A Life Cycle Approach to Chemistry Laboratories at the University of New Haven

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Introduction

The theory behind the life cycle approach is the idea that a given item, say one chemical, has a life (manufacture, use) and a death (disposal) and the environmental impact of both as well as the space in between (lifespan) can be calculated and assessed. The assessment for a chemical would then include the mining or manufacturing stages, related packaging and transportation of any components to the plant at which it is produced, its transportation to the University, its use in the chemistry labs, its method of disposal in the lab, as well as its transportation and disposal as waste after its use. [1]

Using this concept, an analysis of the Chemistry laboratories at the University of New Haven was made possible on both an economic and environmental level. The first step in developing effective strategies and policies to reduce environmental impacts of systems is through quantifying their life cycle impacts. The results of this study will guide faculty and staff in developing strategies to improve the existing state.

Materials and Methods

The goal of this project was to quantify the impact of the Chemistry laboratories on the University of New Haven campus both economically as well as environmentally. The economic impact of each laboratory was assessed by quantifying the amount of materials (chemicals, safety materials, and glassware) used by each laboratory section for an entire academic year, and then using the suppliers utilized by the University in order to price each material used, and thus create a working total cost for each laboratory section.

The materials utilized in each laboratory section were then separated into organic and inorganic chemicals, and the two categories were totaled separately for each laboratory section. These totals were used with the EIO-LCA tool in order to quantify the environmental impacts of each laboratory section, as well as for the Chemistry laboratories collectively.

In order to calculate the amount of waste produced by the University to verify the amount of waste that leaves the laboratories, all of the chemicals from the cost calculations were also converted into for mass purchased, and used in calculations.

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Results

Table 1 shows the number of sections of a given laboratory offered during the academic year at the university. These laboratory sections were then broken down into the number of groups the section utilized, the number of students in a group for a given laboratory section, and the total number of students enrolled in each laboratory section for the academic year.

Table 1. The breakdown of chemistry laboratories at the University of New Haven

Sections/Semester	Fall	Spring	Summer	Students /Section	Students /Group	Groups /Section	Groups /Year	Total Students
Introduction to General Chemistry	4	4		20	2	10	80	160
General Chemistry I	15	6		24	2	12	252	504
General Chemistry II/Chemistry with Applications to Biosystems		13	1	24	2	12	168	336
Organic Chemistry I	12			16	1	16	192	192
Organic Chemistry II		12		16	1	16	192	192
Quantitative Analysis	5			20	3 to 4	6	30	100
Instrumental Methods		6		20	3 to 4	6	36	120
Physical Chemistry I&II	4	3		15	3	5	35	105
Synthetic Methods	1			16	1	16	16	16

Table 2 presents the total cost of supplies purchased for a given laboratory section for the academic year. The total cost was then further broken down into a cost per student enrolled in that laboratory section.

Table 2. The total cost of supplies for each of the chemistry laboratories on campus

Laboratory	Total Cost ($)	Cost per Student ($)
Introduction to General Chemistry	3,987	25
General Chemistry I	14,976	30
General Chemistry II/Chemistry with Applications to Biosystems	26,270	78
Organic Chemistry I	12,964	68
Organic Chemistry II	6,864	36
Quantitative Analysis	4,982	50
Instrumental Methods	3,376	28
Physical Chemistry I&II	4,292	72
Synthetic Methods	4,416	276

Table 3 shows the environmental impact of each laboratory section as characterized by four main categories: energy consumption, greenhouse gas emission, emission of other conventional air pollutants, and transportation impact. Each section had its supplies categorized into organic and inorganic chemicals, and then the EIO-LCA tool was used by inputting the cost data for each category. The total impact of each of the two analyses for a given laboratory section was then added in order to create the total impacts displayed in Table 3.

Table 3. The environmental impact of each of the chemistry laboratories on campus

Laboratory	Energy		Greenhouse Gas		Conventional Air Pollutants		Transportation	
	Total Impact (kWh)	Impact per Student (kWh)	Total Impact (kg CO_2e)	Impact per Student (kg CO_2e)	Total Impact (kg)	Impact per Student (kg)	Total Impact (ton-km)	Impact per Student (ton-km)
Introduction to General Chemistry	3,333	21	5,107	32	4	0.02	30,800	193
General Chemistry I	189,444	376	20,430	41	198	0.4	126,400	251
General Chemistry II/Chemistry with Applications to Biosystems	50,556	150	46,638	139	454	1.3	289,900	863
Organic Chemistry I	196,389	1,023	19,340	101	166	0.9	111,950	583
Organic Chemistry II	81,667	425	8,310	43	74	0.4	49,100	256
Quantitative Analysis	50,000	500	5,053	515	43	0.4	29,870	299
Instrumental Methods	19,167	160	2,099	17	17	0.1	12,960	108
Physical Chemistry I&II	43,611	415	4,590	44	42	0.4	27,930	266
Synthetic Methods	40,278	2,517	4,020	251	34	2.1	23,560	1,473
All Laboratories	674,444	5,588	115,588	718	1,031	6.1	702,470	4,290

Conclusions and Discussion

Upon gathering data on Chemistry laboratory courses regarding the chemicals and other supplies needed for laboratories, as well as the amount of students enrolled in each laboratory during the school year, a few sections stood out as being particularly more expensive to run on a per student basis than others. The most expensive laboratory section was *Synthetic Methods* where the calculated cost was $276 per student.

This section however, is not the most expensive section to run overall, but rather only expensive on a per student basis due to the fact that the laboratory section is only run once a year with a 16 student capacity.

Regarding environmental impacts, the course on *Synthetic Methods* was found to have the largest impact. The impact per student for this laboratory section was around two times as great as or more than the next largest contributing laboratory section in each of the four impact categories that have been defined.

- Energy Used: 2,517 kilowatt hours per student (enough to power a 100 watt light bulb for 3 years!)
- Greenhouse Gas Emission: 251 kg CO_2e per student
- Transportation: 1,473 ton-km per student

Despite its being one of the top five most expensive laboratories per student, *Physical Chemistry I & II* did not have a significant impact on the environment in any of the four categories chosen when compared to other Chemistry laboratories.

The Chemistry laboratories on the UNH campus also put out about 6.2 tons of waste per year of operation. Approximately 85% of this waste is hazardous, and the other 15% is non-hazardous waste. However, the University of New Haven is considered a small waste generator as far as laboratories go, as the campus always has around one ton or less of chemical waste on it at any given time.

Quantifying impacts is a necessary step for keeping track of and reducing environmental impacts. Through the use of the presented results, strategies and policies are planned to be developed to reduce both the economic and environmental impacts of chemistry lab courses.

Almost all of the environmental impact categories considered indicate that *Synthetic Methods* is a hotspot where disproportionate amount of impacts occur on a per student basis when considering the life cycle of products used for this course. Therefore, this would be a good place to examine potential improvements and alternatives.

Literature Cited

1. Hendrickson, C., Lave, L., & Matthews, H. S. (2006).*Environmental life cycle assessment of goods and services*. (pp. 1-12). Washington, DC: Resources for the Future.