

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



NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION



Department of
Environmental
Conservation

Case Study: Long Island - New York State Green Chemistry School Candidate Sachem High School East

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Sachem High School East – Principal Antonetti, Science Department Chairperson, Colleen Plantier, Chemistry teachers: John Castagna, Kevin Sloane, Peggy Doherty, Kathy Stein, Adam Walters, Sean Holden and Colleen Lohr.

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“Evaluation of a suburban school 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 reduction 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 Sachem High School East 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, and 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.

Sachem High School East is one of two high schools in a large suburban district on Long Island and is an “average needs with average resources” school, as categorized by the New York State Department of Education (SED) school report card. It is located in the Long Island region of New York State in Farmingdale in Suffolk County. The school has approximately 14,000 students in grades pre-K-12 and offers a full complement of chemistry courses including non-Regents, Regents, Honors, AP Chemistry and a special course in scientific research which allows students to work on a project in a science area of particular interest to the student. Sachem High School East was constructed in 2004. The science facilities reflect modern newer construction methods.

The study was undertaken in steps: The first step was an evaluation of the necessity for assistance which includes 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

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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 calendar school 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 step was to have 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 Toxic Reduction and Green Chemistry Section of the DEC.

STEP ONE – SITE INVESTIGATION AND ANALYSIS

On May 22, 2012, staff from DEC conducted a preliminary site visit at Sachem High School East, located in Farmingville on eastern Long Island, to determine the scope of the school's chemical usage, storage options, and purchasing practices. The site visit also served to gauge interest by the school personnel in participating in this green chemistry project. There are two regulations which impact science areas in schools. One regulation 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 try to enforce the OSHA laboratory standard or any regulation under the NYS Department of Labor.

Upon review, it was noted that Sachem High School East had all of the necessary chemical safety storage and apparatus for the variety of chemicals that were in use. The chemistry department has pass-through fume hoods, chemical prep rooms adjacent to the classrooms, a central chemical storage area for bulk/infrequently used chemicals and a supportive team of chemistry teachers. Although there was no current chemical inventory at the time of the DEC site assessment, there was a complete Material Safety Data Sheet (MSDS) file.

Although it is unusual for a high school to have its own in-house prepared chemistry laboratory manual, all students who take Regents chemistry, regardless of the teacher, use the same laboratory manual at Sachem High School East. This helps to ensure that all students receive the same high quality instruction. This consistency in material presented suggests that each of the three prep rooms could have a set of chemicals specifically designated for use by Regents chemistry. Excess chemicals, infrequently used chemicals, or chemicals which are highly hazardous in nature could be kept in the central storage room where there are multiple storage cabinets in which chemicals are segregated according to the Flinn Chemical Storage system.

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The common laboratory manual spells out in detail how much of a particular reagent or chemical is required for each activity. There are 53 lab activities per school year; nearly 50% of them do not use any chemicals. Water, M&M candies, paper clips, salt and sand are used in many of the early activities. When chemicals are used, the faculty made a conscious decision to work at either the spot plate scale or the smallest scale possible to get the desired results. In order to determine the chemicals that were required for green chemistry, DEC staff matched the current Beyond Benign green chemistry experiments to New York State Learning Standards, Green Chemistry Standards and National Science Standards (NSES). New York State Education Department (SED) guidelines require that students who wish to take a Regents examination in any of the sciences must complete the course leading up to that particular Regents examination and complete 1,200 minutes of hands-on (not simulated) laboratory experiments with satisfactory documented laboratory reports. Beyond Benign's green chemistry curriculum can provide at least 1,000 of the required 1,200 minutes for a course designed to culminate in the Regent's examination in Physical Setting/Chemistry, Core Curriculum.

A detailed assessment of the laboratory chemical storage areas except for the main storage area was conducted by DEC staff during a second site visit in July, 2012. The last chemical cleanout at Sachem High School East was performed in 2010.

A review of each prep room and the central chemical storage area revealed an excess of chemicals which are stored permanently and not on a short term basis, as is intended by the placement and size of the prep rooms. Outdated solutions took up a considerable amount of space in the rooms. The main storage area revealed a significant supply of alkali metals (Li, Na) and alkaline earth metals (Mg, Ca). In one particular cabinet a large quantity of potassium nitrate was stored with a volatile solvent; this storage situation will need to be addressed. There were no chemicals of Immediate Danger to Life and Health (IDLH). No broken bottles were observed but there were a number of rusted containers; no unknowns were observed.

There were a number of chemicals stored in each storage area as some of the prep areas needed to accommodate more than one course. Nothing flammable or corrosive should be stored on top of cabinets, or within two feet of the ceiling. As seen in the adjacent photo, this was not the case.

From a chemical safety perspective, chemicals stored above eye level can pose a hazard to those who are short in stature; nearly all prep rooms contained chemicals and other supplies above them.



DEC staff worked with chemistry staff at Sachem High School East and undertook the process of looking at each chemical bottle and answering questions such as: *“Where does it belong?”*, *“Do we need it?”*, *“How often is it used?”*, *“How much is in the bottle and can we consolidate like bottles?”*, and *“Is there a safer place to store it?”*.

TRGC staff and the team of chemistry teachers present were able to free up a large amount of space in the prep rooms. At the end of the day, there were no more

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chemicals atop cabinets, a large amount of shelf space was freed for nonhazardous supplies (i.e. aluminum foil, parafilm, karo syrup, club soda) and excess quantities of chemicals were moved to the main storage area.

Unfortunately, due to time and budget limitations within the grant, the central storage area containing the acids, bases, and solvents; were left off the inventory. TRGC staff recommended to the teachers to add the items to the inventory developed by TRGC.

Sachem High School East utilizes a public drinking water system. All liquid wastes are directed to either an underground neutralization tank or an on-site septic system. These systems are managed by the school and emptied on a regular basis. When discharging directly to the septic system instead of a public sewer or sewage treatment system, it is vitally important to reduce the amount of highly toxic chemicals in storage. Extreme care should be taken when disposing of chemicals due to possible releases to the environment.

RESULTS OF THE CHEMICAL INVENTORY

The teachers at Sachem High School East participated with DEC staff in conducting the chemical inventory during the final week of school in June 2012. The one prep area containing research chemicals was not inventoried in July 2012 as well as the main storage area.

The chemical inventory was created by counting each chemical in stock and handwriting the information into a template. However, the chemical inventory did not contain any of the acids or bases stored in the central storage area or any of the chemicals in the research prep room.

For this particular case the chemical inventory was conducted in the preparation rooms only with the teachers that were willing to participate. The teacher assigned to the research room was not a participant of the chemical inventory. In addition, the school central storage area was not included in the project, due to time and budget limitation within the grant. Additional information was mailed to DEC which was included in the inventory.

The results of the July inventory was mailed to DEC's main office in Albany, New York. All of the information collected from the inventory was placed into a MS Excel spreadsheet that can be sorted in many different ways to give the curriculum coordinator (or individual teacher) a snapshot view of what is on hand, where it is located, and how much there is.

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RESULTS OF CHEMICAL STORAGE REORGANIZATION

Table 1

Chemicals by Hazard Type			
	Jun-12	Jul-12	% change
Storage class	lbs.	lbs.	
Blue (Health Hazard)	67.2	37.1	44.8
Red (Flammable)	133.4	65.3	51.0
Green (General Storage)	1195.5	490.3	59.0
Yellow (Oxidizers)	127.2	85.5	32.8
White (Corrosives)	161.3	127.6	20.9
Total	1684.6	805.8	52.2

The chemical inventory and reorganization effort resulted in a 32% reduction of total chemicals inventoried - a decrease from 1139.9 lbs. to 808.4 lbs. The results can be seen in **Table 2- Chemical Inventory by Toxicity** and **Table 3-Hazardous/Highly-Toxic Chemicals**.

Table 2

Chemical Inventory by Toxicity					
Category	# Inventory items June 2012	lbs.	# inventory items July 2012	lbs.	% change (lbs.)
Irritant	151	177.7	99	125.9	29.2
Severe Irritant	56	43.6	22	23.4	46.3
Hazardous to Health	413	353.8	273	238.2	32.7
Very Hazardous to Health	159	150.9	126	125.2	17.0
Possible Carcinogen (2B)	48	29.3	24	18.9	35.5
Known Carcinogen	22	11.7	3	0.7	94.0
total	849	767.0	547	532.3	30.6

Of the original 1,139.9 lbs. of chemicals inventoried, 767.0 lbs. were classified as highly toxic- meaning that 67% of the initial inventory was toxic.

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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 (lbs.)
Sachem East HS	849	767.0	547	532.3	234.7	30.6
Lbs. of hazardous/highly- toxic chemicals recommended for disposal					234.7	30.6 lbs.

In addition to the reduction in highly toxic chemicals, 96.8 lbs. of relative less-toxic chemicals were recommended for disposal. The results can be seen in **Table 4- Sachem High School East Relative Less-Toxic Chemicals** and **Table 5- Relative Less-Toxic Chemicals**.

Table 4

Relative Less-Toxic Chemicals						
School	# Inventory items pre assessment	lbs.	# Inventory items post assessment	lbs.	lbs. of chemicals recommended for disposal	% reduction (lbs.)
Sachem East HS	343	372.9	252	276.1	96.8	26.0
lbs. of relative less-toxic chemicals recommended for disposal					96.8	26.0 lbs.

A significant number of known carcinogens as well as possible carcinogens were identified in the chemical storage area and TRGC staff recommended that these chemicals be removed from the chemical inventory. In addition, several other unwanted and/or unneeded chemicals were recommended for removal. Sachem High School East staff was encouraged to adopt green chemistry principles that will assist the staff in protecting the health of students and teachers and save money in the process. It was determined that Sachem High School would benefit from establishing a chemical management system that included an up to date chemical inventory.

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Most purchasing at the school is done at the beginning of the school year so teachers cannot obtain needed chemicals later in the school year if they are not available. A more precise inventory will assist teachers in making early purchases and ensuring that an adequate supply of chemicals is on hand for the entire school year.

STEP TWO - ACCEPTANCE AND WILLINGNESS

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

STEP THREE - TRAINING

Chemical Hygiene Training

On June 13, 2013, DEC's staff conducted chemical management training for the chemistry teachers at Sachem High School East. All of the chemistry teachers were in attendance, however, the chemical hygiene officer was not. A general overview of an effective chemical management plan was discussed as were ways in which the high school could improve their current system. The training included a discussion of available resources to the chemistry teachers and specific topics regarding safety and toxicity topics. The human toxicity of the current inventory was thoroughly discussed. Sachem High School East had all the necessary space to store their chemicals, but lacked adequate spaces in which to use high hazard chemicals.

Green Chemistry Training

Cancellation of the November 6, 2012 DEC Green Chemistry Workshop in Long Island

On October 29, Hurricane Sandy battered the coasts of New Jersey, the NYC metropolitan area and Long Island causing great devastation. The conditions, even after a week later, on Long Island were poor due to flooding, loss of electrical power, gas shortages, fallen tree debris and downed electrical wires. In consideration of these conditions, particularly since the locale of the intended DEC Green Chemistry Workshop, which was to be held on November 6, 2012, at Sachem High School East in Farmingville, was being used as a shelter, TRGC staff decided to cancel the workshop. The Long Island Green Chemistry workshop was rescheduled for February 1, 2013 at the Chemistry Building on the SUNY Stony Brook campus.

Rescheduled DEC Green Chemistry Workshop in Long Island

SUNY Stony Brook agreed to host DEC's third green chemistry workshop as their Department of Chemistry has a Sustainability Studies Program which connects high school chemistry content to issues of sustainability through engaging students in hands-on lab activities.

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

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workshop, a green chemistry lab 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.



Teachers from Long Island working at green chemistry lab "stations" during the DEC Green Chemistry Workshop

Green Chemistry Labs provided by Beyond Benign for workshop:

- Flame Tests and Emissions Spectra
- Le Chatelier's Principle/Equilibrium
- TAML
- Blackberry Solar Cells
- Recycling Polylactic Acid
- Exothermic & Endothermic
- Reactions Lab
- Catalysts and Oxygen

Workshop Attendance:

There were 39 people who attended the DEC green chemistry workshop, of which 22 were high school science teachers representing Suffolk county in the eastern Long Island region of the state.

Schools Represented	Counties	# of Teachers	Professional Titles
Bayshore HS	Suffolk	1	H.S. Chemistry
Brentwood HS	Suffolk	2	H.S. Chemistry
Comsewogue HS	Suffolk	3	H.S. Chemistry
Connetquot HS	Suffolk	3	H.S. Chemistry
Copaigue HS	Suffolk	1	H.S. Chemistry
Harborfields HS	Suffolk	1	H.S. Chemistry
Miller Place HS	Suffolk	1	Student Teacher
RC Murphy JHS	Suffolk	1	Science Dept. Chair
Sachem East HS	Suffolk	7	H.S. Chemistry
Shoreham-Wading River	Suffolk	1	H.S. Chemistry
West Babylon HS	Suffolk	1	H.S. Chemistry

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RESULTS FROM THE GREEN CHEMISTRY WORKSHOP

An overwhelming consensus among workshop attendees was that they appreciated the “hands on” approach to the green chemistry lab experiments. High satisfaction was expressed with the green chemistry replacement labs and the practical nature of workshop handouts. Teachers indicated that they liked the practical nature of the experiments which facilitated implementation and comprehensibility for the students. They also liked the inquiry based activities associated with the labs. Some participants expressed an interest in learning how green chemistry could address biology concerns, as it relates to chemistry and others were interested in having green chemistry labs that would deal with organics and gases.

Attendees appreciated the enthusiasm and knowledge of the presenters and the quality of the handouts. They appreciated the emphasis on how green chemistry can be used in lab experiments to achieve desired results without producing toxic substances and hazardous working conditions. As with previous workshops held at other locations, attendees indicated that they would like to see additional experiments as well as increasing the number of days of the workshop. They also indicated that they would have been better prepared if they had access to more green chemistry information before the workshop.

Many teachers said that they would definitely start using green chemistry lab experiments in their classrooms. One teacher said, “I can honestly say that this was one of the most engaging workshops that I have attended. As a Junior High School Chairperson, I am always trying to find more inquiry-based activities for the teachers. This program gave me lots of information and resources.” Workshop attendees also enjoyed being able to discuss and network with chemistry teachers from other schools in Suffolk County.

STEP FOUR - IMPLEMENTATION OF GREEN CHEMISTRY IN THE CLASSROOM

Initially, the teachers reported that due to the length of the school cancellation caused by Super storm Sandy, they had to devote the remaining time left of the 2012-2013 calendar school year to catching up on regular chemistry class requirements. The teachers did plan to start trying out the green chemistry labs in the 2013-2014 school years. As of April, 2014, the seven chemistry teachers at Sachem High School East reported back on their use of the following experiments and their results:

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Green Chemistry Experiments	Results
Equilibrium	They will be using the iodine/ starch lab after Spring break.
Flame Test (Emission Spectral Line Analysis)	They used the 3-D glasses and the party candles in this experiment. The students loved the colors, although it was not as effective as the conventional salt solution flame test. The 3-D glasses were a hit.
Types of Reactions Lab	The teachers had used a similar lab. The reactions worked fine even with the lower greener concentrations.
Endo/ Exothermic Reactions	The students loved the pixie sticks, but were grossed out with the liver. The reaction was great, so they were attentive.
Catalyst	Students love the home chemistry of dish detergent, vitamin C caps, food coloring etc.
Additional Comments: We have reduced the concentrations of solutions, and replaced hydro-chloric acid with vinegar in two demos that we do for gas production.	

The chemistry teachers also noted that they were extremely appreciative of the help they received reorganizing and cleaning out the chemical storeroom and have disposed of several types of chemicals they should not be using as there are “greener” alternatives. As a consequence, they have reduced their stockpiles of many of our chemicals.

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 effort resulted in 32% reduction of line item chemicals. Reductions in the chemical inventory will result in decreased costs for disposal of un-used or un-wanted chemicals. Cost savings will also be realized as fewer chemicals will be needed so fewer will be purchased in the 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 over \$19,000.00 as illustrated in Table-5. By having TRGC staff do the actual work the savings to the school was \$7,353.00 as illustrated in the Measurable Results Reporting Form of the final report.

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Table-5

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

Disposal (hazardous)	235 lb. x \$463/50 lb.	\$2,176
Lab Packing	\$2,692/day x 5 day	\$13,460
Disposal (non-hazardous)	97 lb. x \$235/50 lb.	\$456
Drum Loading Area	\$1,806/day x 1 day	\$1,806
Other Transport	\$555.00/event	\$555
PPE Upgrades level C	\$88 per person/ per day x 3 people x 5 days	\$1,320
Total		\$19,773

The workshop and training held as part of this case study enabled 22 science teachers from 11 high schools in Suffolk County to become aware of the benefits of proper chemical management and the principles of green chemistry. An additional 8 observers from organizations as varied as Eastern Suffolk County BOCES, Nassau County BOCES, Port Jefferson Maritime Explorium and SUNY Stony Brook ensured that interested stakeholders have been made aware of the benefits of green chemistry with regard to toxicity reduction and cost savings.

Although the teachers from Sachem High School were late in implementing green chemistry in the classroom, we believe it is not because they have failed to embrace its principles. Rather, the lingering impact of Hurricane Sandy may have played an important role in delaying implementation. Cancellations appear to have forced teachers to play catch-up in completing regular chemistry class requirements instead of implementing new criteria. Based on the response to the workshop and the late comments received to specific green chemistry experiments, we believe that the school will embrace the principles of green chemistry in the 2014-2015 year. As noted in other case histories, it is vitally important to have the support of school administration, when trying to adopt even minor changes to the laboratory manual. If the school administration is not behind the effort and if there no flexibility with the procurement procedures, individual teachers will have a hard time making changes to the lessons plans.

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ADDITIONAL GREEN CHEMISTRY RESOURCES:

Organization	Internet Address
Siena College <ul style="list-style-type: none">Green Chemistry Summer Institute	http://www.sienagreenchemistry.org
Beyond Benign <ul style="list-style-type: none">Green Chemistry Curriculum (free)	http://www.beyondbenign.org
American Chemical Society's Green Chemistry Institute for educators and students <ul style="list-style-type: none">Experiments and Curriculum for downloadList 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 <ul style="list-style-type: none">Searchable database with Green Chemistry education materials uploaded by faculty members and educators worldwideMost 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 <ul style="list-style-type: none">Green Chemistry Modules for download	http://www.scranton.edu/faculty/cannm/green-chemistry/english/drefusmodules.shtml
Carnegie Mellon University Institute for Green Science <ul style="list-style-type: none">Green Chemistry Modules for download	http://igs.chem.cmu.edu/

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REFERENCES:

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

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

Beyond Benign – www.beyondbenign.org

Eastern Suffolk County BOCES – www.esboces.org

SUNY Stony Brook – www.StonyBrook.edu

Sachem High School East – www.sachem.edu/schools/east

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