Geology 474/574
Ground Water Contamination
Winter 2017

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Office Hours: MWF from 9:00 to 10:00 am, or by arrangement
Textbook: *Contaminant Hydrogeology*, 2nd Edition, C. W. Fetter, Waveland Press Inc., 1999

Couse Description

Groundwater Contamination focuses the physical, chemical, and biological processes that govern the transport and fate of chemical contaminants in groundwater. Fate topics will be restricted to organic compounds or non-aqueous phase liquids (NAPLs), and will include factors such as the partitioning processes that govern the mass transfer between the air, liquid, NAPLs, and solid grain phases. Bacteria metabolic processes and the environmental conditions that control the destruction of NAPLs will be examined. Remediation technologies will be introduced as a means to review the theoretical factors that control the fate and transport of chemicals in groundwater. Area 6, a groundwater contaminated Superfund site on the Naval Air Station on Whidbey Island, will be examined as a case study. Please see the **learning outcomes** for this course at the end of the syllabus.

Assessment

Problem Sets

You will complete about five problem sets during the quarter (35% of the grade). One of the learning outcomes of a problem set is to develop a deeper understanding of a physical, chemical, and biological process by applying a mathematical modeling approach through software applications using Mathcad. You will apply and manipulate equations and examine what variables are most important in the equations (i.e., a parameter sensitivity analysis). During this process you generate plots and results and make *observations*. A second objective is to process your thoughts about the results in writing. A <u>one-paragraph</u> discussion after each problem allows you to metacognitively process your thinking (and *learning)* by writing out *inferences* about your *observations*.

Exams

I give one midterm and a final exam. The final exam is weighted more on the second half of the course. My exams are typically short answer essay with an emphasis on process description. I want you to be able to explain in words what controls a chemical fate or transport process. Sometimes I integrate problems that require equation manipulation and calculations. I provide an equation sheet with each exam.

Graduate Student Projects

The graduate students will be required to do an additional research project if they are taking this course at the graduate level.

Grading

The grading breakdown will be as follows: (a curve is possible, but not certain)

Homework	35% (25% for graduate students and 10% for the term project)
Midterm Exam	30%
Exam	35% (Tuesday, March 14, 3:30 - 5:30 pm)

A grading scale will be as follows (a curve is possible but not certain):
100-93 = A, 92-90 = A-, 89-88 = B+, 87-83 = B, 82-80 = B-, 79-78 = C+, 77-73 = C, 72-70 = C-, 69-68 = D+, 67-63 = D, 62-60 = D-, 60 or below = F

Academic honesty is an important part of every course at WWU. For students, academic integrity means challenging yourself, striving for excellence, taking risks and learning from your mistakes, doing your own work, and giving credit whenever you use the work of others. It boils down to caring about your schoolwork and always being honest in carrying it out.

I begin with the assumption that you come to Western and this class with integrity. However, academic integrity and honesty can be challenging due to such things as ignorance, confusion, stress, bad advice, and bad choices. So to help you keep your integrity and good reputation intact, I have resources for you (meaning, by the way, that ignorance will not be an excuse):

- WWU's Integrity Website http://www.wwu.edu/integrity/ provides all the information you need, including why integrity is important, how to promote it, as well as types of academic dishonesty and how to avoid them, particularly plagiarism. It also includes WWU's policy and procedures on academic honesty (appendix D of the WWU Catalog).

- See me if you have any concerns or questions about academic integrity regarding yourself or your classmates. An ounce of prevention is worth a pound of cure, especially where penalties and one's reputation are at stake. I am here to help. Please read the Integrity section

If you have a documented **disability** you must report to me during the first week of class to discuss your needs. If you need disability-related accommodations, please notify Student Support Services at 650-3083 (phone) or 650-3725 (TTY) or http://www.wwu.edu/depts/drs/ Please feel free to **talk to me** anytime about your performance in the course or possible ways you can improve.

Attendance is not required but it is expected. It is your responsibility to get notes for the classes you miss. I encourage you to visit my office for help and clarification, but do not use my office hours to obtain lecture material that you miss (unless you have an excused absence).

Your **professional conduct** in this course is important. I facilitate my courses in a professional manner and have the same expectations of you. By professional, I mean having a respectful demeanor, arriving to class on time, no texting or internet surfing during class, communicating with courteous emails, producing neat organized and well written student works, and by all means, maintaining academic honesty. Think about how you would like me to communicate your professionalism to a potential employer.

I am committed to establishing and maintaining a classroom climate that is inclusive and respectful for all students and an environment free of discrimination and harassment. Federal and State laws, as well as WWU University policies, protect students, faculty and staff against discrimination.

I reserve the right to change the syllabus as required throughout the term to better meet the instructional needs of the class.

Groundwater Contamination Topics

Introduction (Chapter 1)

1. Groundwater--what is it, where is it, and why is it important?
2. Sources of ground water contamination
3. Drinking water standards

Physical mass transport in saturated media (Chapter 2)

4. Molecular diffusion in air, liquids, and porous media—Fick's 1st Law
5. Molecular diffusion and Fick's 2st Law
6. Transport by advection
7. Mechanical dispersion and dispersivity
8. Scale of effects of dispersivity and estimating dispersivity
9. The advection-dispersion equation (PDE) and applications

Mass transport in unsaturated media (Chapter 4)

10. Unsaturated water flow
11. Physical nonequilibrium and mobile-immobile mass exchange
12. Physical diffusion model
13. The advection-dispersion equation (PDE) and applications in unsaturated porous media

Sorption and retardation of organic contaminants (Chapter 3 and Chapter 7)

14. Introduction to organic compounds (hydrophobic non-aqueous phase liquids (NAPLs))
15. Equilibrium reactions and sorption isotherms
16. Sorption (partitioning) coefficients (K_d)
17. Relating sorption to aquifer organic carbon (OC) and to octanol-water portioning coefficients (K_{ow})
18. The Retardation factor and the advection-dispersion equation (PDE) and applications

MIDTERM EXAM

Organic compounds in ground water (Chap 7, Sec 7.1-7.5)

16. Physical properties of organic compounds (NAPLs)
17. Organic structure and nomenclature

Biodegradation of organic compounds (Chapter 3, Sec 3.9 and Chapter 7, Sec 7.6-.77)

18. Basic requirement for biodegradation in aquifers
19. Aerobic and anaerobic biodegradation
20. Electron acceptors and REDOX chemistry around a contaminant plume
21. Natural attenuation biodegradation in NAPL contaminated aquifers
22. The advection-dispersion equation coupled with biodegradation processes in multiple dimensions
23. Applications at Area 6 on the Naval Air Station

Multiphase fluid flow (Chapter 5)

24. Saturation, interfacial tension, wettability, and capillarity
25. Vapor pressures, solubilities, and mass transfer between phases
26. Relative permeability and Darcy's Law for two-phase flow
27. Two-phase flow equations (PDEs)

Site remediation (Chapter 9)

28. Pump-and-treat, soil-vapor extraction, air stripping, activated carbon, NAPL skimming

Learning Outcomes for Geology 474/574

GEOL 473 Course Student Learning Outcomes: Student will understand:

1. **sources of groundwater contamination**
   Course objectives: Students will be able to:
   a. describe common point and nonpoint sources of groundwater contamination
   b. describe common fuel and solvent contaminants

2. **the physical transport processes of contaminants in groundwater**
   Course objectives: Students will be able to:
   a. determine what controls molecular diffusion in air, water, and saturated and unsaturated porous media
   b. determine what controls mechanical mixing in saturated and unsaturated porous media
   c. quantify the hydrodynamic dispersion coefficient
   d. apply the advection-dispersion equation for solutes in multiple dimensions

3. **the mass transfer processes that influence the transport of non-aqueous phase liquids (NAPLs) in groundwater**
   Course objectives: Students will be able to:
   a. determine the sorption (partitioning) coefficient for NAPLs given an aquifer organic carbon (OC) content or an octanol-water partition coefficient (K_{ow})
   b. estimate the retardation factor for organic compounds
   c. apply the advection-dispersion equation that considers sorption processes in multiple dimensions
   d. apply Henry's law for partitioning between air and water
   e. apply Raoult's law for partitioning between NAPL and air
   f. estimate partitioning between NAPL and water given a compounds solubility

4. **fate processes, specifically the biodegradation of organic compounds in groundwater**
   Course objectives: Students will be able to:
   a. describe the basic requirement for biodegradation in aquifers
   b. distinguish between aerobic and anaerobic biodegradation
   c. determine electron acceptors given REDOX chemistry around a contaminant plume
   d. assess natural attenuation biodegradation in NAPL contaminated aquifers
   e. apply the advection-dispersion equation that considers biodegradation processes in multiple dimensions
5. **common remediation technologies used to clean up contaminated aquifers**
   Course objectives: Students will be able to:
   a. link theory of fate and mass transfer process discussed in class with the design of remediation technologies in unsaturated and saturated porous media

GEOL 574 Course Student Learning Outcomes: Student will understand:

1. **the GEOL 474 course outcomes and objectives**

2. **how to analyze and interpret scientific data**
   Course objectives: Students will be able to:
   a. Apply fate and transport principles to a topic outside the realm of GEOL 474.

Geology 474/574 – Groundwater Contamination provides information for the following Geology degree program outcomes:

	B.A. Geology	B.S. Geology	B.S. Geophysics	GUR	M.S. Geology
Outcomes	*2. Earth's surface is affected by dynamic processes on a range of timescales.* *7. Graduates have developed their observational, analytical and quantitative skills (field, lab, computer, and classroom)*	*2. Earth's surface is affected by dynamic processes on a range of timescales.* *7. Graduates have developed their observational, analytical and quantitative skills (field, lab, computer, and classroom)* *10. Graduates (alone or in teams) will be able to present geological information clearly*	*2. Earth's surface is affected by dynamic processes on a range of timescales.* *7. Graduates have developed their observational, analytical and quantitative skills (field, lab, computer, and classroom)* *10. Graduates (alone or in teams) will be able to present geological information clearly*	*1. Analyze and communicate ideas effectively in oral, written, and visual forms.* *3. Use quantitative and scientific reasoning to frame and solve problems.*	*3. Analyze and interpret scientific data;* *4. Communicate scientific concepts and results effectively through both written and oral means, and to a range of audiences.*