Environmental Soil Chemistry
SOCR 567
4 Credits (3-0-1)

Professor

Dr. Thomas Borch is the instructor for this class. He is a Professor in the Department of Soil and Crop Sciences and in the Department of Chemistry and can be reached by email Thomas.Borch@ColoState.Edu or by phone 970-491-6235. His office hours: open door policy.

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Lecture Description SOCR567 (3 credits)

Our focus will be the chemistry of terrestrial environments and the interactions of soil constituents with bacteria, organic carbon, nutrients and pollutants.

The class will be taught in the spring semester for 3 credits with Monday, Wednesday and Friday lectures from 9:00 – 9:50 am in the Plant Science Building Room W1.

Recitation Description SOCR567 (1 credit)

In addition to the lectures students will critically review (1 page written reviews are required from all of the students each week) and discuss scientific peer-reviewed journal articles that are relevant to the lecture section of this course. In addition, specific questions need to be answered for each of the articles reviewed. Each week one student will in addition to the written review also present (using PowerPoint) the paper for the class - this presentation will then be followed by questions and discussion concerning the presented paper. The recitation will be taught in the spring semester for 1 credit with a Friday recitation from 8:00 – 8:50 am in the Plant Science Building Room W1.

Learning Objectives SOCR567

- Students will learn fundamental principles of soil and environmental chemistry such as sorption/desorption, ion exchange, precipitation, dissolution, oxidation-reduction, polymerization, and hydrolysis.
- Students will learn synchrotron-based spectroscopic techniques used in molecular environmental chemistry.
- Students will learn to evaluate the environmental importance of specific interactions among soil constituents, nutrients and pollutants.
- Students will learn soil and environmental biogeochemical processes important for the development of soils and the fate of nutrients and pollutants.
- Students will learn to write and orally present a scientific report based on an environmental soil chemistry case study
- Students will learn state-of-the-art soil (bio)remediation theories and strategies
- Students will learn to read and critically evaluate peer-reviewed literature on topics related to Environmental Soil Chemistry.

- Students will learn to write and orally present an advanced scientific report based on an environmental chemistry case study

- Students will learn to solve advanced environmental soil chemistry problem sets

Policies

Note sheets are allowed for the final exam: Students can bring two pages (one-sided) typed/handwritten or one page (two-sided) typed/handwritten with notes for the final exam. Additional information: Cheating is unacceptable and will be reported.

Required Textbook

Title : Soil and Water Chemistry: An Integrative Approach
Author : Michael E. Essington
Publisher : CRC Press
Edition/Year : 2nd edition/2015
ISBN : 9781466573154
Additional information : none
Type : Required resource

Other Recommended Textbooks

Title : Environmental Soil Chemistry (2nd Edition)
Author : Donald L. Sparks
Publisher : Academic Press
Edition/Year : 2002
ISBN : 0-12-656446-9
Additional information : none
Type : Highly Recommended resource

Title : Environmental Chemistry of Soils
Author : Murray B. McBride
Publisher : Oxford University Press, Inc.
Edition/Year : 1994
ISBN : 0-195-07011-9
Additional information : none
Type : Recommended resource

Evaluation SOCR567

This class will meet jointly with SOCR467 for 3 hours of lecture per week. However, the recitation section will be separate from the undergraduate class. In addition, the graduate students will be graded separately from the undergraduate students on all assignments and the home work sets, take-home exam as well as the final exam will require more integrative and in-depth understanding of the lecture material.

The lecture portion will be evaluated as detailed below. The four problem sets will consist of multiple questions that relate to the chemistry learnt in-class and will require many advanced calculations/quantitative answers which will be evaluated by the instructor. The take home exam will be a group project that will apply the chemistry learnt in-class to solve a realistic environmental problem. This project will be evaluated based on a written report and an oral defense of the project. The final exam will include short answers and calculations. Students will review journal articles during the recitation sections and learn about how to review and write a scientific article. The graduate students will meet with the professor in a separate recitation time for further discussion of lecture topics and student presentation of the readings. The papers to be reviewed are related to the topics (book chapters) that will be covered during the lectures. The papers to be reviewed will be selected to provide the students with current state-of-knowledge of the topics from the lecture sections. Graduate students will be expected to contribute to the discussion of the journal articles in recitation and to write a 1 page (single spaced) review of each article. The reviews will summarize the main points of the paper and critique the authors arguments.

Based on a percent scale where 100% is the highest obtainable grade the students will be evaluated as follows:

In-class participation (5%)

Four Problem sets (40%; 10% each)

Take-home exam (25%; written part 15% and oral part 10%)

Final exam (20%)

Recitation (10%)

Prerequisite SOCR567

CHEM 331 (Quantitative Analysis) or similar course

Lecture Outline and Reading Assignments SOCR567 (use it as a guide since it might not align 100% with the lectures)

Lesson 1
Objectives : Introduction to Environmental Soil Chemistry
Topics : History, Evolution, and Contaminants in Waters and Soils
Readings : Chapter 1 in Essington
Suggested Readings: Chapter 1 in Sparks
Lesson 2
Objectives : Introduction to Molecular Environmental Soil Chemistry
Topics : Advanced Analytical Techniques such as Synchrotron Radiation Based Techniques
Suggested Readings : Chapter 1 in Sparks
Lesson 3
Objectives : Review of Chemical Principles
Topics : Types of chemical bonding, Activity, Thermodynamic Properties
Readings : Chapter 1 in MB McBride
Lesson 4
Objectives : Review of Chemical Principles
Topics : Equilibrium Constants, Solubility Products, Acidity/Basicity Constants, Complexations and

Chelation Reactions
Readings : Chapter 1 in MB McBride

Lesson 5
Objectives : Review of Chemical Principles
Topics : Electrochemistry, Kinetics,
Readings : Chapter 1 in MB McBride

Lesson 6
Objectives : Learn About Important Inorganic Soil Components
Topics : Paulings Rule, Primary Soil Minerals
Readings: Chapter 2 in Essington
Suggested Readings : Sparks Chapter 2; pp 43-51

Lesson 7
Objectives : Learn About Important Inorganic Soil Components
Topics : Secondary Soil Minerals, Clay Groups
Readings Chapter 2 in Essington
Suggested Readings : Sparks Chapter 2 pp 51-59

Lesson 8
Objectives : Learn About Important Inorganic Soil Components
Topics : Oxides, Hydroxides, Oxyhydroxides, Surface Area, CEC, XRD,
Readings: Essington Chapter 2
Suggested Readings : Sparks chapter 2 pp 59-73

Lesson 9
Objectives : Learn about the chemistry of soil organic matter (SOM)
Topics : Carbon cycling, composition of SOM
Readings: Chapter 4 in Essington
Suggested Readings : Sparks chapter 3, pp 75 - 88

Lesson 10
Objectives : Learn about SOM Chemistry
Topics : SOM fractionation, Structure, and Charge
Readings: Chapter 4 in Essington
Suggested Readings : Sparks chapter 3 pp 88 - 101

Lesson 11
Objectives : Learn about SOM chemistry relevant to environmental processes
Topics : SOM-Metal interactions, SOM-Clay Complexes, and retention of pesticides by humic substances
Readings: Chapter 4 in Essington
Suggested Readings : Sparks chapter 3 pp 101-113

Lesson 12
Objectives : Learn about soil solution-solid phase equilibria
Topics : 1) Measurement and speciation of the soil solution. Review ion activity and activity coefficients (self-study)
Readings: Chapter 5 in Essington
Suggested Readings : Sparks chapter 4 p 115-126

Lesson 16
Objectives : Learn about soil solution-solid phase equilibria
Topics : Dissolution and Solubility Processes
Readings: Chapter 5 in Essington
Suggested Readings : Sparks chapter 4 p 127-132

Lesson 17
Objectives : Learn about sorption phenomena
Topics : Terminology, surface functional groups, surface complexes
Readings: Chapter 7 in Essington
Suggested Readings : Sparks chapter 5 p 133 - 144

Lesson 18
Objectives : Learn about surface complexation, sorption isotherms and equilibrium-based adsorption models

Topics : Surface complexes; Freundlich and Langmuir equations
Readings: Chapter 7 in Essington
Suggested Readings: Sparks chapter 5 p 144 - 151

Lesson 19

Objectives : Learn about Double-Layer Theory and Models
Topics : Gouy-Chapman Model, diffuse electric double-layer model/calculations,
Readings: Chapter 7 in Essington
Suggested Readings : Sparks chapter 5 p 151 -155

Lesson 20

Objectives : Learn about Double-Layer Theory and Models
Topics : Gouy-Chapman Model
Readings: Chapter 7 in Essington
Suggested Readings : Sparks chapter 5 p 155-159

Lesson 21

Objectives : Learn about the Stern Theory and sorption of metal cations and anions
Topics : Stern Theory, deficiencies of double-layer models, sorption of metal cations and of anions
Readings: Chapter 7 in Essington
Suggested Readings : Sparks chapter 5 p 159-163 (on p 163 only Fig. 5.16); p 172-176

Lesson 22

Objectives : Learn about surface precipitation
Topics : surface precipitation, speciation of metal-contaminated soils
Readings: Chapter 7 in Essington
Suggested Readings : Sparks chapter 5 p 177-182

Lesson 23

Objectives : Learn about points of zero charge and ion exchange processes
Topics : pzc, CEC, AEC
Readings: Chapter 7 and 8 in Essington
Suggested Readings : Sparks chapter 5 and 6 p 183 - 190

Lesson 24

Objectives : To learn about Ion Exchange Processes
Topics : CEC constants, selectivity coefficients, thermodynamics of ion exchange
Readings: Chapter 8 in Essington
Suggested Readings : Sparks chapter 6 p 192 - 194

Lesson 25

Objectives : Learn about thermodynamics of ion exchange and "experimental" interpretations
Topics : delta G, H, and S for an ion exchange process and calculation of equilibrium exchange constants, selectivty coefficients, and exchanger phase activity coefficients.
Readings: Chapter 8 in Essington
Suggested Readings : Sparks chapter 6 p 195 -205

Lesson 26

Objectives : Discuss the objectives of the different case studies in the Take-Home Exam.
Topics : Fate and transport of nutrients, contaminants, pharmaceuticals, and organic matter.
Readings : None
Assignments : Take-Home Exam

Lesson 27

Objectives : Learn about kinetics of soil chemical processes
Topics : Rate limiting steps, time scales of chemical reactions, rate laws, reaction order, rate constants, kinetic models
Readings : Sparks chapter 7 p 207-215

Lesson 28

Objectives : Learn about kinetic models and methodologies
Topics : Elovic equation, parabolic diffusion equation, fractional power, flow methods anf relaxation techniques
Readings : Sparks chapter 7 p 215 -228

Lesson 29

Objectives : Learn about Kinetics of important soil chemical processes
Topics : kinetics of sorption-desorption reactions, precipitation/dissolution reactions, organic contaminants, ion exchange
Readings : Sparks chapter 7 p 228 - 238

Lesson 30
Objectives : Learn about kinetics of mineral dissolution and redox chemistry of soils
Topics : rate-limiting steps, surface-controlled dissolution, ligand-promoted dissolution, proton-promoted dissolution, oxidation-reduction reactions and potentials, Eh vs pH and pe vs pH diagrams
Readings : Sparks chapter 7 p 238 - 244 and Sparks chapter 8 p 245 - 253

Lesson 31
Objectives : Learn about important redox processes
Topics : pe - pH diagrams, and impact of Fe (bio)reduction on the fate and transport of nutrients and contaminants
Readings: Chapter 9 in Essington
Suggested Readings : Sparks chapter 8 p 251 -265

Lesson 32
Objectives : Learn about Redox Chemistry of Soils
Topics : Measurement and use of redox potentials, and important redox reactions in soils
Readings: Chapter 9 in Essington
Suggested Readings : Sparks chapter 8 p 253 -265

Lesson 33
Objectives : Learn about the chemistry of soil acidity
Topics : acid rain, mine spoil and acid sulfate soils, solution chemistry of aluminum, (non)exchangeable Al
Readings: Chapter 10 in Essington
Suggested Readings : Sparks Chapter 9 p 267 - 277

Lesson 32
Objectives : Learn about soil acidity
Topics : titration analyses, liming soils
Readings: Chapter 10 in Essington
Suggested Readings : Sparks chapter 9 p 277 -283

Lesson 33
Objectives : Learn about the chemistry of saline and sodic soils
Topics : irrigation water quality, sources of soluble salts, total dissolved solids (TDS), electrical conductivity (EC), parameters for measuring the sodic hazard (ESP and SAR).
Readings: Chapter 11 in Essington
Suggested Readings : Sparks chapter 10 p 287-299

Lesson 34
Topics : Student Presentations

Lesson 35
Topics : Student Presentations

Lesson 36
Topics : Student Presentations

Lesson 37
Objectives : Review material I

Lesson 44 (Last Lesson)
Objectives : Review material II

Recitation Outline SOCR567

Recitation 1
Objectives : Learn how to read and organize a scientific peer-reviewed journal article
Readings: None

Recitation 2
Objectives : Learn how to review/evaluate a scientific peer-reviewed journal article

Readings: None
Recitation 3
Objectives : Learn how to review/evaluate a scientific peer-reviewed journal article
Readings: To be announced
Recitation 4
Objectives : Review and presentation of journal article
Readings: To be announced (see examples below)
Recitation 5
Objectives : Review and presentation of journal article
Readings: To be announced
Recitation 6
Objectives : Review and presentation of journal article
Readings: To be announced
Recitation 7
Objectives : Review and presentation of journal article
Readings: To be announced
Recitation 8
Objectives : Review and presentation of journal article
Readings: To be announced
Recitation 9
Objectives : Review and presentation of journal article
Readings: To be announced
Recitation 10
Objectives : Review and presentation of journal article
Readings: To be announced
Recitation 11
Objectives : Review and presentation of journal article
Readings: To be announced
Recitation 12
Objectives : Review and presentation of journal article
Readings: To be announced
Recitation 13
Objectives : Review and presentation of journal article
Readings: To be announced
Recitation 14
Objectives : Learn how to write a scientific paper
Readings: To be announced
Lesson 15 (Last Recitation)
Objectives : Learn how to write a scientific paper
Readings: None

Examples of papers to be reviewed in the recitations:

Bhattacharyya, A.; Campbell, K. M.; Kelly, S. D.; Roebbert, Y.; Weyer, S.; Bernier-Latmani, R.; Borch, T. Biogenic Non-Crystalline U(IV) Revealed as Major Component in Uranium Ore Deposits. *Nat. Commun.* **2017**, *8*, 15538.

Hagemann, N.; Joseph, S.; Schmidt, H. P.; Kammann, C. I.; Harter, J.; Borch, T.; Young, R. B.; Varga, K.; Taherymoosavi, S.; Elliott, K. W.; et al. Organic Coating on Biochar Explains Its Nutrient Retention and Stimulation of Soil Fertility. *Nat. Commun.* **2017**, *8* (1).

Daugherty, E. E.; Gilbert, B.; Nico, P. S.; Borch, T., Complexation and Redox Buffering of Iron(II) by Dissolved Organic Matter. *Environ Sci Technol* **2017,** *51*, (19), 11096-11104.

Burgos, W. D.; Castillo-Meza, L.; Tasker, T. L.; Geeza, T. J.; Drohan, P. J.; Liu, X.; Landis, J. D.; Blotevogel, J.; McLaughlin, M.; Borch, T.; Warner, N. R., Watershed-Scale Impacts from Surface Water Disposal of Oil and Gas Wastewater in Western Pennsylvania. *Environ Sci Technol* **2017,** *51*, (15), 8851-8860.

Summary Explanation

	SOCR467	SOCR567
Lectures	Same as SOCR567	Same as SOCR467
Readings	Different from SOCR567	Different from SOCR467 (students will read additional sections of the required book)
Problem Sets	Different from SOCR567	Different from SOCR467 (students will solve more integrative and in-depth problems sets)
Take-home exam	Different from SOCR567	Different from SOCR467 (a more in-depth analysis of the case-studies will be required)
Final exam	Different from SOCR567	Different from SOCR467 (students will solve more integrative and in-depth problems sets)
Recitation	Not a part of SOCR467	The recitation section is exclusively for SOCR567 students and will continue to discuss the principles presented in the lecture material and integrate this with the current research papers being reviewed by the graduate students