

**THE UNIVERSITY OF WESTERN ONTARIO –
FACULTY OF ENGINEERING SCIENCE
DEPARTMENT OF CIVIL AND ENVIRONMENTAL
ENGINEERING**

**CEE 4428b – Selected Topics in Civil Engineering:
Subsurface Contamination by Hazardous Industrial Chemicals**

Course Outline 2009/2010

This course deals with subsurface contamination by hazardous industrial liquids such as PCB oils, gasoline, jet fuel, chlorinated solvents and coal tars. These compounds represent some of the most prevalent, toxic, and recalcitrant subsurface pollutants throughout the industrialized world. The fundamentals of multiphase/multicomponent flow and transport will be outlined followed by specific treatment of both denser-than-water and lighter-than-water non-aqueous phase liquids (DNAPLs and LNAPLs). The course will examine the fate of these contaminants in water, oil, and vapour phases and their subsurface distribution in both unconsolidated aquifers and fractured rock systems. As well, it will examine their sampling and detection, as well as the processes and applications of innovative clean-up technologies, in addition to discussing regulatory aspects, and selected case histories.

The objectives of the course are:

- Develop an understanding the history, prevalence, sources, and regulatory framework surrounding industrial organic chemicals in the subsurface;
- Demonstrate knowledge of the range of compounds considered LNAPLs and DNAPLs., and the properties of the subsurface fluids (air, water, and contaminants) that influence the fate of these compounds in the subsurface;
- Recognize the differences that various subsurface environments (e.g., aquifers, aquitards, fractured bedrock) have on the fate of industrial chemicals;
- Develop the ability to manipulate mathematical relationships that describe the flow and transport of groundwater and industrial liquids through soil;
- Investigate a variety of established and innovative methods for site characterization and contaminant mapping and monitoring.;
- Learn about a variety of state-of-the-art remediation techniques, both the processes that underpin them as well as their application;
- Examine case studies the illustrate how the theory, techniques, and regulations intersect on real projects.
- Develop an appreciation for the role of mathematical and numerical modelling in understanding the behaviour of these compounds

Prerequisites:

Completion of third year of BEng. or BSc. degree.

Corequisites:

None.

Antirequisites:

None

Note: It is the **student's responsibility** to ensure that all Prerequisite conditions are met or that special permission to waive these requirements has been granted by the Faculty. It is also the **student's responsibility** to ensure that he/she has not taken a course listed as an Antirequisite. The student may be dropped from the course or not given credit for the course towards his/her degree if he/she violates the Prerequisite, Corequisite or Antirequisite conditions.

Contact Hours:

Average of 3 lecture hrs/wk + 1 design lab/tutorial hr/wk
(average recommended additional personal study: 4-6 hrs/wk).

Instructor:

J.I. Gerhard, Ph.D., P.Eng.,
Canada Research Chair in Geoenvironmental Restoration Engineering
Spencer Engineering Building Room 3069.
Email: jgerhard@eng.uwo.ca

Admin.Asst.: Ms. Laurence, Spencer Engineering Building Room 3005, Ext. 519-661-2139.
Email: slaurence@eng.uwo.ca

Textbook:

None required. Comprehensive notes will be developed during the class.

Useful texts relevant to the course:

Fetter, 1999. Contaminant Hydrogeology, Prentice Hall, 500 p.

Bear, 1972, Dynamics of Fluids in Porous Media, Dover Books, 764 p.

J.F. Pankow, and J.A. Cherry (Eds.), Chlorinated Solvents and Other DNAPLs in Groundwater, Waterloo Press, 474 p.

Assignments and Design Project:

Weekly assignments to work through course material will be required. These assignments will be for practice and will be addressed in tutorial sessions. They will be indicative of the types of questions to expect on the midterm and final exam.

A project will be conducted that will include: (a) computer applications and/or written and oral presentations. These vary from year to year and the attendance in the class.

Graduate students will have additional requirements of oral and written analysis of key papers in the literature and a more extensive project and/or assignments. The purpose is to permit the graduate students to explore the material in more depth; when possible, opportunity will be provided to explore the material relevant to their thesis research topic.

Units:

SI units will be used in lectures and examinations.

Use of English:

In accordance with Senate and Faculty Policy, students may be penalized up to 10% of the marks on all assignments, tests, and examinations for the improper use of English. Additionally, poorly written work with the exception of the final examination may be returned without grading. If resubmission of the work is permitted, it may be graded with marks deducted for poor English and/or late submission.

Attendance:

Any student, who, in the opinion of the instructor, is absent too frequently from class or laboratory periods in any course, will be reported to the Dean (after due warning has been given). On the recommendation of the Department concerned, and with the permission of the Dean, the student will be debarred from taking the regular examination in the course.

Cheating:

University policy states that cheating is a scholastic offence. The commission of a scholastic offence is attended by academic penalties, which might include expulsion from the program. If you are caught cheating, there will be no second warning (see Scholastic Offence Policy in the Western Academic Calendar).

Plagiarism:

Students must write their essays and assignments in their own words. Whenever students take an idea, or a passage from another author, they must acknowledge their debt both by using quotation marks where appropriate and by proper referencing such as footnotes or citations. Plagiarism is a major academic offence (see Scholastic Offence Policy in the Western Academic Calendar).

Conduct:

Students are expected to arrive at lectures on time, and to conduct themselves during class in a professional and respectful manner that is not disruptive to others.

Sickness and Other Problems:

Students should immediately consult with the instructor or Department Chair if they have any problems that could affect their performance in the course. Where appropriate, the problems should be documented (see attached). The student should seek advice from the Instructor or Department Chair regarding how best to deal with the problem. Failure to notify the Instructor or Department Chair immediately (or as soon as possible thereafter) will have a negative effect on any appeal.

Repeating Course

The Senate (SCAPA) approved the following policy in Engineering with regard to students who are repeating a failed course:

Students who have failed an Engineering course (ie.<50%) must repeat all components of the course. No special permissions will be granted enabling a student to retain laboratory, assignment or test marks from previous years. Previously completed assignments and laboratories cannot be resubmitted for grading by the student in subsequent years.

Notice:

Students are responsible for regularly checking their email and the course WebCT site.

Consultation:

Students are encouraged to discuss problems with their teaching assistant and/or instructor in tutorial sessions. Office hours will be arranged for the students to see the instructor and teaching assistants. Other individual consultation can be arranged by appointment with the appropriate instructor.

Accreditation (AU) Breakdown

Engineering Science	=	75 %
Engineering Design	=	25 %
Total AU's (57.3)	=	100 %

Course Schedule:

<u>Date</u>	<u>Lecture Topic</u>
Lecture 1	Introduction: Why NAPLs are important
Lecture 2	Conceptual models of subsurface contamination
Lecture 3	Darcy's Law and heterogeneity
Lecture 4	Groundwater flow equation
Lecture 5	Solute Transport and Sorption
Lecture 6	Interfacial physics
Lecture 7	Capillary pressure and scaling
Lecture 8	Relative permeability
Lecture 9	Multiphase Darcy's Law and flow equations
Lecture 10	Residual NAPL calculations
Lecture 11	Stable pool height calculations
Lecture 12	NAPL heights in observation wells
Lecture 13	Midterm Exam
Lecture 14	NAPLs in fractures
Lecture 15	NAPL dissolution
Lecture 16	Dissolved plume evolution
Lecture 17	Bulk soil sample analysis
Lecture 18	Multicomponent NAPLs and partitioning
Lecture 19	Remediation: Waterflooding
Lecture 20	Waterflooding case study
Lecture 21	Remediation: Steam and Chemical flooding
Lecture 22	Remediation: Thermal + case study
Lecture 23	Remediation: Surfactant and Alcohol enhanced solubilization
Lecture 24	Remediation: Bioremediation + case study
Lecture 25	Partial mass removal and alternative remedial objectives
Lecture 26	Review of Course Material

Evaluation:

The final course mark will be determined as follows:

Midterm	25%
Final examination	50%
Assignments	0%
Project	25%
Total	100%

Note: Students must pass all components to pass this course. (Students who have an average failing mark on any of their examinations, design project or assignments will be assigned the aggregate mark or 48%, whichever is smaller).

The document "*Instruction for students unable to write tests or examinations or submit assignments as scheduled*" IS ATTACHED AND IS PART OF THIS COURSE OUTLINE.



The University of Western Ontario
Faculty of Engineering
2009-2010

**INSTRUCTIONS FOR STUDENTS UNABLE TO WRITE TESTS
OR EXAMINATIONS OR SUBMIT ASSIGNMENTS AS SCHEDULED**

IF, ON MEDICAL OR COMPASSIONATE GROUNDS, YOU ARE UNABLE TO WRITE TERM TESTS OR FINAL EXAMINATIONS OR COMPLETE COURSE WORK BY THE DUE DATE, YOU SHOULD FOLLOW THE INSTRUCTIONS LISTED BELOW. YOU SHOULD UNDERSTAND THAT ACADEMIC ACCOMMODATION WILL NOT BE GRANTED AUTOMATICALLY ON REQUEST. YOU MUST DEMONSTRATE TO YOUR DEPARTMENT (OR THE UNDERGRADUATE SERVICES OFFICE IF YOU ARE IN FIRST YEAR) THAT THERE ARE COMPELLING MEDICAL OR COMPASSIONATE GROUNDS THAT CAN BE DOCUMENTED BEFORE ACADEMIC ACCOMMODATION WILL BE CONSIDERED. DIFFERENT REGULATIONS APPLY TO TERM TESTS, FINAL EXAMINATIONS AND LATE ASSIGNMENTS. READ THE INSTRUCTIONS CAREFULLY. (SEE THE 2009 UWO ACADEMIC CALENDAR).

A. GENERAL REGULATIONS & PROCEDURES

1. CHECK THE COURSE OUTLINE TO SEE IF THE INSTRUCTOR HAS A POLICY FOR MISSED TESTS, EXAMINATIONS, LATE ASSIGNMENTS OR ATTENDANCE.
2. BRING YOUR REQUEST FOR ACADEMIC ACCOMMODATION TO THE ATTENTION OF THE CHAIR OF YOUR DEPARTMENT (OR THE UNDERGRADUATE SERVICES OFFICE IF YOU ARE IN FIRST YEAR) PRIOR TO THE SCHEDULED TIME OF THE TEST OR FINAL EXAMINATION OR DUE DATE OF THE ASSIGNMENT. IF YOU ARE UNABLE TO CONTACT THE RELEVANT PERSON, LEAVE A MESSAGE WITH THE APPROPRIATE DEPARTMENT (OR WITH THE UNDERGRADUATE SERVICES OFFICE, IF YOU ARE IN FIRST YEAR). THE ADDRESSES, TELEPHONE AND FAX NUMBERS ARE GIVEN AT THE END OF THESE INSTRUCTIONS. DOCUMENTATION MUST BE PROVIDED AS SOON AS POSSIBLE.
3. IF YOU DECIDE TO WRITE A TEST OR AN EXAMINATION YOU SHOULD BE PREPARED TO ACCEPT THE MARK YOU EARN. REWRITING TESTS OR EXAMINATIONS OR HAVING THE VALUE OF A TEST OR EXAMINATION REWEIGHTED ON A RETROACTIVE BASIS IS NOT PERMITTED.

B. TERM TESTS

1. If you are unable to write a term test, inform your instructor and the Chair of your Department (or the Undergraduate Services Office if you are in first year) prior to the scheduled date of the test. If the instructor is not available, leave a message for him/her at the department office and inform the Chair of the Department (or the Undergraduate Services Office if you are in first year).
2. Be prepared to provide supporting documentation to the Chair and the Undergraduate Services Office (see next page for information on documentation).
3. Discuss with the instructor if and when the test can be rescheduled. **N.B.** The approval of the Chair (or the Undergraduate Services Office if you are in first year) is required when rescheduling term tests.

C. FINAL EXAMINATIONS

1. If you are unable to write a final examination, contact the Undergraduate Services Office **PRIOR TO THE SCHEDULED EXAMINATION TIME** to request permission to write a Special Final Examination. If no one is available in the Undergraduate Services Office, leave a message clearly stating your name & student number (please spell your full name).
2. Be prepared to provide the Undergraduate Services Office with supporting documentation (see next page for information on documentation) the next day, or as soon as possible (in cases where students are hospitalized). The following circumstances are not considered grounds for missing a final examination or requesting special examinations: common cold, sleeping in, misreading timetable and travel arrangements.
3. In order to receive permission to write a special examination, you must obtain the approval of the Chair of the Department **and** the Associate Dean and in order to apply you must sign a "Recommendation for a Special Examination Form" available in the Undergraduate Services Office. The Undergraduate Services Office will then notify the course instructor(s) and reschedule the examination on your behalf.

N.B. It is the student's responsibility to check the date, time and location of the special examination.

D. LATE ASSIGNMENTS

1. Advise the instructor if you are having problems completing the assignment on time (**prior** to the due date of the assignment).
2. Be prepared to provide documentation if requested by the instructor (see reverse side for information on documentation).
3. If you are granted an extension, establish a due date. The approval of the Chair of your Department (or the Associate Dean if you are in first year) is not required if assignments will be completed prior to the last day of classes.
4. i) Extensions beyond the end of classes must have the consent of the instructor, the department Chair and the Associate Dean. Documentation is mandatory.

- ii) A Recommendation of Incomplete Form must be filled out indicating the work to be completed and the date by which it is due. This form must be signed by the student, the instructor, the department Chair and the Associate Dean.

SHORT ABSENCES

If you miss a class due to a minor illness or other problems, check your course outlines for information regarding attendance requirements and make sure you are not missing a test or assignment. Cover any readings and arrange to borrow notes from a classmate.

EXTENDED ABSENCES

If you are absent more than one week or if you get too far behind to catch up, you should consider reducing your workload by dropping one or more courses. (Note drop deadlines listed below). You may want to seek advice from the academic counsellor in your Department or the counsellors in the Undergraduate Services Office if you are in first year.

DOCUMENTATION

If you consulted Student Health Services regarding your illness or personal problem, you should complete a Records Release Form in your Departmental Office (or in the Undergraduate Services Office if you are in first year). This form will be forwarded to Student Health Services who in turn will provide confirmation of the problem to the Department or Associate Dean as requested. At your request the Department (or Undergraduate Services Office if you are in first year) will send confirmation to your instructor(s).

If you were seen by an off-campus doctor, you must provide the doctor with a Student Medical Certificate to complete and then bring it to the Department (or the Undergraduate Services Office if you are in first year). **This note must contain the following information: severity of illness, effect on academic studies, duration of absence.**

In Case of Serious Illness of a Family Member: Provide a Student Medical Certificate to your family member's physician to complete and bring it to the Department (or the Undergraduate Services Office if you are in first year).

In Case of a Death: Obtain a copy of the death certificate or the notice provided by the funeral director's office. You must include your relationship to the deceased and bring it to the Department (or the Undergraduate Services Office if you are in first year).

For Other Extenuating Circumstances: If you are not sure what documentation to provide, ask the Departmental Office (or the Undergraduate Services Office if you are in first year) for direction.

Note: Forged notes and certificates will be dealt with severely. To submit a forged document is a scholastic offence (see below).

ACADEMIC CONCERNS

You need to know if your instructors have a policy on late penalties, missed tests, etc. This information may be included on the course outlines. If not, ask your instructor(s).

You should also be aware of attendance requirements in some courses. You can be debarred from writing the final examination if your attendance is not satisfactory.

If you are in academic difficulty, check out the minimum requirements for progression in the calendar. If in doubt, see your academic counsellor.

Calendar References: Check these regulations in your 2009 Western Academic Calendar:

Absences Due to Illness - page 25
Academic Accommodations for Disabled Students - page 26
Academic Accommodations for Religious or Holy Days - page 28
Course Withdrawals - pages 45-46
Debarred from Writing Examinations - page 38
Incomplete Standing - page 18
Scheduling of Term Assignments – page 39
Scholastic Offences - page 21-25
Special Examinations - page 37

Note: These instructions apply to all students registered in the Faculty of Engineering regardless of whether the courses are offered by the Faculty of Engineering or other faculties in the University.

<u>Drop Deadlines:</u>	First term half course (i.e. "A" or "F"):	October 15, 2009
	Full courses and full-year half courses (i.e. "E", "Y" or no suffix):	November 30, 2009
	Second term half or second term full course (i.e. "B" or "G"):	February 12, 2010

Undergraduate Services Office:	SEB 2097	telephone: (519) 661-2130	fax: (519) 661-3757
Dept. of Chemical and Biochemical Engineering:	TEB 477	telephone: (519) 661-2131	fax: (519) 661-3498
Dept. of Civil and Environmental Engineering:	SEB 3005	telephone: (519) 661-2139	fax: (519) 661-3779
Dept. of Electrical and Computer Engineering:	TEB 279	telephone: (519) 661-3758	fax: (519) 850-2436
Dept. of Mechanical and Materials Engineering:	SEB 3002	telephone: (519) 661-2136	fax: (519) 661-3020