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. Relevant analytical and numerical models are employed to better understand the concepts, their application, and the underlying mathematics. As well, the course covers field applications, including site investigation techniques as well as innovative clean-up technologies.

The objectives of the course are:

- Develop an understanding of 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.
- Solve mathematical relationships that describe multiphase flow in the subsurface and the partitioning of industrial liquids to other phases (vapour, soil, groundwater).
- Utilize mathematical and numerical modelling to investigate properties and problems related to the behaviour of these compounds.
- Demonstrate knowledge of established and innovative methods for site characterization and contaminant mapping and monitoring.
- Develop appreciation for a variety of established and innovative remediation techniques, both the processes that underpin them as well as their application;
- Explore how science, ethics, economics, and politics intersect to influence environmental policy and cleanup drivers.
- Appreciate the need for self-directed study and lifelong learning with respect to environmental issues and technologies.
**Calendar Copy:**
This course deals with soil and groundwater contamination by organic industrial liquids. Multiphase flow through porous media will be covered, linking key physics and chemistry to contaminant behaviour in the field. Relevant analytical and numerical models are employed. Practical aspects covered include site investigation techniques and innovative clean-up technologies.

**Prerequisites:**
For 4479 Students: CEE 3386a/b Numerical Modelling for Environmental Engineers
For 9890 Students: An upper year course in Groundwater Flow & Contaminant Transport
In exceptional circumstances, by permission of the instructor.

**Corequisites:**
None.

**Antirequisites:**
None

Note: It is the student's responsibility to ensure that all Prerequisite and Corequisite 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 they have not taken a course listed as an Antirequisite. The student may be dropped from the course or not given credit for the course towards their degree if they violate the Prerequisite, Corequisite or Antirequisite conditions.

**Contact Hours:**
3 lecture hours/week
Lectures will be delivered synchronously through ZOOM (and simultaneously recorded for later posting to the course OWL site). Lectures will be organized into learning modules which students should review on a weekly basis. Review of lecture material and self-study should take approximately 6 hours per week.

This lecture session will also incorporate live questions and discussion to support the learning objectives and gain participation marks. The instructor will actively engage students by using iClicker in real time. Tutorials will not be recorded to allow free and open discussion and to not inhibit any questions or opinions. If you are unable to attend on a regular basis for a specific reason, please contact the instructor at the beginning of the term to explain and discuss possible alternative arrangements in exceptional circumstances.

Lectures are scheduled weekly for Mondays 10:30 – 12:30 am via Zoom (link can be found on course OWL site). The first will be on Monday September 14.
Instructor:

Dr. Jason I. Gerhard; e-mail: jgerhard@uwo.ca

Office hours: scheduled for Mondays 12:30 pm – 1:30 pm via Zoom (link can be found on course OWL site).

Teaching Assistant: Jiahao Wang; email: jwan753@uwo.ca

Administrative Assistant: Sandra McKay; email: smckay@uwo.ca

Textbook:
None required. Comprehensive notes will be provided and discussed during the class. Supplementary readings will be provided.

General Learning Objectives

<table>
<thead>
<tr>
<th>Problem Analysis</th>
<th>E(A)</th>
<th>Team Work</th>
<th>Ethics and Equity</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigation</td>
<td></td>
<td>Communication</td>
<td>E(A)</td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td>T</td>
<td>Professionalism</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td>Engineering Tools</td>
<td>E(A)</td>
<td>Impact on Society</td>
<td>T</td>
<td>E(A)</td>
</tr>
</tbody>
</table>

Course Schedule and Topics:

<table>
<thead>
<tr>
<th>Date</th>
<th>Lecture Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td>Course outline, introduction, historical legacy</td>
</tr>
<tr>
<td>Week 2</td>
<td>NAPL physical properties</td>
</tr>
<tr>
<td>Week 3</td>
<td>NAPL chemical properties</td>
</tr>
<tr>
<td>Week 4</td>
<td>Capillary pressure</td>
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<tr>
<td>Week 5</td>
<td>Relative permeability</td>
</tr>
<tr>
<td>Week 6</td>
<td>Phase Partitioning</td>
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<tr>
<td>Week 7</td>
<td>DNAPL pools and multiphase flow equations</td>
</tr>
<tr>
<td>Week 8</td>
<td>MIDTERM</td>
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<tr>
<td>Week 9</td>
<td>Reading Week</td>
</tr>
<tr>
<td>Week 10</td>
<td>DNAPL modelling and field behaviour</td>
</tr>
<tr>
<td>Week 11</td>
<td>Site remediation introduction</td>
</tr>
<tr>
<td>Week 12</td>
<td>Remediation presentations</td>
</tr>
<tr>
<td>Week 13</td>
<td>Remediation presentations &amp; Review</td>
</tr>
</tbody>
</table>

The instructor may expand, revise, or reschedule material presented in the course as appropriate.
**Evaluation:**

The final course mark will be determined as follows:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Participation</th>
<th>Assignments</th>
<th>Midterm Test</th>
<th>Mini-Project</th>
<th>Written Final Examination</th>
<th>Oral Final Examination</th>
</tr>
</thead>
<tbody>
<tr>
<td>4479</td>
<td>10%</td>
<td>20%</td>
<td>15%</td>
<td>10%</td>
<td>35%</td>
<td>10%</td>
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<tr>
<td>9890</td>
<td>5%</td>
<td>10%</td>
<td>15%</td>
<td>10%</td>
<td>15%</td>
<td>35%</td>
</tr>
</tbody>
</table>

1. **Midterm Test and Exam:**

A two-hour midterm test will be held during regular class hours. This is tentatively scheduled for 10:30 am – 12:30 pm, Monday, October 26.

A three-hour written final examination will be held during the regular examination period. The date and time will be scheduled by the Registrar’s office and sometime in the middle of the term. After the written final exam has been marked (i.e., approximately one week later), a 15-minute oral examination will be conducted between the professor and the student in which the written examination answers as well as follow-up questions will be posed and discussed.

Both the midterm test and final examination will be open book exams. They must be completed by the individual student without any external help or collaboration. Ensuring this is the case will be part of the oral final exam. Also, both the midterm test and final examination answers will be submitted via Turnitin to ensure no copying or plagiarism (from other students or from material on the internet). Moreover, the student will be required to be on Zoom, with video on, throughout the exam to allow remote proctoring (more details below).

2. **Assignments:**

Assignments will be given on a bi-weekly basis. They are long assignments, covering 2 weeks worth of material, so do not put off starting them and ensure you dedicate adequate time to completing them. You can discuss the assignments with colleagues, but ensure the answer you submit are yours alone. All written submissions will be passed through Turnitin to ensure no copying or plagiarism. Assignments are to be submitted prior to the due date to OWL. Late assignments will be assessed a penalty of 10% per day, to a maximum of 4 days, after which they will receive a mark of zero. Extensions are to be negotiated with the course instructor, not the teaching assistants.
The maximum number of missed assignments for each student will be one; if more than one assignment is missed a student may be barred from writing the final exam. Only a selection of questions will be marked in each assignment, but the questions to be marked will not be determined or announced in advance. The intention is for students to complete the entire assignment in order to maximize learning the course material.

3. **Mini-Project:**

Both graduate and undergraduate students will complete a mini-project. This is, in essence, a more in-depth assignment that involves integrating much of the learning in the course. Considerable guidance is given in lectures and tutorials. The majority of this will be conducted in the final four weeks of the course.

4. **Graduate Project:**

Graduate students will conduct a research project and present their findings via an oral presentation on a specialized topic relevant to the course. There is considerable flexibility and choice in the topic. Further details will be provided in a special lecture and tutorial on the project.

5. **Participation**

Participation is an important component of this course. It will be assessed in primarily three ways:

(a) Attendance at classes, live participation in classes, and participation in the test-your-learning quizzes using iClicker which will occur during the classes.

(b) Posting to the online discussion forums in OWL.

(c) Viewing and participating in Project presentations. This may include asking questions in real-time, or asking and answering questions asynchronously (e.g., via Forum or VoiceThread).

**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.

**Plagiarism:**

Students must write their assignments and exams in their own words. Whenever students take an idea, or a passage from a source, they must acknowledge that source by proper referencing such as footnotes or citations. Plagiarism is a major academic offence (see Scholastic Offence Policy in the Western Academic Calendar).

All required papers or essay-style submissions may be subject to submission for textual similarity review to the commercial plagiarism detection software under license to the University for the detection of plagiarism. All papers submitted for such checking will be included as source documents in the reference database for the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between The University of Western Ontario and Turnitin.com.
(http://www.turnitin.com). For numerical submissions, teaching assistants will be checking for evidence of copying; excessive similarity between assignments will be taken as evidence of plagiarism at the discretion of the course instructor.

**Cheating:**
University policy states that cheating is a scholastic offence. The commission of a scholastic offence is attended by academic penalties that might include expulsion from the program. If you are caught cheating, there will be no second warning.
For more information on scholastic offenses, please see:  
http://www.uwo.ca/univsec/handbook/appeals/scholastic_discipline_undergrad.pdf

**Attendance:**
Any student who, in the opinion of the instructor, has not engaged sufficiently in class, laboratory, or tutorial periods 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 final examination in the course.

**Accommodation:**
(I) For Undergraduate Students 
Students with disabilities work with Accessible Education (formerly SSD) which provides recommendations for accommodation based on medical documentation or psychological and cognitive testing. The accommodation policy can be found here: Academic Accommodation for Students with Disabilities.

(II) For Graduate Students 
Please contact the course instructor if you require material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Accessible Education at 661-2111 x 82147 or http://academicsupport.uwo.ca/accessible_education/index.html, for any specific question regarding an accommodation.

**Academic Consideration for Student Absence**
(I) For Undergraduate Students 
Students will have up to two (2) opportunities during the regular academic year to use an on-line portal to self-report an absence during the term, provided the following conditions are met: the absence is no more than 48 hours in duration, and the assessment for which consideration is being sought is worth 30% or less of the student’s final grade. Students are expected to contact their instructors within 24 hours of the end of the period of the self-reported absence, unless noted on the syllabus. Students are not able to use the self-reporting option in the following circumstances:

- for exams scheduled by the Office of the Registrar (e.g., December and April exams)
- absence of a duration greater than 48 hours,
- assessments worth more than 30% of the student’s final grade,
- if a student has already used the self-reporting portal twice during the academic year

If the conditions for a Self-Reported Absence are not met, students will need to provide a Student Medical Certificate if the absence is medical, or provide appropriate documentation if there are compassionate grounds for the absence in question. Students
are encouraged to contact their Faculty academic counselling office to obtain more information about the relevant documentation.

Students should also note that individual instructors are not permitted to receive documentation directly from a student, whether in support of an application for consideration on medical grounds, or for other reasons. **All documentation required for absences that are not covered by the Self-Reported Absence Policy must be submitted to the Academic Counselling office of a student's Home Faculty.**

For Western University policy on Consideration for Student Absence, see [Policy on Academic Consideration for Student Absences - Undergraduate Students in First Entry Programs](http://www.uwo.ca/univsec/pdf/academic_policies/appeals/medicalform.pdf).

(II) For Graduate Students

Students should immediately consult with the Instructor (for a particular course) or Associate Chair (Graduate) (for a range of courses) if they have problems that could affect their performance. The student should seek advice from the Instructor or Associate Chair (Graduate) regarding how best to deal with the problem. Failure to notify the Instructor or the Associate Chair (Graduate) immediately (or as soon as possible thereafter) will have a negative effect on any appeal. Obtaining appropriate documentation (e.g., a note from the doctor) is valuable when asking for accommodation due to illness.

**Religious Accommodation**

Students should consult the University's list of recognized religious holidays, and should give reasonable notice in writing, prior to the holiday, to the Instructor and an Academic Counsellor if their course requirements will be affected by a religious observance. Additional information is given in the [Western Multicultural Calendar](http://www.uwo.ca/univsec/pdf/academic_policies/appeals/medicalform.pdf).

**Use of Recordings:**

All of the remote learning sessions for this course may be recorded. The data captured during these recordings may include your image, voice recordings, chat logs and personal identifiers (name displayed on the screen). The recordings will be used for educational purposes related to this course, including evaluations. The recordings may be disclosed to other individuals under special circumstances. Please contact the instructor if you have any concerns related to session recordings.

The lecture notes and online lecture videos and tutorial sessions are copyrighted to the instructor and legally protected. Do not post these videos and lecture notes on any other website or online forums. The recording of the live/synchronous sessions of the course without the permission from the instructor is prohibited. The illegal posting and sharing of the copyrighted course content could be subjected to legal actions.

Participants in this course are not permitted to record any material or sessions, except where recording is an approved accommodation, or the participant has the prior written permission of the instructor.
**Conduct:**

Some components of this course will involve online interactions. To ensure the best experience for both you and your classmates, please honour the following rules of etiquette:

- please “arrive” to class on time
- please use your computer and/or laptop if possible (as opposed to a cell phone or tablet)
- ensure that you are in a private location to protect the confidentiality of discussions in the event that a class discussion deals with sensitive or personal material
- to minimize background noise, kindly mute your microphone for the entire class until you are invited to speak, unless directed otherwise
- please be prepared to turn your video camera off at the instructor’s request if the internet connection becomes unstable
- unless invited by your instructor, do not share your screen in the meeting

The course instructor will act as moderator for the class and will deal with any questions from participants. To participate please consider the following:

- if you wish to speak, use the “raise hand” function and wait for the instructor to acknowledge you before beginning your comment or question
- remember to unmute your microphone and turn on your video camera before speaking
- self-identify when speaking.
- remember to mute your mic and turn off your video camera after speaking (unless directed otherwise)

General considerations of “netiquette”:

- Keep in mind the different cultural and linguistic backgrounds of the students in the course.
- Be courteous toward the instructor, your colleagues, and authors whose work you are discussing.
- Be respectful of the diversity of viewpoints that you will encounter in the class and in your readings. The exchange of diverse ideas and opinions is part of the scholarly environment. “Flaming” is never appropriate.
- Be professional and scholarly in all online postings. Cite the ideas of others appropriately.

Note that disruptive behaviour of any type during online classes, including inappropriate use of the chat function, is unacceptable. Students found guilty of Zoom-bombing a class or of other serious online offenses may be subject to disciplinary measures under the Code of Student Conduct.

**Online Proctoring Notice:**

Tests and examinations in this course will be proctored using Zoom. You will be required to keep your camera on for the entire session, hold up your student card for identification purposes, and share your screen with the invigilator if asked to do so at any time during the exam. The exam session will not be recorded.*

More information about the use of Zoom for exam invigilation is available in the Online Proctoring Guidelines at the following link: https://www.uwo.ca/univsec/pdf/onlineproctorguidelines.pdf.

Completion of this course will require you to have a reliable internet connection and a device that meets the system requirements for Zoom. Information about the system requirements are available at the following link:
* Please note that Zoom servers are located outside Canada. If you would prefer to use only your first name or a nickname to login to Zoom, please discuss this with your instructor in advance of the test or examination.

**Notice:**
Students are responsible for regularly checking their email, course website (https://owl.uwo.ca) and notices posted outside the Civil and Environmental Engineering Department Office.

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

**Accreditation (AU) Breakdown**
- Engineering Science = 75%
- Engineering Design = 25%
- Total AU’s (57.3) = 100%

The document “INSTRUCTIONS FOR STUDENTS UNABLE TO WRITE TESTS OR EXAMINATIONS OR SUBMIT ASSIGNMENTS AS SCHEDULED” is part of this course outline.