster.ca; available by appointments)
Teaching assistants: TBA

1. COURSE OBJECTIVES

At the end of the course, students will have solid understanding of fundamentals of biological reactions in various wastewater treatment processes. Students will also practice and obtain relevant skills and techniques in evaluating and designing wastewater treatment processes.

2. COURSE SPECIFIC POLICIES

Attendance: Lecture attendance is expected but will not be reflected in grading. It is strongly recommended that the students not miss lectures. Lab attendance is mandatory.

Examinations: The McMaster Standard Calculator may be used during examinations. You may bring one crib sheet (letter size; double sided) in the mid-term exam and 2 sheets to the final exam.
- Crib sheets must be prepared only by hands (hand-written or hand-drawn materials only).
- Photocopied or printed information of any size is NOT allowed.
- Photocopies of your own handwriting (e.g., homework assignments and note) are NOT allowed.

Assignments: 4 assignments will be posted on Avenue. Late assignments will be assessed a penalty of 20% per academic day. Late assignments may not be accepted depending on course schedule. It is your responsibility to communicate with the instructor / lab supervisor on how you submit late assignments and reports.

In-class quizzes: The objective of in-class quizzes is to ensure that you know very essential course materials. There will be 2 in-class quiz exams. The quiz dates will be announced a few days in advance.

Term project: The term project consists of two separate parts: (1) Model development; and (2) Report preparation using the model. The first part should be done individually while you work in a group (as assigned for laboratory works) for the second part. Everyone in a group is equally responsible for preparing project reports (i.e., no leader assigned in the term project). Graduate students enrolled in CIV ENG 6V04 must work individually both in the first and second parts of the term project. The term project topic will be given later on Avenue.

Laboratory experiments: Each student must participate in mandatory laboratory sessions, which will provide supplemental exposure to important concepts we will be covering in the course. We will have four regular lab sessions in addition to a preliminary lab. The dates for lab sessions will be announced on the Avenue calendar. Lab experiments will be conducted in groups of four students. All group members must participate in all labs. Each group is responsible for submitting a report. All group members are expected to take part in report preparation. Expected formats and structure of a lab report will be posted on Avenue. A late penalty of 20% per academic day will be applied. All group members must read the lab handout prior to a lab session. There may be pre-lab quizzes to ensure that you have read the lab handouts and understand experimental steps and materials. Both of the lab report and quiz will be included in your lab evaluation. During the preliminary lab session, we will have a safety presentation and group assignment. Attendance at this preliminary lab is also mandatory.

Field Trip: There will be a field trip to a local wastewater treatment plant. Detailed plan will be announced later.

Tutorials: Prerequisite materials and design examples will be covered in tutorials. We will also learn to use commercial simulation tools. We do not have tutorials every week and tutorial dates will be announced on Avenue.

MSAF Policy: When a self-reporting relief is submitted, the portion of the missed academic work will be automatically transferred to the final examination. It is still your responsibility to notify the instructor of your MSAF submission. Put "MSAF, 4V04" in your email heading. For a group work (including lab attendance, lab reports, and term project reports), an MSAF will NOT be accepted.

Laboratory Safety: The lab space can be a dangerous place if you do not follow safety rules!
The Faculty of Engineering is committed to McMaster's University Workplace and Environmental Health and Safety Policy which states: "Students are required by University policy to comply with all University health, safety and

environmental programs". It is your responsibility to understand McMaster University Workplace and Environmental Health and Safety programs and policies. For information on these programs and policies please refer to McMaster University Environmental and Health Support Services Occupational Safety Risk Management Manual at (suggested reading: Sections 10 through 16):
http://www.workingatmcmaster.ca/med/document/Lab-Safety-Handbook-1-36.pdf
(You can also find this lab safety handbook on Avenue under the Content tab of this course.)
It is also your responsibility to follow any specific Standard Operating Procedures (SOPs) provided for some of the experiments and the laboratory equipment.
The safety requirements for JHE 220 are listed below. Students not abiding by these safety requirements will be given one warning. Second offences will result in the student being asked to vacate the laboratory, and receiving a grade of zero for that particular lab.
- Glasses or safety glasses/goggles must be worn in the lab *at all times*.
- Contact lenses are *not* to be worn in the lab.
- No short (i.e., above the knee) pants or skirts are permitted in the lab – lab coats must be worn over top of your clothing in these instances.
- Closed-toe shoes must be worn at all times.
- No loose clothing allowed.
- Long hair must be tied back.
- Gloves must be worn *at all times.*

3. SCHEDULE (may change depending on lab schedule)

WEEK 1: Introduction of biological wastewater treatment
WEEK 2: Characterization of wastewater: Suspended solid, oxygen demand, nitrogen and phosphorus
WEEK 3: Kinetics of microbial growth and substrate utilization: Monod equation and its applications
WEEK 4: Estimation of kinetic parameters in biological wastewater treatment: Y, Ks, k (μ_m), b
WEEK 5-6: Conventional activated sludge and its design
WEEK 7: Activated Sludge Model #1 (ASM1)
WEEK 8: Gas transfer and aeration system design
WEEK 9-10: ***Mid-term***; Settling and thickening of wastewater sludge
WEEK 11: Nutrient removal in wastewater treatment
WEEK 11: Sequencing batch reactors (SBRs), membrane bioreactors (MBRs)
WEEK 12: Attached growth reactors
WEEK 13: Anaerobic digestion for wastewater sludge treatment
FINAL EXAM: Scheduled during the regular University Final Examination period established by the Registrar's Office

4. ASSESSMENT OF LEARNING	WEIGHT %
Mid-term examination (12:30-2:20pm on March 2)	20%
Final examination	30%
Assignments (4 assignments)	20%
In-class quizzes	2%
Term project and reports	12%
Laboratory experiments and reports	16%

5. LEARNING OUTCOMES

CEAB Learning Indicators Measured in This Course

1.1 Competence in Mathematics
1.2 Competence in Natural Sciences
1.3 Competence in Engineering Fundamentals
1.4 Competence in Specialized Engineering knowledge (I, D, A--both)
2.2 Demonstrates an ability to identify a range of suitable engineering fundamentals (including mathematical techniques) that would be potentially useful for analyzing a technical problem.
2.3 Obtains substantiated conclusions as a result of a problem solution including recognizing the limitations of the solutions.
3.2 Selects appropriate model and methods and identifies assumptions and constraints.
3.3 Estimates outcomes, uncertainties and determines appropriate data to collect.
4.1 Recognizes and follows an engineering design process. (This means an iterative activity that might include recognizing the goal, specifying the constraints and desired outcomes, proposing solutions, evaluating alternatives, deciding on a solution, and implementing.)
4.2 Recognizes and follows engineering design principles including appropriate consideration of environmental, social and economic aspects as well as health and safety issues.
4.3 Proposes solutions to open-ended problems.
4.5 Includes appropriate health and safety considerations

5.1 Evaluates and selects appropriate modern tools.
5.2 Demonstrates an ability to use modern/state of the art tools.
6.3 Works in a group, taking a leadership role as appropriate and relinquishing the leadership role as appropriate. (Lab experiments and report preparation; term project)
7.3 Constructs effective oral or written arguments as appropriate to the circumstances (Report preparation)

Learning Outcomes (Corresponding Graduate Attributes in Parenthesis)

1. Introduction

- Know the two main objectives of wastewater treatment. (1.4)
- Be able to explain how to remove particulate organic compounds. (1.3)
- Be able to explain why we need to remove nutrients in WWT. (1.2)
- Be able to explain how to remove dissolved (and colloidal) organic compounds. (1.3)
- Know the wastewater treatment trains with individual unit processes (1.4)
- Know the sludge (biosolids) treatment trains with individual unit processes. (1.4)

2. Wastewater Analysis

- Know the solids categorization based on size and volatility. (1.4)
- Know the definition of TS, TFS, FFS, VFS, TSS, FSS, and VSS. (1.4)
- Know how to measure TSS and VSS. (1.4)
- Know the meaning of TSS and VSS for the microorganism concentration. (1.4)
- Can calculate ThOD for a given chemical composition. (1.2)
- Know the definition of NOD. (1.4)
- Know the definition of COD and can measure COD for a water sample. (1.4)
- Know the definition of BOD and can measure BOD for a water sample. (1.4)
- Plot "measured BOD vs. time" with and without nitrification. (1.4)
- Know how to find BOD_L from measured BOD_5. (1.4)
- Know the definition of TOC. (1.4)
- Know the nitrogen compounds in wastewater. (1.4)
- Know the phosphorus compounds in wastewater. (1.4)

3. Microbial kinetics

- Know the definition of catabolism, anabolism, and metabolism. (1.2)
- Know the definition of microbial yield coefficient. (1.4)
- Can correlate dS/dt and dX/dt using Y. (1.4)
- Know the rate expression for microbial growth. (1.4)
- Know the Monod equation and can plot μ as a function of S. (1.4)
- Know the rate expression for substrate utilization. (1.4)
- Know the rate expression for microbial decay and net growth rate. (1.4)
- Know the five kinetic parameters: Y, Ks, k (μ_m/Y), and b. (1.4)
- Know the definition of specific substrate utilization, U. (1.4)
- Know the definition of food-to-microorganism ratio, F/M ratio. (1.4)

4. Conventional Activated Sludge Process

- Know the difference between chemostat and activated sludge systems. (3.2)
- Be able to draw the activate sludge process and know the assumptions. (3.2)
- Know the definition of solids retention time both in verbal and mathematical expressions (1.4)
- Be able to perform mass balance on X across the entire system and derive the S expression. (1.1; 1.4)
- Be able to perform mass balance on S across the entire system and derive the X expression. (1.1; 1.4)
- Know that 1/θc is equivalent to the net cell growth rate (1.4)
- Know the physical meaning of θc (1.4)
- Know the following correlations between θc and microbial composition in AS (1.2; 1.4)
    - Short θc: we will have only fast-growing microorganisms in AS.
    - Long θc: we will have both fast- and slow-growing microorganisms in AS.
    - Nitrifying bacteria are slow-growing microorganisms; thus, nitrification will occur for long θc.
- Can do mass balance on X across clarifier to find the expression for Qr/Q (1.3; 1.4)
- Can find the equation for waste sludge production: QwXr (1.4)
- Can find minimum solids retention time (θ_c^m) by assuming washout (1.4)
- Know the combine sewer and separate sewer systems (1.4)
- Know how θc controls the following AS operation factors. (1.4)
    - θc ↑ → S ↓ (if θc > 5d, S is already sufficiently small and thus rather independent on θc.)
    - θc ↑ → amount of waste sludge ↓ (by which eqn?) → $ ↓ for sludge (biosolids) management
    - θc ↑ → X ↑ (by which eqn?) → O_2 requirement ↑ → $ ↑ for aeration
    - θc ↑ → X ↑ → Qr ↑ (by which eqn?) → $ ↑ for RAS pumping
    - θc ↑ → activation of nitrifying bacteria → NH_3 removal ↑
    - θc ↑ → "may" cause sludge bulking problem
- Can explain the following operation factors and their effects. (1.4)
    - S0 ↑ → X ↑ (by which eqn?)

- Xr ↑ (better clarifier) → Qr ↓ (by which eqn?)
- V ↑ → X ↓ (by which eqn?) → Qr ↓ (by which eqn?)

- Be able to design an activated sludge system (4.1)
- Know the major capital and operation costs for wastewater treatment (4.2)
- Able to do mass balance on X_i (inert solids) to find X_i concentration in aeration tank (1.4)

5. Estimation of Microbial Kinetics

- Can use the equation for 1/U to find Ks and k (3.3)
- Can use the equation for for 1/θc to find Y and b (3.3)
- Can use the Arrhenius equation for temperature correction of kinetic coefficients. (1.2)
- Know the model for multiple substrates and inhibitors (1.4; 3.2)
- Know the two types of microorganisms in WWT: heterotrophs and autotrophs (1.2)
- Know how heterotrophs grow under aerobic and anoxic conditions (1.2; 1.4)
- Know how autotrophs grow under aerobic conditions (1.2; 1.4)
- Know the effect of pH on microbial growth and can include the effect in the model equation (1.4; 3.2)

6. Activated Sludge Model No. 1

- Know the 10 components in Activated Sludge Model No. 1 (1.4)
- Be able to explain hydrolysis of particulate substances (1.4)
- Be able to explain ammonification of soluble organic nitrogen compounds (1.2; 1.4)
- Know two mechanisms of ammonia consumption in activated sludge processes (1.2; 1.4)
- Know the distribution of decayed cell materials. (1.4)
- Be able to sketch the reaction charts in ASM1 (1.4)
- Be able to write a mass balance equation on each component (1.3)
- Be able to solve the 10 mass balance equation using a numerical method (Term Project) (1.1)
- Can use ASM No.1 to better understand how CAS works (Term Project) (5.2)
- Know the benefits and limitations of ASM No.1 (2.3; 3.3; 5.1)
- Attempt to expand ASM No.1 for an emerging contaminant (Term Project) (4.3)
- Can use commercial software (e.g., BioWin) (5.2)

7. Aeration systems in activated sludge

- Be able to calculate the oxygen requirement for BOD removal and nitrification (1.4)
- Know Henry's law (1.2)
- Know the kinetics of gas transfer (1.2)
- Can correct the kinetic and equilibrium constants for temperature, surfactant, and activity coefficient (1.4)
- Can design an aeration system by finding actual O_2 transfer rate (4.1)

8. Sedimentation tanks

- Know the four types of settling (1.4)
- Can plot the G_b curve vs. particle concentration from settling column tests (4.1)
- Can use the graphical method to find the limiting solids flux (4.1; 5.2)
- Can determine the clarifier size based on the found limiting flux (4.1)
- Know the state point and its physical meaning (1.4)
- Know factors to be considered in designing secondary clarifiers (4.1)
- Know the design trade-off among clarifier, aeration tank and return sludge pump (2.2; 4.2)
- Know sludge volume index (1.4)
- Know the definition of sludge bulking
- Know what cause sludge bulking and how to control it (1.4; 4.2)
- Know the definition of rising sludge and how to control it (1.4)

9. Nutrient removal in wastewater treatment

- Know that nutrient is removed as WAS (1.4)
- Can explain nitrification (1.2; 1.4)
- Can explain denitrification (1.2; 1.4)
- Know the three types of reactor conditions and resulting redox reactions (1.2; 1.3; 1.4)
- Know how phosphorus accumulating organisms (PAOs) remove phosphorus (1.2; 1.4)
- Know various BNR processes (1.4; 5.1)
- Know the benefits and limitations of the individual BNR processes (1.4; 5.1)
- Know the fate of excessively uptaken P in later sludge treatment processes (4.3)
- Know the chemical phosphorus removal method (1.2; 1.4)

10. Sequenting batch reactors (SBRs)

- Know the operation steps of SBRs (1.4)
- Can analyze SBR performance by doing mass balance during the React step (1.1; 1.4; 3.2)
- Know the benefits of SBRs compared to continuous flow systems (4.2)

11. Membrane bioreactors (MBRs)

- Know the advantages and disadvantages of MBRs compared to CAS (1.4; 4.2)
- Two types of MBRs: External side-stream MBRs; Submerged MBRs (1.4; 4.2)

12. Attached growth reactors

- Know the four types of attached growth reactors (1.4)
- Know the advantages and disadvantages of attached growth systems (1.4)
- Know three distinct regions in the biofilm system (1.4)
- Can drive the micro-scale mass balance equation and set up the boundary conditions (1.1; 1.3)
- Know the equation for mass flux in the liquid film. (1.4)
- Know the definition of the shallow and deep biofilms. (1.4)
- Know the kinetic expression for S removal in biofilm depending on the rate-limiting component. (1.4)
- Can set up the macro-scale mass balance equation depending on the type of attached growth reactors (3.2)
- Can find the effluent quality from a numerical grid by equating the micro- and macro-scale mass balance equations (1.1)

13. Anaerobic Digestion

- Know the objective of anaerobic digestion (1.4)
- Know the four macro nutrients and their monomers (1.2)
- Be able to sketch the anaerobic reaction chart (1.4)
- Can explain hydrotropic methanogenesis (1.2; 1.4)
- Can explain acetoclastic methanogenesis (1.2; 1.4)
- Can explain anaerobic oxidation (β-oxidation) (1.2; 1.4)
- Can explain fermentation (1.2; 1.4)
- Can explain hydrolysis (1.2; 1.4)
- Be able to find out the rate-limiting reaction from multiple chain reactions. (1.4)
- Know the effect of pH on anaerobic digestion (1.4)
- Know the effect of temperature on anaerobic digestion (1.4)
- Know the consequences of having sulfate in wastewater (1.3; 1.4)
- Know the role of ammonia (NH_3) in pH buffering and toxic effects (1,2; 1.4)
- Know the two (three) types of reactors (1.4; 4.2)
- Know the benefits of anaerobic digestion (1.4)
- Can find the rate of CH_4 production (1.4)
- Know the design factors of anaerobic digesters (4.2)
- Know the important operation and monitoring factors (1.4)

6. COMMUNICATIONS

It is the student's responsibility to:

- Maintain current contact information with the University, including address, phone numbers, and emergency contact information.
- Use the University provided e-mail address or maintain a valid forwarding e-mail address.
- Regularly check the official University communications channels. Official University communications are considered received if sent by postal mail, by fax, or by e-mail to the student's designated primary e-mail account via their "@mcmaster.ca" alias.
- Accept that forwarded e-mails may be lost and that e-mail is considered received if sent via the student's @mcmaster.ca alias.
- Check the McMaster/Avenue email and course websites on a regular basis during the term.

7. POLICIES

ACADEMIC INTEGRITY

You are required to exhibit honesty and use ethical behaviour in all aspects of the learning process. Academic credentials you earn are rooted in principles of honesty and academic integrity.

Academic dishonesty is to knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage. This behaviour can result in serious consequences e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: "Grade of F assigned for academic dishonesty"), and/or suspension or expulsion from the university.

It is your responsibility to understand what constitutes academic dishonesty. For information on the various types of academic dishonesty please refer to the *Academic Integrity Policy*, located at www.mcmaster.ca/academicintegrity.

The following illustrates only three forms of academic dishonesty:

1. Plagiarism. e.g. the submission of work that is not own or for which other credit has been obtained
2. Improper collaboration in group work
3. Copying or using unauthorized aids in tests and examinations.

PROTECTION OF PRIVACY ACT (FIPPA)

The Freedom of Information and Protection of Privacy Act (FIPPA) applies to universities. Instructors should take care to protect student names, student numbers, grades and all other personal information at all times. For example, the submission and return of assignments and the posting of grades must be done in a manner that ensures confidentiality - see http://www.mcmaster.ca/univsec/fippa/fippa.cfm

ACADEMIC ACCOMMODATION OF STUDENTS WITH DISABILITIES POLICY

Students with disabilities who require academic accommodation must contact Student Accessibility Services (SAS) https://sas.mcmaster.ca/ to make arrangements with a Program Coordinator. Student Accessibility Services can be contacted by phone 905-525-9140 ext. 28652 or e-mail sas@mcmaster.ca. For further information, consult McMaster University's https://www.mcmaster.ca/policy/Students-AcademicStudies/AcademicAccommodation-StudentsWithDisabilities.pdf

ACADEMIC ACCOMMODATION FOR RELIGIOUS, INDEGENOUS OR SPIRITUAL OBSERVANCES (RISO)

Students requiring academic accommodation based on religious, indigenous or spiritual observances should follow the procedures set out in the RISO policy. Students requiring a RISO accommodation should submit their request to their Faculty Office normally within 10 working days of the beginning of term in which they anticipate a need for accommodation or to the Registrar's Office prior to their examinations. Students should also contact their instructors as soon as possible to make alternative arrangements for classes, assignments, and tests.

REQUESTS FOR RELIEF FOR MISSED ACADEMIC TERM WORK – MSAF (ASSIGNMENTS, MID-TERMS, ETC)

The McMaster Student Absence Form is a self reporting tool for **Undergraduate Students** to report absences that last up to 5 days and provides the ability to request accommodation for any missed academic work. Please note, this tool cannot be used during any final examination period.

You may submit a maximum of 1 Academic Work Missed requests per term. It is YOUR responsibility to follow up with your Instructor immediately regarding the nature of the accommodation.

If you are absent more than 5 days or exceed 1 request per term you MUST visit your Associate Dean's Office (Faculty Office). You may be required to provide supporting documentation.

This form should be filled out immediately when you are about to return to class after your absence. http://www.mcmaster.ca/msaf/

ANTI-DISCRIMINATION

The Faculty of Engineering is concerned with ensuring an environment that is free of all discrimination. If there is a problem, individuals are reminded that they should contact the Department Chair, the Sexual Harassment Officer or the Human Rights Consultant, as soon as possible.
https://www.mcmaster.ca/policy/General/HR/Discrimination_and_Harassment.pdf

EXTREME CIRCUMSTANCES

The University reserves the right to change the dates and deadlines for any or all courses in extreme circumstances (e.g., severe weather, labour disruptions, etc.). Changes will be communicated through regular McMaster communication channels, such as McMaster Daily News, A2L and/or McMaster email.

8. MCMASTER GRADING SCALE (can be different in this course)

Grade	Equivalent Grade Point	Equivalent Percentages
A+	12	90-100
A	11	85-89
A-	10	80-84
B+	9	77-79
B	8	73-76
B-	7	70-72
C+	6	67-69
C	5	63-66
C-	4	60-62
D+	3	57-59
D	2	53-56
D-	1	50-52
F	0	0-49