CIEE Global Institute – Yucatan

Course name: Environmental Chemistry
Course number: (GI) CHEM 1003 MEME
Programs offering course: Yucatan Summer STEM and Society
Language of instruction: English
U.S. Semester Credits: 3
Contact Hours: 45
Term: Summer 2019

Course Description

Students use fundamental principles of chemistry to gain an understanding of the source, fate, and reactivity of compounds in natural and human-impacted environments. Emphasis will be placed on the environmental implications of the chemistry of the atmosphere, hydrosphere, and lithosphere. Students will explore the chemistry of environmental issues like climate change, air pollution, stratospheric ozone depletion, pollution, water treatment, and use of insecticides and herbicides. While there is no formal laboratory, students will explore applications with instructor and hands on demonstrations.

Learning Objectives

Upon completion of this course, students will:

- Use SI units, significant figures, the scientific method and basic chemical principles to approach chemical environmental processes and challenges
- Identify and describe major environmental issues at home, abroad and on local to global scales
- Employ chemistry to explain major biogeochemical processes and how humans change them
- Summarize the chemistry of major human-caused environmental changes to air, soil, water (freshwater and ocean) and their impacts on humans and nonhuman biodiversity
- Explore the chemistry of important tropospheric processes, including greehhouse gases, ozone depletion, photochemical smog and acid precipitation
- Understand the basic chemistry of the greenhouse effect, the sources and sinks of the family of greenhouse gases, and their implications for climate change
- Describe the nature, reactivity, and environmental fates of toxic organic chemicals, and the chemistry of natural waters and of their pollution and purification
- Research an important environmental chemistry problem and prepare a formal presentation on that issue
- Critically review news articles from the media on environmental chemistry issues and evaluate the accuracy of the science presented
- Become an enlightened and engaged stakeholder in matters related to environmental chemistry, at home and abroad

Course Prerequisites

None

Methods of Instruction

This course is taught through the use of lectures (CIEE instructors and guest speakers), discussions, laboratory demonstrations, interviews, readings, and an internet based research project. There are co-curricular visits to local research centers. CIEE-led lectures, readings, laboratory demonstratons and guided research with discussions supply foundational information, concepts, and terminology, and help students make necessary connections. Guest lectures and interviews with researchers, engineers, farmers, and environmental professionals offer unusual opportunities to learn about "on-the-ground" application of chemical principles applied to environmental problems.

Assessment and Final Grade

Attendance and class participation	20%
Independent research project written and oral report	20%
Weekly Quizzes	20%
Problem Sets	10%
Essays on Speakers/Site Visits	15%
Final exam	20%

Course Requirements

Attendance and class participation (20%)

Attendance is noted for each lecture, discussion session, and activity. As the 4-week session proceeds, students earn points for thoughtful commentary, questions, and participation in discussions and for attendance.

independent research project written and oral report (20%)

Students will undertake an internet-based project to investigate the chemistry of a key environmental problem, linked to their own lives, the lives of local people and globally. Evaluation will be based on (1) quality of data collection and analysis; (2) an individual written report (formated for an environmental chemistry, peer-review journal); (3) an oral presentation (Powerpoint) for an audience of scientist peers.

Weekly Quizzes (15%) At the end of each week, students will complete a quiz covering content from that week. There will be three quizzes in total. Quizzes will include True/False, multiple choise, fill in the blank, short and long answer formats.

Problem Sets (10%)

Each week, students will complete a set of chemical problems associated each topic. These problems will include the chemical nature of environmental processes studied, how they are changing and extrapolations to what they tell us about our likely future.

Essays on Speakers/Site Visits (30%)

Students will write critical essays addressing topics from invited speakers and site visits. These essays will summarize major elements of the talk or visit, fully explain the environmental chemistry behind it, and extend learning outcomes by further researching associated chemistry, environmental challenges and suggested solutions.

Final Exam (20%)

Students take a comprehensive exam on basic chemical concepts, environmental chemistry of major biogeochemical processes, how these are changing and what it means to society, as well as possible solutions covered in the course.

Attendance Policy

Regular class attendance is required throughout the program, and all unexcused absences will result in a lower participation grade for any affected CIEE course. Due to the intensive schedules for Short Term programs, unexcused absences that constitute more than 10% of the total course will result in a written warning.

Students who transfer from one CIEE class to another during the add/drop period will not be considered absent from the first session(s) of their new class, provided they were marked present for the first session(s) of their original class. Otherwise, the absence(s) from the original class carry over to the new class and count against the grade in that class.

For CIEE classes, excessively tardy (over 15 minutes late) students must be marked absent. Attendance policies also apply to any required co-curricular class excursion or event, as well as to Internship, Service Learning, or required field placement. Students who miss class for personal travel, including unforeseen delays that arise as a result of personal travel, will be marked as absent and unexcused. No make-up or re-sit opportunity will be provided.

Attendance policies also apply to any required class excursion, with the exception that some class excursions cannot accommodate any tardiness, and students risk being marked as absent if they fail to be present at the appointed time.

Weekly Schedule

Week 1

- Topic 1: Origins - A Chemical History of the Earth from the Big Bang to Present. Students will explore the Big Bang, how stars and elements formed, nucleosynthesis and the birth of our solar system. They will study how the Earth has changed since its creation. They will establish an understanding of the basic elements, how they were formed and in where they persist on the planet. Students go onto study how life emerged through biochemicals, macromolecules, self-replication and molecular evolution.
- Demonstrations on general properties of important elements
- Possible Excursions
    - Planetario Arcadio Poveda Ricalde
- Discussion (graded participation):
    - Chemical evidence for Mérida's place in the Sixth Mass Extinction
- Readings
    - Chapter 1: Origins
    - Mann, A. 2018. Life after the asteroid apocalypse. PNAS 115(3): 5820-5823.
    - Krishnamurthy, R., 2017. Giving rise to life: Transition from prebiotic chemistry to protobiology. *Accounts of chemical research*, *50*(3), pp.455-459.
- Assigned problems from Chapter 1
- Weekly Quiz 1
- Essay 1

Week 2

- Topic 2: Atmosphere – Students begin with an overview of the chemical nature of the atmosphere. They explore the atmospheric layers: Exosphere, Thermosphere, Mesosphere and Troposphere. Students investigate the troposphere in terms of planetary energy budget and the chemistry of the greenhouse effect. Students learn basic chemistry of greenhouse gases, smog and ozone. Students then examine how greenhouse gases are measured. Finally, students link greenhouse gas accumulation to global climate change.
- Demonstrations on internal combustion engines and how their emmisions impact the Troposphere.
- Possible Excursions
    - Center for Research and Advanced Studies (CINVESTAV Mérida)
- Discussion (graded participation):
    - Climate Change and the Yucatan Peninsula
- Online Research: Climate change impacts and predictions for the Yucatan Peninsula
- Readings
    - Chapter 3: Atmosphere
    - Aguilar, M.D. and de Fuentes, A.G., 2013. Climate Change and Water Access Vulnerability in the Human Settlement Systems of Mexico: The Merida

Metropolitan Area, Yucatan 4(1): 14-41. http://www.inegi.org.mx/rde/RDE_08/Doctos/RDE_08_Art2.pdf
    - Kennett, D.J., Breitenbach, S.F., Aquino, V.V., Asmerom, Y., Awe, J., Baldini, J.U., Bartlein, P., Culleton, B.J., Ebert, C., Jazwa, C. and Macri, M.J., 2012. Development and disintegration of Maya political systems in response to climate change. *Science*, *338*(6108), pp.788-791.
- Assigned problems from Chapter 3
- Weekly Quiz 2
- Essay 2

Week 3

- Topic 3: The Lithosphere – Students examine soil formation from physical weathering, chemical weathering, how minerals interact with different components of the lithosphere as well as the atmosphere and hydrosphere. Students analyze organic matter decays and adds to soil structure and fertility. This involves study of respiration and redox chemistry. Students will then look at human disturbance to the lithosphere, including metals and complexation, and phytoremediation efforts to correct problems. Soil acid deposition is then considered with buffering: limestone, cation exchange, aluminum and biotic systems. Aluminum toxicity and pH will also be studied.
- Demonstrations on general chemical properties of local limestone soils
- Possible Excursions
    - Yucatán Center for Scientific Research (CICY)
- Internet Research
    - Chemistry of Karst topography and its importance to ancient and contemporary Mayan society
- Discussion (graded participation):
    - Yucatán Soils: Carbon Sequestration, Agricultural Output and Human Impact
- Readings
    - Chapter 4: The Lithosphere
    - Estrada-Medina, H., Bautista, F., Jiménez-Osornio, J.J.M., González-Iturbe, J.A. and Aguilar Cordero, W.D.J., 2013. Maya and WRB soil classification in Yucatan, Mexico: differences and similarities. *ISRN Soil Science*, *2013*.
    - Beach, T., Dunning, N., Luzzadder-Beach, S., Cook, D.E. and Lohse, J., 2006. Impacts of the ancient Maya on soils and soil erosion in the central Maya Lowlands. *Catena*, *65*(2), pp.166-178.
- Assigned problems from Chapter 4
- Weekly Quiz 3
- Essay 3

Week 4

- Topic 4: Hydrosphere – Students continue with an overview of the chemical nature of the hydrosphere. They explore unusual chemistry of water and apply it to freshwater stratification, thermohaline circulation and salinity. Students investigate water as a

solvent, including temperature and salinity effects. Students then analyze water in the context of the carbon, nitrogen, phosphorus and sulfur cycles, with special attention to how these cycles are changing with human global impact. Students explore water quality and how to maintain it.

- Demonstrations on potentiometric pH measurements, Total Dissolved Solids (TDS), Salinity, Total Organic Carbon (TOC) and Biological Oxygen Demand (BOD)
- Possible Excursions
    - Mérida Water treatment plant, local cenote (freshwater spring)
- Discussion (graded participation):
    - Planetary thresholds: how close and what can we do about it?
- Online Research: Plantary Boundaries and thresholds of major Biogeochemical Cycles
- Readings
    - Chapter 5: The Hydrosphere
    - Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., De Vries, W., de Wit, C.A. and Folke, C., 2015. Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223), p.1259855.
    - Chuang, P.C., Young, M.B., Dale, A.W., Miller, L.G., Herrera-Silveira, J.A. and Paytan, A., 2017. Methane fluxes from tropical coastal lagoons surrounded by mangroves, Yucatán, Mexico. *Journal of Geophysical Research: Biogeosciences*, *122*(5), pp.1156-1174.
- Assigned problems from Chapter 5
- Weekly Quiz 4
- Final Exam

Course Materials

Textbook

Overway, K.S., 2017. *Environmental Chemistry: An Analytical Approach*. John Wiley & Sons.

Readings

Aguilar, M.D. and de Fuentes, A.G., 2013. Climate Change and Water Access Vulnerability in the Human Settlement Systems of Mexico: The Merida Metropolitan Area, Yucatan 4(1): 14-41.

Beach, T., Dunning, N., Luzzadder-Beach, S., Cook, D.E. and Lohse, J., 2006. Impacts of the ancient Maya on soils and soil erosion in the central Maya Lowlands. *Catena*, *65*(2), pp.166-178.

Chuang, P.C., Young, M.B., Dale, A.W., Miller, L.G., Herrera-Silveira, J.A. and Paytan, A., 2017. Methane fluxes from tropical coastal lagoons surrounded by mangroves, Yucatán, Mexico. *Journal of Geophysical Research: Biogeosciences*, *122*(5), pp.1156-1174.

Estrada-Medina, H., Bautista, F., Jiménez-Osornio, J.J.M., González-Iturbe, J.A. and Aguilar Cordero, W.D.J., 2013. Maya and WRB soil classification in Yucatan, Mexico: differences and similarities. *ISRN Soil Science*, *2013.*

Kennett, D.J., Breitenbach, S.F., Aquino, V.V., Asmerom, Y., Awe, J., Baldini, J.U., Bartlein, P., Culleton, B.J., Ebert, C., Jazwa, C. and Macri, M.J., 2012. Development and disintegration of Maya political systems in response to climate change. *Science*, *338*(6108), pp.788-791.

Krishnamurthy, R., 2017. Giving rise to life: Transition from prebiotic chemistry to protobiology. *Accounts of chemical research*, *50*(3), pp.455-459.

Mann, A. 2018. Life after the asteroid apocalypse. PNAS 115(3): 5820-5823.

Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., De Vries, W., de Wit, C.A. and Folke, C., 2015. Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223), p.1259855.

Online Resources

FAO. Climate Smart Agriculture (2017) http://www.fao.org/climate-smart-agriculture/overview/en/

Natural Resources Defense Council. (2015). http://www.nrdc.org/energy/renewables/geothermal.asp

Nature latest research and reviews in Environmental Chemistry https://www.nature.com/subjects/environmental-chemistry

United States Department of Energy. (2015). Geothermal Energy. http://energy.gov/eere/geothermal/geothermal-energy-us-department-energy

United Nations Framework Convention on Climate Change. (2014). *The Mechanisms under the Kyoto Protocol: Emissions Trading, the Clean Development Mechanism and Joint Implementation.* http://unfccc.int/kyoto_protocol/mechanisms/items/1673.php

Yucatan Times

http://www.theyucatantimes.com/2018/02/opinion-are-we-really-aware-of-the-water-crisis-in-the-yucatan/