# Making Smith College Chemistry More Sustainable?

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5/6/03 EVS 300

## Abstract

The objective of this project was to understand the current environmental impact of chemistry labs at Smith College to recognize what can be done to make our department more sustainable and become a safer environment for students. There is a growing need to make chemical practices more sustainable, be it in industry, manufacturing or academics. What better place to teach green chemistry than at Smith College. The leading women graduating with a chemistry degree will be environmentally aware, which is exactly what is needed in the $21^{st}$ century. This paper will not attempt to turn the chemistry department "green"; rather it will offer ideas and suggestions that will illustrate what steps can be taken to become more sustainable.

## Introduction

Currently at Smith, the Chemistry department requires the majors to take a number of core chemistry classes that have a required lab section. In chemistry labs students are taught how to perform a variety of lab techniques and reactions. The labs help to supplement the course material to give students an application of the material they are learning in the classroom. Many of the chemicals used are toxic and pose environmental and human health effects. There is an exorbitant amount of hazardous waste created in these labs and large quantities of water and electricity are used when performing these labs. This project will illustrate some ways in which the amount of resources used and waste created can be minimized directly and indirectly. The fact that environmental issues are not currently part of the traditional chemistry courses at Smith is part of why there is little interest by chemists at Smith into environmental issues. If we start to incorporate new ideas and methods into our department that foster green chemistry, we will create a better awareness of current environmental problems and hopefully stimulate young ladies' interest in this type of chemistry.

> "The principles of green chemistry focus on reducing, recycling, or eliminating the use of toxic chemicals in chemistry by finding creative ways to minimize the human and environmental impact without stifling scientific progress." [1]

## **Methods**

The twelve principles of green chemistry was the driving force behind much of my research and because they are the principles of our future, I am including them in Appendix 1.[2]

Identifying toxic chemicals is very important in all aspects of chemistry educations as it will allow students to differentiate between those chemicals which are harmful to people and nature and those which are benign and/or recyclable. The current environmental impact that chemistry labs at Smith incur was estimated by evaluating the waste generated from CHM 111 lab course (fall 2002) along with the toxicity. I spoke with Margaret Rakas, the Hazmat coordinator for Smith's science department, for the waste disposal information.

Introducing new chemical procedures in the lab that are "green" will contribute to the integrity of the chemistry department and possibly stimulate students to become interested in alternative chemical procedures rather than the current harmful ones. Viable "green" alternatives to the labs students perform were researched online. Some of the subjects researched were virtual lab technologies and green lab alternatives. I looked at the University of Oregon for possible "green" lab alternatives that are feasible to implement in the departments curriculum.

Possible design strategies for the new science center that cater to a more environmentally safe and aware chemistry lab facility were researched as well. I talked to Bob McCullough of the Physical Plant at Smith as well as members of the chemistry department for their input on the new building. Researching online followed up the ideas and suggestions obtained.

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[1] http://www.uoregon.edu/~hutchlab/

[2] Anastas, P. T.; Warner, J. C. *Green Chemistry: Theory and Practice*, Oxford University Press: New York, 1998, p.30. By permission of Oxford University Press

## Results and Discussion

In lab, students use reactive, flammable, corrosive and toxic chemicals in many of their lab assignments. Tons of Waste is generated from these procedures, and Smith pays to have it disposed. The wasted generated from the general chemistry lab (CHM111) was extensive and contained many toxic chemicals. Based on the waste disposal information, eco-toxic metals such as, nickel, copper and manganese are generated in CHM 111. Barium, chromium, lead, mercury and silver are all hazardous metals and are used in CHM 111 as well. The fact that large quantities of waste that are toxic are generated from the first lab class at Smith shows that there is room for improvement.

One lab taught in this course that causes concern is the “six solution lab” where students are asked to analyze and identity six unknown solutions. The problem is that the solutions contain toxic chemicals such as barium, silver and lead. This lab is preformed first in CHM 111, when students are not very experienced in the lab. The lab is very valuable in that it teaches students about the physical properties of elements and helps them identify unknowns, however, it is dangerous and creates toxic and hazardous waste products. One solution to this problem is to do this lab in a virtual environment. This would eliminate the waste problems and health risks, while providing the same, if not more, experience with the subject matter. Virtual labs are up and coming and they provide the student with the opportunity to make mistakes without risk, which is especially important at the introductory level. Not only that, they allow for students to gain practice and become familiar with their capabilities in a lab without having to be exposed to toxic chemicals before they are ready.

It came to my attention while talking with Lale Burke of the chemistry department that one very important aspect of sustainable chemistry is the engineering of lab facilities. She told me that in order to get hot water from the tap in a first floor lab, she has to let the water run for a good fifteen minutes. This is because the hot water heater is on the fourth floor and it has to travel far, through cold pipes, to reach the first floor facility. This is clearly a faulty design. Valuable resources such as gallons of water and electricity are used to create specific reaction conditions, there is no sense wasting them on poorly designed facilities. When talking to Physical Plant about the new science building, I became aware of a fact that was most exciting. Bob McCullough alerted me to the fact that the new building is being designed with sustainability in mind. The architects, Bohlin Cywinski & Jackson, have a sustainable design expert on their crew. The goal is to become LEED certified (Leadership in Energy and Environmental Design) by the US Green Building Council. The chemistry building will be designed soon with major input from the chemistry department to insure that the facilities will meet the curriculum.  It is very important to make sure that our lab facilities utilize our earth's precious resources wisely. This will not only create a sense of pride, it will undoubted save the college money when their annual water and electricity bills are cheaper.

A major concern is the use of water as a vacuum source in the labs. David Bickar, a lab professor here at Smith College, estimates that water aspirators alone use more than a million gallons of water each semester. The new lab facilities *must* have a central vacuum system. This will insure that million of gallons of fresh water are not wasted each semester to create a vacuum because the new facility will do it without water all together. The cost of the new vacuum system would be covered by the decrease in water costs every semester.

"The future of green chemistry depends upon the next generation of scientists understanding not only how to design chemical transformations and products which are efficient and effective, but that also take into account their impacts on human health and the environment", says Paul Anastas, chief of the U.S. EPA s Industrial Chemistry Branch.[3] How is this to be accomplished when we do not require our chemistry majors to engage in any environmental courses? A way in which the chemistry department can become more sustainable would be to require all chemistry majors take an environmental (or green) chemistry course. Environmental chemistry is offered currently to non-science majors but it does not count toward the chemistry major for those chemistry majors who decide to take it. The reason is that it is an introductory level course. Shouldn't chemistry students then be aware of these "introductory" issues then before graduating from Smith College with a chemistry degree? What message is this sending to the students? Is the health and well being of our environment not of utter and urgent importance? Are we more concerned with making lots of money than helping humanity?

Developing sustainability is a primary goal for the present and future as we are beginning to realize that natural resources are not limitless and that the environment as we know it today can only be sustained through conscious effort. Efforts for better preservation of resources and the protection of the environment must be initiated in all scientific fields, including chemistry. The most appropriate time to introduce this topic to young chemists is during their introduction to the science. In this way, preservation will become second nature to them when they begin to work alone in the laboratory. If our students are made aware of the issues early on, take environmental chemistry in the freshmen or sophomore year; they will be that much more likely to want to do research in this area. When chemistry students are as familiar with these issues,

[3] http://pubs.acs.org/cgi-bin/article.cgi/esthag-a/2000/34/i23/html/12news4.html/QueryZIP/A-pages/(((<MANY><PARAGRAPH>(green)))<AND>(PUBYR@@>=@@1999))<OR>(((<MANY><PARAGRAPH>(green))<AND>@@ASAP@@<IN>@@VOL))

then chemistry as a field can hope to make serious advances towards the goals of sustainable development.

Introducing a new topic into an already overcrowded syllabus is a common problem across countries and at all education levels. Hence, the decision was made by American Chemical Society (ACS) to develop resources that give instructors flexibility in incorporating green chemistry concepts into a variety of existing courses. There are many online resources including a book of case studies based on the Presidential Awards in Green Chemistry; a video, also featuring the Presidential Awards; and an annotated bibliography, which is posted on the ACS Education Web page as a searchable database. This year, ACS plans to publish a set of green chemistry laboratory activities and demonstrations developed by educators at the University of Oregon, University of Massachusetts at Boston, and the University of Southern Alabama.

Government has played a significant role in promoting green chemistry research and development. The U.S. EPA and National Science Foundation (NSF) established the Green Chemistry Program in 1991. This and subsequent research initiatives provided the initial funding for green chemistry research efforts. Today, the joint EPA-NSF Technology for a Sustain able Environment program provides the largest single U.S. government source of funds (approximately $10 million annually) for basic research in the green chemistry area. [4]

Another issue of concern is the use of organic solvents. This is of growing concern in industry and manufacturing procedures as well. If we can begin to find ways to phase out these toxic substances, we will surely be setting the right step forward. One area of research that I

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[4] http://pubs.acs.org/cgi-bin/article.cgi/esthag-a/2001/35/i05/html/05hjer.html/QueryZIP/A-pages/(((<MANY><PARAGRAPH>(green)))<AND>(PUBYR@@>=@@1999))<OR>(((<MANY><PARAGRAPH>(green))<AND>@@ASAP@@<IN>@@VOL))

become familiar with is the use of supercritical carbon dioxide ($scCO_2$) as a reaction medium for many organic and synthetic procedures.[5,6]

Supercritical $CO_2$ exhibits a number of unique properties. This makes it an attractive candidate as a reaction medium for polymerizations. It also is an environmentally benign "green" solvent, exhibits tunable properties, is cheap and readily available and product separation is achieved by simply venting the $CO_2$. Polymerizations in $scCO_2$ require the use of stainless steel autoclaves capable of withstanding pressures of over 300 barr at 300°C. These autoclaves are purchasable from a variety of manufacturers and would be a great supplement to our research capabilities for all areas of chemistry. Although chemistry can be rendered more “green” in many ways, for example, by recycling or through waste disposal, life-cycle assessment of many products in chemical industry shows that most of the negative environmental impact of a reaction is related to its energy consumption and the processes used to create the starting materials. That is why using carbon dioxide, a waste product, is so intriguing as a new alternative in chemical processes.

Another idea that I had to minimize the amount of waste while at the same time educating students about sustainability was to teach a lab about waste disposal. This would illustrate the fate of our waste more explicitly while at the same time teaching students how to clean up after themselves by disposing of their own waste. Unfortunately, by EPA law chemistry labs at Smith College cannot treat their own waste. However, there are permits that can be granted to professors for research into novel waste treatment, which would allow some treatment of waste on campus. Hopefully the next professor hired in Smith’s Chemistry department will be a

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[5] Leitner, Walter. Supercritical Carbon Dioxide as a Green Reaction Medium for Catalysis: *Acc. Chem. Res*. **2002**, 35, 746-756.
[6] Furstner, A. et al. Olefin Metathesis in Supercritical Carbon Dioxide: *J. Am Chem Soc.* **2001**, 123, 9000-9006

professor specializing in environmental chemistry so that Smith can take a lead role in become a more sustainable college campus while making waste treatment a viable option for research.

## **Conclusion**

We are now discovering that many of the common chemicals used in labs pose environmental and health hazards. There has been an effort to inform students of the toxicity of the labs and what necessary precautions must be taken. Can we take this a step further? Incorporating the principles of green chemistry into our curriculum will not only teach current Smithies that there are alternatives to current practices that can be better for our environment, it is a powerful recruiting opportunity for future Smith chemistry students.

I hope that my paper has illustrated things that can be done to make chemistry at Smith become more sustainable. I hope that we can move forward into the 21st century taking the environmental costs of chemistry into account. This is a lofty goal when budget and politics get involved. However, it is a good goal and an important step towards reaching the realistic, looming and inevitable goal, which is to sustain our quality of life on this planet.

## Appendix I

## Twelve Principles of Green Chemistry[2]

1. **Prevention -** It is better to prevent waste than to treat or clean up waste after it has been created.
2. **Atom Economy -** Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3. **Less Hazardous Chemical Syntheses -** Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. **Designing Safer Chemicals -** Chemical products should be designed to affect their desired function while minimizing their toxicity.
5. **Safer Solvents and Auxiliaries -** The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.
6. **Design for Energy Efficiency -** Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.
7. **Use of Renewable Feedstocks -** A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.
8. **Reduce Derivatives -** Unnecessary derivatization (use of blocking groups, protection/ deprotection, temporary modification of physical/chemical processes) should be

[2] Anastas, P. T.; Warner, J. C. *Green Chemistry: Theory and Practice*, Oxford University Press: New York, 1998, p.30. By permission of Oxford University Press

minimized or avoided if possible, because such steps require additional reagents and can generate waste.

9. **Catalysis -** Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
10. **Design for Degradation -** Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.
11. **Real-time analysis for Pollution Prevention -** Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
12. **Inherently Safer Chemistry for Accident Prevention -** Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.