EVALUATION OF A RURAL HIGH SCHOOL REGARDING ITS ABILITY TO IMPLEMENT THE PRINCIPLES OF GREEN CHEMISTRY IN THEIR SCIENCE CLASSES

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

NEW YORK STATE OF OPPORTUNITY. Department of Environmental Conservation

ACKNOWLEDGEMENTS:

United States Environmental Protection Agency (EPA), Region 2 -In appreciation to EPA Region 2 for the grant funding, supporting New York State DEC's green chemistry in schools program. A word of thanks to Walter Schoepf, Environmental Scientist for EPA Region 2's Pollution Prevention Team, to recognize of his support and guidance to DEC's green chemistry in NYS schools program, as well as his presentation and attendance at DEC's Capital District and NYC green chemistry workshops.

New York State Education Department (SED) -In appreciation to Will Jaacks, Associate in Science Education in the SED Office of Curriculum, Instruction and Instructional Technology, for all of his assistance and time in providing feedback at monthly meetings with DEC and hours devoted to reviewing documents related to the DEC green chemistry in NYS schools program and presenting at the Capital District DEC green chemistry workshop.

Beyond Benign -In appreciation to Dr. Amy Cannon, Co-Founder and Executive Director of Beyond Benign and Kate Anderson, Director of K-12 Education for Beyond Benign, for the excellence of their green chemistry presentations and labs at the four DEC green chemistry workshops in the Hudson Valley, Capital District, Long Island and NYC areas of New York State.

Sullivan County Board of Cooperative Educational Services (BOCES) -A word of thanks to Michael La Fountain, Health and Safety Coordinator for Sullivan County school districts for his assistance with the chemical cleanout at Liberty High School and for his outreach efforts to teachers in his districts schools promoting DEC's green chemistry workshop at Liberty H.S.

A special word of thanks to all the teachers and administrators at Liberty High School who agreed to take part in DEC's green chemistry for NYS schools program as their region's green chemistry candidate school and with their commitment to adopt the principles of green chemistry in their classroom labs.

Liberty High School- Principal Jack Strassman, Science Department Head Michael Hazelnis and Chemistry Teacher Regina Pegg.

Disclaimer:

Although the information in this document has been funded wholly or in part by the United States Environmental Protection Agency under grant #NP96296412 to the New York State Department of Environmental Conservation, it has not gone through the Agency's publication review process and, therefore, may not necessarily reflect the views of the Agency and no official endorsements should be inferred.

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"Evaluation of a rural school district regarding its ability to implement the principles of green chemistry in their science classes"

ABSTRACT

The primary goal of the grant program, "Pollution Prevention Practices at NYS Schools with a Focus on Green Chemistry", is to promote green chemistry and proper chemical management in schools. A secondary goal is to provide insights to stakeholder groups of those benefits of green chemistry and to provide evidence of the benefits, in terms of toxicity reductions and cost savings, which can be achieved through chemical management and green chemistry. The objective of the individual case studies is to determine whether or not the chosen school has the capability and commitment to implement the principles of green chemistry in their school. It is evident that the overall objectives of the grant program as well as the objectives of the individual case studies have been met. As a result of this grant program the principles of green chemistry have been advanced, stakeholder groups have been made aware of the benefits of green chemistry through toxicity reductions and cost savings and green chemistry principles have been implemented in high school chemistry classes.

INTRODUCTION

The goal of this case study is to ascertain whether or not Liberty High School can benefit from proper chemical management and the implementation of the principles of green chemistry. Additionally, a function of this study will be to provide evidence of the benefits, in terms of toxicity reduction and cost savings that can be achieved through chemical management. The results of the case study will also be used to illustrate the benefits of partnerships between tertiary level educators and their institutions, as well as teachers in the secondary school system. It is anticipated that the case studies can be used as educational tools to illustrate the benefits of proper chemical management and green chemistry to key stakeholder groups.

Liberty High School is a rural, "high needs" school with limited resources, as categorized by the New York State Education Department (SED) school report card. It is located in the southern Catskill Mountain region of New York State in Sullivan County. The district has approximately 695 students in grades 9-12 and offers a variety of science courses at the high school level (9-12) including Forensics, Environmental Science and Advanced Placement Biology.

The study was undertaken in steps: The first step was an evaluation of the necessity for assistance which included a site investigation by New York State Department of Environmental Conservation (DEC), Toxic Reduction & Green Chemistry (TRGC) staff, to determine if the school was a viable green chemistry candidate. The second step included a commitment by school administration and staff to take the necessary steps to implement the principles of green chemistry for one school calendar year in their chemistry classes. The third step included completing green chemistry training conducted by TRGC staff and Beyond Benign, a non-profit organization contracted by DEC. The fourth and final step was having

the candidate school report back to DEC on their teaching results after implementing the principles of green chemistry in their high school classes.

This project was funded by a grant from the United States Environmental Protection Agency, Region 2 (USEPA), administered by the Division of Materials Management's Toxics Reduction and Green Chemistry Section of the DEC.

STEP ONE –SITE INVESTIGATION AND ANALYSIS

In March of 2011, DEC staff conducted a preliminary site visit at Liberty High School to determine the scope of chemical usage, storage options, and purchasing practices, and to gauge interest by school personnel in participating in this project. DEC was assisted by personnel from the Sullivan County Board of Cooperative Extension (BOCES) for the initial site visit. There are two regulations, which impact science areas in schools. One of the regulations comes from the State Education Department (SED). SED law requirements specify locked and secure chemical storage rooms and cabinets. In addition, chemical inventories must be updated at least annually and kept in a secure location. The other regulation is from the Occupational Safety & Health Administration (OSHA)'s "Laboratory Standard 29 CFR 1910.140", which the authority has been delegated to the New York State Department of Labor under a state plan. This is a more comprehensive regulation, which seeks to reduce significant risks associated with hazardous chemical exposure in a manner appropriate to laboratories. The goal of this project was not to enforce the OSHA laboratory standard or any regulation under the NYS Department of Labor.

The chemical storage area had controlled access and had recently undergone a renovation. The former science instruction and chemical storage areas were original to the building (1960's) and in need of remodeling. The remodeling was undertaken in the summer of 2010, and the 2010-2011 school years were the first in the new area. The initial site assessment indicated that years of chemical acquisitions without maintaining an annual chemical inventory had resulted in an overabundance of dated and highly toxic chemicals in storage.

The next step in the process required that a thorough analysis of the chemical inventory be performed by DEC staff to identify chemicals that the school needed to segregate and dispose of immediately; chemicals that the school had previously marked for disposal, and; those which were required to implement the principles of green chemistry. In order to determine the chemicals that were required for green chemistry, TRGC staff matched the current Beyond Benign green chemistry experiments to SED Science Learning Standards and Core Curriculum. SED regulations require that students who wish to take a Regents examination in any of the sciences must complete the course study leading up to that particular Regents examination and complete 1200 minutes of hands-on (not simulated) laboratory experiments with satisfactory documented laboratory reports. Beyond Benign's green chemistry curriculum can provide at least 1000 of the required 1200 minutes for a course designed to culminate in the Regent's examination in Physical Setting/Chemistry Core Curriculum.

A follow-up visit was conducted by DEC in June 2011, to assist the high school chemistry teacher with the reorganization of the chemical storage area.

RESULTS OF THE CHEMICAL INVENTORY

The results of the chemical inventory indicated that Liberty's high school chemistry teacher had inherited a large amount of chemicals. The inventory contained 851 line item chemicals. Each bottle, container or solution was assigned a line on the inventory. A significant number of chemicals in the inventory were deemed highly hazardous and were determined to be of limited usefulness. The inventory also contained an excessive quantity of acids as well as acutely toxic chemicals. All chemicals were safely stored in appropriate cabinetry and kept locked.

RESULTS OF CHEMICAL STORAGE REORGANIZATION

The inventory was pared down to approximately 279 line items, a 67 % reduction. After the reorganization, all that remained was a small amount of acetone. Items determined to be highly hazardous were removed by a hazardous waste contractor. A side benefit of the reorganization was an increase in space and cabinets available for future storage.

Throughout the chemical inventory and reorganization process, the chemistry teacher was given the opportunity to keep chemicals based on a "one year plan." This plan allows for the determination of chemicals to be used throughout the following school year, by affixing a colored dot to all of the bottles that are opened or used during the current school year. If, at the end of the school year the bottle does not have a colored dot, then it is tagged for disposal.

Table 1-Chemicals by Hazard Type, (J.T. Baker Chemical Storage Color Code), shows an overall decrease in the number of chemicals recommended for disposal by 65%. These values include those chemicals which were considered to be IDLH (of immediate danger to life and health). The greatest decrease was seen with the oxidizers and corrosive (75.2% and 79.6% respectively).

Table 1

Chemicals by Hazard Type			
	April-11	June-11	**% change**
Storage class	**lbs**	**lbs**	
Blue (Health Hazard)	33.0	10.4	**68.5**
Red (Flammable)	102.0	61.7	**39.5**
Green (General Storage)	394.5	151.3	**61.6**
Yellow (Oxidizers)	112.3	27.8	**75.2**
White (Corrosives)	206.6	42.2	**79.6**
Totals	**848.4**	**293.4**	**65.4**

Using toxicity data gathered from the MSDS' for each chemical, **Table 2-Chemical Inventory by Toxicity and Table 3- Hazardous/Highly-Toxic Chemicals** shows the recommended reduction in chemical inventory based on toxicity. When toxicity is taken into account, TRGC staff recommended that

65.9% of the inventory be disposed. The total recommended reduction in toxic chemicals was almost 400 lbs.

Table 2

Chemical Inventory by Toxicity					
Category	# Inventory items April 2011	lbs	# inventory items June 2011	lbs	**% reduction**
Known Carcinogen	15	8.6	4	2.2	**74.4**
Possible Carcinogen (2B)	49	29.6	10	12.9	**56.4**
Very Hazardous to Health	78	107.8	24	37.5	**65.2**
Hazardous to Health	255	273.7	87	113.6	**58.5**
Severe Irritant	21	21.6	5	3.6	**83.3**
Irritant	140	163.4	36	36.2	**77.8**
Total	558	**604.7**	166	**206.0**	**65.9**
Total highly-toxic chemical reduction				**398.7**	**lbs**

The chemical inventory and reorganization effort resulted in a 66 % reduction of line item chemicals.

Table 3

Hazardous/Highly-Toxic Chemicals						
School	# of Inventory items pre-assessment	lbs	# of inventory items post - assessment	lbs	# of lbs of chemicals recommended for disposal	% reduction
Liberty HS	558	604.7	166	206	398.7	65.9
lbs of hazardous/highly toxic chemicals for disposal					**398.7 lbs.**	

In addition to the above recommendations for disposal, DEC staff recommended an additional 151.7 lbs of relative-less toxic chemical reduction. **Table 4-Liberty High School Relative Less-Toxic Chemicals and Table 5-Relative Less-Toxic Chemicals Recommended for Disposal** shows the number of inventory items and the corresponding quantities in inventory at two points of the process.

Table 4

Liberty High School Relative Less-Toxic Chemicals				
# Inventory Items April 2011	lbs	# Inventory Items June 2011	lbs	% reduction
293	239.2	113	87.5	**63.4**
total relative less-toxic chemicals reduced			**151.7**	**lbs**

Table 5

Relative Less-Toxic Chemicals Recommended for Disposal						
School	# Inventory items pre-assessment	lbs	# Inventory items post-assessment	lbs	lbs of chemicals recommended for disposal	**% reduction**
Liberty HS	293	239.2	113	87.5	151.7	63.4
lbs of relative less- toxic chemicals for disposal				**151.7 lbs**		

Through the use of the one year plan, it is estimated that there will be a further reduction of chemicals on site. Further, of all the items tagged for disposal, only 15 % will require a hazardous waste hauler.

STEP TWO- ACCEPTANCE AND COMMITMENT

Upon hearing and reviewing the results of the initial assessment by TRGC staff, with a thorough explanation of the program, Liberty High School administrative staff and faculty expressed their commitment, for one calendar school year, to take the necessary steps in implementing the principles of green chemistry in their chemistry labs.

STEP THREE- TRAINING

Chemical Hygiene Training

Liberty High School's chemistry teacher was trained by DEC staff on the principles of laboratory safety. The training was integrated into the hands-on analysis of the chemical inventory. The hands-on analysis presented many opportunities to discuss proper storage, handling and disposal methods of chemicals, relative less-toxic substitutions as well as elements of a sustainable chemical management program. The presentation included an overview on the general guidelines of the OSHA laboratory standards and their applicability to schools. The presentation highlighted the importance of having a chemical hygiene officer. The chemical hygiene officer must be an employee of the district and must have an understanding of chemistry and safety by training, experience or education. Training included topics such as, the components of a chemical hygiene plan, the definition of hazardous waste, how to dispose of preserved specimen fluids, and how to dispose of qualitative analysis solutions.

As a result of the chemical inventory, reorganization and chemical hygiene training, Liberty High School's chemistry teacher indicated that she did not plan to order any new chemicals for the 2011-2012 school year as she now has the tools to move forward with the implementation of green chemistry in the classroom.

Green Chemistry Training

The purpose of the green chemistry workshop was to offer training to high school teachers on how to infuse the principles of green chemistry into a traditional high school level curriculum. For this workshop, a green chemistry laboratory booklet was created by Beyond Benign staff, replacing traditional laboratory activities that use and teach techniques and materials that are hazardous to human health and the environment with more benign chemicals and procedures.

Green Chemistry Labs provided by Beyond Benign for workshop:

- **Reactions**
- **Essential Oil Extraction Using Liquid CO2**
- **Equilibrium/Le Chatelier's Principle**
- **Enthalpy of Combustion**
- **Acids, Bases and pH**
- **Green "er" Redox**
- **Solubility**
- **Sublimation**

Teachers from the Hudson Valley working at green chemistry lab "stations" during the DEC green chemistry workshop

Workshop Attendance:
The DEC green chemistry workshop was held at Liberty High School on October 7, 2011. A total of 41 people attended the workshop, with 28 science teachers representing all the counties of the Hudson Valley region of the state.

Schools Represented	Counties	Number of Teachers	Professional Titles
Germantown HS	Columbia	1	H.S. AP Chemistry
Charlotte Valley CSD	Delaware	1	H.S. Science
Sidney CSD	Delaware	1	H.S. Chemistry
Arlington HS	Dutchess	1	H.S. Regents Chemistry
Tuxedo HS	Orange	1	H.S. Chemistry and Forensics
Washingtonville HS	Orange	1	H.S. Chemistry
Cooperstown CSD	Otsego	1	H.S. Chemistry and Physics
Haldane CSD	Putnam	1	H.S. Chemistry
Felix Festa MS	Rockland	2	M.S. Science
Nanuet UFSD	Rockland	2	H.S. Environmental Science
Fallsburg HS	Sullivan	1	H.S. Chemistry
Liberty HS	Sullivan	2	H.S. Chemistry and Earth Science
Sullivan West CSD	Sullivan	5	H.S. Chemistry
Tri-Valley CSD	Sullivan	1	H.S. Chemistry and Physics
Onteora HS	Ulster	1	H.S. Chemistry
SUNY-New Paltz	Ulster	1	Adjunct Professor of Chemistry
Blind Brook UFSD	Westchester	1	H.S. Science
Hendrick Hudson SD	Westchester	1	H.S. Science
Ossining HS	Westchester	1	H.S. Chemistry
Rye HS	Westchester	2	H.S. Chemistry and Physics

RESULTS OF GREEN CHEMISTRY WORKSHOP

The general consensus expressed by the green chemistry workshop participants was that they enjoyed and appreciated the “hands-on” participation at the laboratory stations that were set up around the classroom. Participants enjoyed being able to discuss and network with other chemistry teachers as they worked the “stations.” The teachers expressed high satisfaction with the green chemistry replacement experiments

and handouts and were appreciative of the practical nature of the experiments. They appreciated learning about safer methods to do chemistry experiments and acknowledged that the workshop had raised their "green" awareness.

The workshop participants indicated that they would like to see the workshop content increased. They pointed out a need to clarify workshop objectives, and that TRGC should provide better information prior to the workshop on what exactly green chemistry is, so that they may be better informed and prepared. The teachers pointed out the need for specific, measurable and repeated results for the proffered green chemistry experiments. They want to see additional topics included in future workshops, such as: titration, nuclear, compounds, a list of green chemistry substitutions, energy evaluations of green chemistry versus traditional chemistry experiments and purchasing/budgeting comparisons between green chemistry versus traditional chemistry experiments.

STEP FOUR – IMPLEMENTATION OF GREEN CHEMISTRY IN THE CLASSROOM

Since the October 2011 green chemistry training workshop, Liberty High School's chemistry teacher has implemented the following green chemistry techniques:

- Introduction of chemical safety and environmental impacts discussions
- Used Reaction experiments developed by Beyond Benign
- Instituted more model-based determinations/computer animations
- Introduced a chemistry demonstration that simulated a corporate environment that factors in time and money into the experiments

Site Visit

TRGC staff visited a chemistry laboratory session at Liberty High School to view their implementation of the principles of green chemistry. At that time, Liberty High School's chemistry teacher was using a green chemistry experiment designed by Beyond Benign on acids and bases, which substitutes derivatives from blueberries, beets, red cabbage and vinegar as pH indicators instead of using more traditional indicators like phenolphthalein[1], a possible carcinogen. There were 21 students in the classroom, half were 11th grade students and half were 12th grade students. The class began with a "white board" question discussion (i.e. "Which solution has the highest boiling point at standard pressure?") After the discussion, students were directed to don safety goggles and get ready for the day's lab activity: "*Testing for Acids and Bases.*"

After some confusion by the students on how to proceed with the experiment, they settled down and were very engaged with the experiment exercise. The students responded strongly to distinct color changes, but were frustrated that so many of the indicator colors came out with little variation. DEC staff observed many students smelling indicators. Such unpredictable behavior exhibited, on occasion, by students in chemistry class underscores the benefit of using benign substances to lessen health and safety liabilities. Negatively, TRGC staff observed that the chemistry teacher opted not to inform the students that they would be working with green chemistry experiments, preferring to wait for the next class or explain why

[1] Science Lab.com, Material Safety Data Sheet, Section 3 Hazards Identification

it was "green." DEC staff believed that it would have been preferable if it had been made known to the students, right from the start, to raise their awareness about the benefits of using a greener process with more benign chemicals. An obvious benefit to all was the ease of clean up. When the experiment was completed, all equipment was simply rinsed with water and poured down the drain.

Liberty High School's chemistry teacher had many concerns and comments about this initial green chemistry lab experiment. She indicated that food-based reagents have to be made fresh; therefore, she could not prepare the solutions and store them ahead of time. This used up valuable time for the actual experiment. Traditionally, most lab materials must be ordered ahead of the new school year for budgeting reasons. This means that ordering fresh ingredients may be a problem for the teacher. If fresh ingredients are purchased too early, they may spoil. If the teacher buys supplies, out- of- pocket, they might or might not get reimbursed.

In addition, preparing the indicators was relatively time consuming, and the results were not definitive. Although the students enjoyed the intensive "hands-on" nature of the experiments, not all had enough time to finish their labs in one class period.

Other comments received about the green chemistry experiments indicate that there is a need for more detailed instructions from Beyond Benign with regard to their experiments.

OVERALL SUMMARY AND CONCLUSION

The goals of this case study were accomplished. The overall methodologies used for this case study indicates that the format works. The inventory, training and actual implementation of the green chemistry principles has allowed TRGC to evaluate the program and make the necessary changes to improve it for the next phase. The school showed that they were capable of working in a cooperative manner with the DEC and made the commitment to implement green chemistry practices. The study showed that the school benefitted from proper chemical management practices and were made aware of the benefits as the chemical inventory and reorganization efforts resulted in a 67% reduction of line item chemicals. This in turn will result in future savings and lower disposal costs. In addition, savings will be realized as fewer chemicals will be needed in green chemistry experiments, resulting in fewer chemicals purchased in the near future.

Significant cost savings were realized with regard to disposal of chemicals identified during the chemical inventory and re-organization process. If the school had to hire a private contractor to do the inventory, transportation and disposal of chemicals, the cost would have been $21,540 as illustrated in Table-6. By having TRGC staff do the actual work and BOCES paying for the transportation and disposal, the cost was $11,591 (a savings of $9,949), as illustrated in the Measurable Results Reporting Form of the final report.

Table-6

New York State Division of Remediation Vendor-Estimated Amount Breakdown for Lab Packs

Disposal (hazardous)	398 lb x $463/50 lb	$3,686
Lab Packing	$2,692/day x 5 day	$13,460
Disposal (non-hazardous)	152 lb x $235/50 lb	$714
Drum Loading Area	$1,806/day x 1 day	$1,806
Other Transport	$555.00/event	$555
PPe[2] Upgrades level C	$88 per person/ per day x 3 people x 5 days	$1,320
Total		$21,540

The workshop and training held as part of this case study enabled 28 science teachers representing all the counties of the Hudson Valley to become aware of the benefits of proper chemical management and the principles of green chemistry. This ensures that interested shareholders have been made aware of the benefits of green chemistry with regard to toxicity reduction and cost savings. Green chemistry techniques and experiments have been implemented at the school.

While it was beneficial to have the support of the school principal and district superintendent, it resulted in having only one chemistry teacher trained in the principles of green chemistry which was a drawback for the teacher in this case study. This chemistry teacher would have benefitted from having fellow chemistry teachers trained and implementing the same green chemistry principles to "*bounce ideas off of*" and offer support in trying out new techniques in the classroom. Liberty High School's chemistry teacher only tried a couple of experiments in the eight-month period from October 2011 to June 2012.

It would be more beneficial to train as many chemistry teachers as possible in a school so that they could work together on the implementation. However, in regards to the overall methodologies used for this case study, the format works. The inventory, training and actual implementation of the green chemistry principles has allowed us to evaluate the program and to make the necessary changes to improve it for the next study.

[2] Personal protective equipment

ADDITIONAL GREEN CHEMISTRY RESOURCES:

Organization	Internet Address
Siena College • Green Chemistry Summer Institute	http://www.sienagreenchemistry.org
Beyond Benign • Green Chemistry Curriculum (free)	http://www.beyondbenign.org
American Chemical Society's Green Chemistry Institute for educators and students • Experiments and Curriculum for download • List of ACS books on Green Chemistry	http://www.acs.org/greenchemistry
Greener Educational Materials (GEMS) Database thru the University of Oregon for educators and students • Searchable database with Green Chemistry education materials uploaded by faculty members and educators worldwide • Most curriculum is available for download (free) or with primary literature information	http://greenchem.uoregon.edu/gems.html
GCEdNet-Green Chemistry Education Network	http://cmetim.ning.com/
University of Scranton Greening Across the Chemistry Curriculum • Green Chemistry Modules for download	http://www.scranton.edu/faculty/cannm/green-chemistry/english/drefusmodules.shtml
Carnegie Mellon University Institute for Green Science • Green Chemistry Modules for download	http://igs.chem.cmu.edu/

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United States Environmental Protection Agency (USEPA) – www.epa.gov/region2

New York State Education Department (SED) – www.nysed.gov

Beyond Benign – www.beyondbenign.org

Sullivan County BOCES – www.scboces.org

Liberty High School – www.libetyk12.org/hs/highschool_home.cfm

OSHA Laboratory Standard (29 CFR 1910.1450) – www.osha.gov

New York State Plan for Public Employee Safety and Health (PESH) – www.osha.gov/dcsp/osp/stateprogs/new_york.html

NYSED C& I (Curriculum and Instruction) – www.p12.nysed.gov/ciai/mst/scirg.html