



A Laboratory Sequence to Reduce Waste in the General Chemistry Laboratory

A case study prepared by Beyond Benign as part of the Green Chemistry in Higher Education program: A workshop for EPA Region 2 Colleges and Universities

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Summary:

Dr. Matthew Fountain at SUNY Fredonia has revised their General Chemistry II labs to result in a drastic reduction in waste and the use of hazardous chemicals. By utilizing the waste from one experiment in the following experiment, there has been almost a 90% reduction in waste.

Background:

This case study is a result of an EPA Region 2 Source Reduction grant¹ titled *Green Chemistry in Higher Education: A Workshop for Region 2 Colleges and Universities*.

The Green Chemistry in Higher Education workshop was carried out at Siena College on July 18-21, 2013. 29 faculty members participated from 20 different institutions in New York and New Jersey. The workshop consisted of three main focus areas: green chemistry case studies for lecture and course work, green chemistry laboratory exercises, and toxicology and environmental impact.

During the workshop participants were able to test a variety of greener laboratory exercises for introductory and organic chemistry courses. Many of the laboratory exercises can be used as a laboratory sequence that can enable the reduction of waste in the general chemistry laboratory. The lab sequence is described further in this case study.



¹ Disclaimer: Although the information in this document has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement X9-96296312 to Beyond Benign, it has not gone through the Agency's publications review process and, therefore, may not necessarily reflect the views of the Agency and no official endorsement should be inferred.

Additional Resources for Green Chemistry in General Chemistry and Beyond:

Greener Educational Materials (GEMs) Database (University of Oregon)

- Website: <http://greenchem.uoregon.edu/gems.html>
- Description: Searchable database with Green Chemistry educational materials uploaded by faculty members and educators world-wide
- Most curriculum is available for download (free-of-charge) or with primary literature information
- Google map of Green Chemistry educators

American Chemical Society's Green Chemistry Institute

- Website: www.acs.org/greenchemistry
- Description: Green Chemistry Resources for educators and students
- Experiments and Curriculum available for download
- List of ACS books on Green Chemistry

Green Chemistry Commitment

- Website: www.greenchemistrycommitment.org
- Description: A program of Beyond Benign to adopt Green Chemistry Learning Objectives in higher education.
- Case studies are available, university highlights, and curriculum resources

Beyond Benign

- Website: www.beyondbenign.org
- Description: Green Chemistry Curriculum available on-line (free-of-charge)
- Regional Outreach and Community Educational Events

GCEdNet - Green Chemistry Education Network

- Website: <http://cmetim.ning.com/>
- Description: A place where Green Chemistry educators share resources
- Blogs, discussions and chat rooms

University of Scranton Greening Across The Chemistry Curriculum

- Website: <http://www.scranton.edu/faculty/cannm/green-chemistry/english/drefusmodules.shtml>
- Description: Green Chemistry modules available for download
- Power point presentations, hand-outs available

Carnegie Mellon University Institute for Green Science

- Website: <http://igs.chem.cmu.edu/>
- Description: Green Chemistry modules available for download
- Power point presentations, hand-outs available

Laboratory Sequence:

The laboratory sequence is a set of 4 experiments where waste from one experiment can be used in the following experiment. The laboratory sequence is further described below:

- 1) A Greener Approach for Measuring Colligative Properties² - This experiment uses fatty acids in order to measure the colligative properties on a pure solvent and a mixture with an unknown fatty acid. The fatty acid waste from this experiment can be used as raw materials for the preparation of biodiesel or soap.

- a. Replaces a traditional experiment that uses organic solvents (2-methyl-2-propanol or cyclohexane) and halogenated aromatic compounds (naphthalene, p-nitrotoluene, or 1,4-dibromobenzene).³
- b. Waste that is generated consists of fatty acids, which can be used in other experiments, therefore reducing the waste generated in this experiment to essentially zero.³



- 2) The Wood Ash Titration Lab⁴ - Wood ash is used as a source of base for this titration experiment that replaces traditional titration experiments that use oxalic acid. The base solution can be concentrated by distilling off water and the base can be used for base hydrolysis in the biodiesel lab.

- a. Replaces a traditional experiment that uses oxalic acid and phenolphthalein indicator, both with high human hazards. Avoids the use of 375 grams of oxalic acid per group of 100 students, resulting in a \$120.11 purchasing and waste disposal cost savings.⁵
- b. Results in a reduction in the amount of waste by 3.5 gallons.⁵ The waste can be reduced even further if the base solution is used in the preparation of biodiesel. Please note that the volume of the base solution must be reduced in order to concentrate the base solution, therefore increasing the energy requirements for this experiment.



² McCarthy, S. M., and Gordon-Wylie, S. W., "A Greener Approach for Measuring Colligative Properties", *J. Chem. Ed.*, 82 (1), 2005, 116-119.

³ See Molar Mass Determination by Freezing Point Depression case study

⁴ Ash Water Titration: Renewable Resources for the Preparation of Biodiesel Laboratory Exercise by Professor Irvin J. Levy, Gordon College

⁵ See Wood Ash Titration case study

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The laboratory sequence is a set of 4 experiments where waste from one experiment can be used in the following experiment. The laboratory sequence is further described below:

- 3) Preparation of Biodiesel⁶ - Vegetable oil can be obtained from cafeterias and/or kitchens and used as starting materials for the preparation of biodiesel, or the fatty acids from the colligative properties lab can be used as starting materials. The base from the wood ash titration lab can be used for the conversion of the triglycerides in the vegetable oil to biodiesel.

- Glycerin is a byproduct of this lab and can be used to make soap in another laboratory exercise.
- The biodiesel product can be used on some campuses as a fuel source.
- The biodiesel product can be used to test and discuss viscosity, and other physical properties.



- 4) Preparation of soap⁷ - The fatty acid waste from the colligative properties lab can be used in a saponification reaction lab to make soap. The soap can be pH tested and then used for general purposes. The glycerin byproduct created in the preparation of biodiesel can also be used as a raw material feedstock for making soap, thus reducing the waste from the biodiesel experiment to close to zero.

- The product from this lab is used as hand soap and also used to clean countertops and surfaces in the lab therefore resulting in little to no waste.



⁶ Preparation and Viscosity of Biodiesel from Vegetable Oil, Siena College, Organic Lab 2, Adapted from Nathan R. Clarke, John Patrick Casey, Earlene D. Brown, Ezenwa Oneyima and Kelley J. Donaghy, American University, Department of Chemistry, American University, 4400 Massachusetts Avenue NW, Washington, DC 20016-8014. *J. Chem. Ed.*, 83(2), 257-259 (2006), by Dr Darius Robinson.

⁷ Science Buddies Staff. (2014, October 23). *The Chemistry of Clean: Make Your Own Soap to Study Soap Synthesis*. Retrieved November 8, 2014 from http://www.sciencebuddies.org/science-fair-projects/project_ideas/Chem_p096.shtml

Conclusions:

The laboratory sequence for general chemistry described within this case study can be used a means for reducing the waste within the general chemistry laboratory course, while providing a context for learning the subject. The waste generated in each of the laboratory experiments can be used as starting materials for the following experiments, therefore reducing waste disposal costs, and also purchasing costs associated with raw materials.

Wood Ash Titration: A case study prepared by Beyond Benign as part of the Green Chemistry in Higher Education program: A workshop for EPA Region 2 Colleges and Universities

Download this and other case studies at the following link:
<http://www.greenchemistrycommitment.org/resources/case-studies/>