Chemical Strategies Partnership
a project of the Tides Center
founded by The Pew Charitable Trusts
with major support from The Heinz Endowments

To: Brad Manning, Ken Brown (UNH)

CC: Jill Kauffman Johnson

From: Tom Votta, Freda Fung

Date: December 3, 2003

Re: DRAFT UNH Case Study

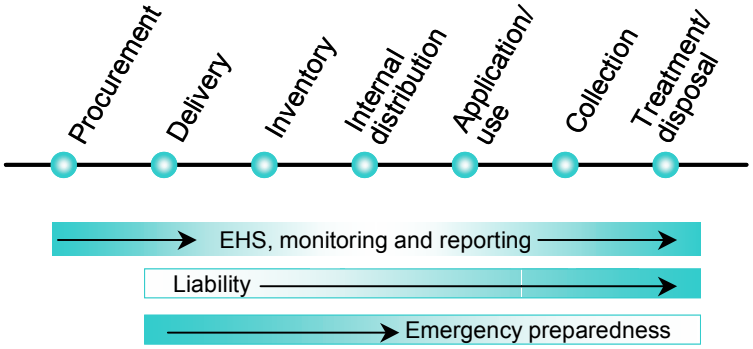
Chemical Environmental Management System (CEMS) at

University of New Hampshire

I. Background

This case study documents the chemical management system of the University of New Hampshire (UNH). It intends to illustrate a "best practice" of chemical management in the university and research setting. This memo provides a description of the chemical management system at UNH, discusses costs for setting up the system, and examines critical factors for the success of the system to improve chemical management at UNH.

Figure 1: The Chemical Management Lifecycle



We will use the chemical lifecycle (Figure 1) to characterize the current chemical management system of UNH. The stages of the lifecycle show different activities that are required to use a chemical. In the educational setting, we see a strong focus on procurement, inventory, use, disposal, EH&S and emergency preparedness.

Boston Office: (at Tellus Institute)
11 Arlington Street, Boston MA 02116 USA
Tel: +1.617.266.5400 Fax: +1.617.266.8303
www.chemicalstrategies.org
electronic transmission

Founded in 1866, UNH is a public university serving 10,800 undergraduate students and 2,000 graduate students. Located in the rural town of Durham, NH, UNH comprises the colleges of Liberal Arts, Engineering and Physical Sciences, Life Sciences and Agriculture, the School of Health and Human Services, the Whittemore School of Business and Economics, and the Thompson School of Applied Science. UNH also has an urban commuter campus at Manchester, NH.

Prior to the establishment of a centralized chemical management system, UNH had no designated unit responsible for tracking what chemicals were stored on the campus, or overseeing how chemicals were being managed. Most chemical users (such as researchers and facility maintenance staff) purchased their own chemicals, and they were responsible for proper management of their own chemicals.

UNH's initiative to develop an extensive chemical management system stemmed from enforcement actions. In 1997, a three-day U.S. Environmental Protection Agency (EPA) inspection found violations of the Resource Conservation and Recovery Act (RCRA) at various UNH laboratories and storage facilities. In a consent agreement with EPA, UNH agreed to pay a fine of $49,000 and implement a web-based information system – estimated to cost about $180,000 - to manage chemicals the university uses and stores. In addition, the university promised to document that it has trained personnel in hazardous waste management and has performed internal inspections in all areas where hazardous wastes are stored.

UNH's efforts to establish a chemical management system started out by evaluating existing chemical inventories. The Environmental, Health and Safety Department (EH&S) conducted the first campus-wide chemical inventory audit in 1998 to document all existing chemicals stored on the campus. More than 42,000 chemical containers were identified, each container was tagged with a barcode, and all chemical records were inputted in a Microsoft Access file. To reach the goal of eliminating mercury from the campus, EHS urged owners of chemicals that contain mercury to dispose of or recycle the chemicals.

While conducting the first audit, EH&S was also looking for an off-the-shelf chemical inventory management software product to facilitate tracking and management of chemical inventory information in the long run. After comparing the functionalities of inventory management systems that were available at that time, UNH purchased an information software, ChIM, from a software company, Vertere, in the fall of 1998. The ChIM software was chosen because it possessed functionalities that UNH considered best fit its needs. For instance, Vertere has licensed with Sigma Aldrich and Fisher Scientific to have catalogs of chemicals from these two suppliers built into ChiM. This function greatly saved the labor for creating chemical records – when ChiM users create a new chemical record, they only need to type in a product number and all related information of the corresponding chemical will be automatically filled in. In addition, the software has a built-in auto-tag generation function for creating a unique identification number for each container that allows users to easily print out the corresponding barcode tag, or if users have their own bar-code tags, the system allows users to scan the barcode of each container into the database. The chemical records from the first audit, in Access format, were then imported into the ChiM database (with a fee) after the software was purchased.

After the first audit, EH&S set up a new procedure to track newly purchased chemicals. Every time a researcher purchased a new chemical, he/she would need to tag a bar code on the chemical

container – a number of barcode labels were distributed to each laboratory – and submit a standard paper form to EH&S with the barcode number and the respective chemical information (e.g. chemical owner, chemical name, storage location, etc). Based on the paper forms, EH&S entered chemical records into the centralized database which could only be accessed from the four computers in the EH&S office that had ChiM installed.

In 1999, a second campus-wide audit was conducted to verify the centralized chemical inventory records, and a 20% discrepancy was identified. The discrepancy came from chemicals that had been removed or disposed after the first audit, as well as newly purchased chemicals that had not been recorded in the centralized database. It was believed that new chemical purchases were underreported because the system for reporting newly purchased chemicals using paper forms did not get buy-in from researchers. Since researchers could not access the centralized database, unless they kept copies of the reporting forms, it was difficult for them to see any results of their efforts and recognize the value of maintaining an up-to-date chemical inventory.

Findings from the second audit highlighted the limitations of ChiM to provide a campus-wide accessible information system. Since ChiM is not a web-based system, the only way to allow all chemical users have access to chemical inventory records is to install the software in each individual's computer. However, an annual site license fee was required for installation in each computer where it is used, therefore, the use of ChIM campus-wide would entail high costs. Even though at that time Vertere had plans to upgrade ChiM to a web-based system, there was no definite timeframe for such an upgrade. With the intention to minimize costs in the long run and fulfill UNH's specific needs, UNH decided to develop in-house a web-based chemical information tracking software and named it the Chemical Environmental Management System (CEMS).

The information tracking software was jointly developed by EH&S and the Research Computing Center (RCC) at UNH. Programming of the CEMS started in the winter of 2000. The first version of the CEMS was piloted in a marine biology laboratory, and laboratories of the Department of Microbiology in January 2001. At the same time, two centralized receiving areas - the Chemistry Stockroom and the EH&S Chemical Transfer Station - were set up, where newly purchased chemicals are received and tagged with barcodes, and new chemical inventory records are created in the centralized inventory database. A campus wide education and outreach program was launched in parallel to educate chemical users on how to use CEMS (e.g. how users can access their own chemical inventory records, and how to search for surplus chemicals), and inform them of the new receiving arrangement, as well as their responsibilities under the new arrangement.

Receiving feedbacks from the pilot laboratories and other chemical users, RCC upgraded the CEMS and launched a revised version campus-wide in the fall of 2001.[1] CEMS now provides a web interface where chemical users, EH&S staff, and local Fire and Police Departments can log on to their own customized homepages. For instance, homepages of all chemical users provide direct links to run queries on the existing chemical inventory. The information system also allows users to post a request for hazardous waste disposal pick-up, or to designate surplus chemicals so that other users know when searching the chemical inventory. Homepages of EH&S staff and local

[1] To further the efforts to eliminate use of mercury, EHS initiated a thermometer exchange program, through which EH&S would pay for the replacement of mercury-containing thermometers with non-mercury thermometers. This program was rolled out at the same time as the introduction of CEMS.

Fire and Police Departments provide additional links to view special information on classes of chemicals with particular environmental or explosive characteristics.

The goals of the chemical management system at UNH are to:

- Be in compliance with environmental legislation
- Ensure that chemicals are not stored indefinitely on campus
- Optimize chemical purchases, and reduce chemical use in teaching laboratories, where appropriate.
- Improve laboratory safety and emergency preparedness
- Identify hazardous materials on campus and possible non-hazardous substitutions

The system is now implemented campus-wide, supporting 67 departments, 320 chemical users and 255 laboratory associates. The system also keeps chemical inventory records and door signs of non-educational facilities, such as the vehicle maintenance garage, the greenhouse pesticide and fertilizer storage areas, storage areas for facility maintenance supplies and custodial cleaning supplies.

In addition to software development, RCC performs ongoing maintenance, troubleshooting and upgrading of the system. For instance, RCC is developing two new modules for radioactive and biological inventories. In addition, UNH allows other universities to license the CEMS software, with RCC acting as the Application Service Provider to maintain the software for the licensees.[2] RCC, therefore, continues to develop new features to cater for the needs of licensees.

II. Chemical Management Processes at UNH

An overview of the current chemical management system at UNH is presented in Figure 2. As shown in the figure, the CEMS system tracks chemicals from the time they arrive at the campus to the point of disposal. The following section summarizes how UNH manage chemicals at each chemical lifecycle stage under the current chemical management system.

1. Procurement

Most researchers and university staff purchase their own chemicals. Chemicals are mainly acquired via two pathways: by individual purchasing cards (credit cards or p-cards) or through orders through the Business Service Centers. Researchers are free to choose whichever chemical suppliers they prefer, subject to their research and teaching needs. Chemical information is entered into the CEMS system only when the chemical is delivered to the campus (see next section "Inventory"). Thus the CEMS only contains information of chemicals currently on-site and does not contain information on the total dollar value of chemical purchases.[3] Additionally, since the

[2] Brown University is the first university that has bought the CEMS license for managing its chemical inventory. In addition, University of Massachusetts – Amherst has also signed on to use CEMS. They are currently undergoing their first chemical inventory audit which mainly focuses on Morrill Hall, the primary science building on campus. More information about CEMS can be found at: http://www.cems-info.sr.unh.edu/.

[3] The system originally planned to create an interface connecting to the procurement stage of chemical suppliers, and organized meetings with the three main chemical suppliers -Sigma Aldrich, Fisher Scientific and VWR International – to discuss the

system was designed as a hazardous material tracking system, rather than an accounting system, it does not track the proportion of chemicals purchased through these two pathways. However, it is believed that there are advantages for researchers to purchase chemicals through the use of purchasing cards.[4]

There are in general no restrictions on chemical purchases, except for prohibited chemicals – such as Dimethyl mercury – and chemicals that contain radionuclides, which require approval from EH&S prior to purchasing.[5] Even though requisition of chemicals does not go through the CEMS, EH&S encourages both chemical users and the business center to look online for surplus chemicals before placing an order.

According to the CEMS database, about 65% of chemicals are ordered through three main suppliers - Sigma Aldrich, VWR International (VWR), and Fisher Scientific. Each of these main suppliers acts as both suppliers of chemicals and distributors.[6]

2. Inventory

The CEMS information software currently records an inventory of 49,883 chemical containers.[7] Inventory records of newly acquired chemicals are created at the centralized receiving locations, where EH&S staff or other designated parties are responsible to receive chemicals, tag chemical containers with bar codes, and input chemical information– such as CAS number, chemical owner, storage location, vendor, product number, container size, unit of measure, and type of container - into the centralized inventory database. After tagging barcodes, EH&S staff deliver chemicals to individual users or departments. EH&S requires that all chemicals received at the Chemical Transfer Station be delivered to chemical users the same day as arrival.

Chemicals acquired for non-laboratory use (e.g. custodial and facility maintenance chemicals) are not received at the centralized receiving locations. The inventory records of these chemicals are kept up-to-date through periodic inventory audits undertaken by EH&S.

---

feasibility. RCC finally decided that it would be too difficult to create such an interface in CEMS because the ordering web pages of some suppliers are linked to their own inventory database, and so cannot be accessed directly through CEMS. Also, many vendors do not have web sites for ordering chemicals.

[4] By ordering chemical using p-cards, researchers can better manage grant funding by dedicating a p-card to a particular grant, and obtaining multiple cards for multiple grants. In addition, researchers place orders directly with suppliers and can check any order themselves.

[5] Dimethyl mercury is prohibited at UNH campus. Chemicals containing a radionuclide must be approved and ordered by the UNH Radiation Safety Officer.

[6] Information extracted from the CEMS database, as of January 2, 2003. Since the database provides information on manufacturers and not suppliers, it was assumed that the suppliers and manufacturers have exclusive contracts as follows:
VWR International - Distributor for Aldon, Alfa Aesar, BDH, Burdick & Jackson, EM Science, ICN Bio, JT Baker, Mallinckrodt, Pierce, Ricca, Shelton, and Ultra;
Sigma Aldrich – Distributor for Sigma, Aldrich, Fluka, and Supelco brands.
Fisher Scientific – Distributor of its own brand name product, Fisher Scientific as well as Acros Chemicals and other secondary manufactures.

[7] According to the CEMS inventory database, as of July 21, 2003.

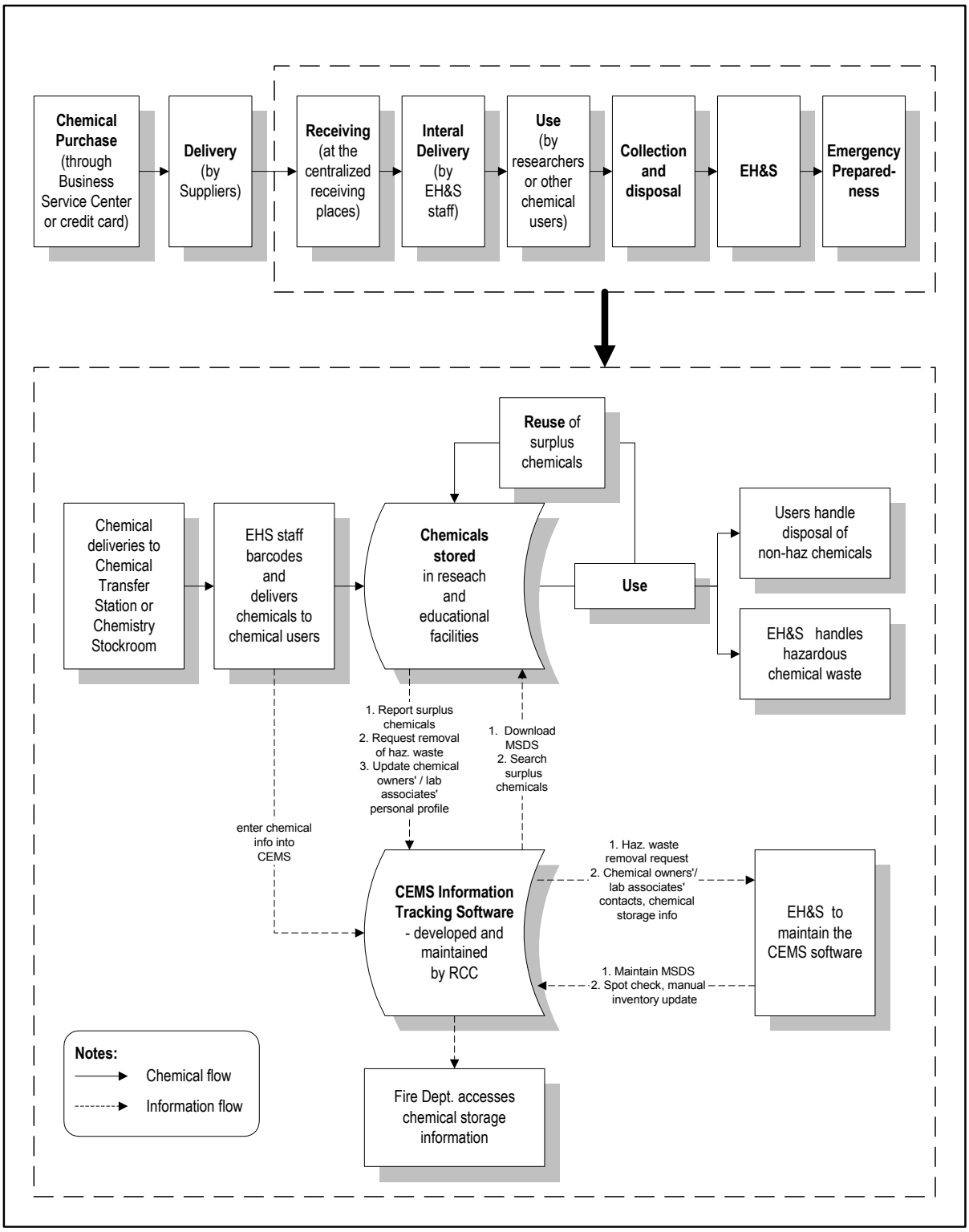


Figure 2: University of New Hampshire - Chemical Environmental Management System

All chemicals ordered by the Chemistry Department are currently received at the Chemistry Stockroom. The Chemistry Stockroom also holds stock of selected chemicals that are dispensed to chemical users of other departments. The Chemistry Stockroom now holds 523 chemical containers (as of October 2003), i.e. about 1% of the total inventory.[8]

Chemicals ordered by the staff of other departments are arranged to be delivered to the Chemical Transfer Station. In order to avoid chemical orders from circumventing the centralized receiving system, UNH established an agreement with the three main suppliers to deliver all chemicals - except those ordered by departments in Parsons Hall - to the Chemical Transfer Station. UNH also communicates regularly with UPS, FedEx and other shipping companies to educate them about sending all parcels containing chemicals to the Chemical Transfer Station.[9]

While EH&S does not have a regular audit schedule to systematically verify consistency of the inventory data with the actual inventories in each laboratory, it has set up a guideline to visit at least 10% of laboratories annually to identify chemicals that have circumvented the receiving system and have not been barcoded. These audits are conducted at laboratories that show "questionably" low disposal quantity compared to inventory, or are performed when:

- A researcher moves to another laboratory, or leaves the university, and all chemicals in the laboratory need to be either scanned out of the CEMS database entirely, or rescanned into a new location. This happens about seven to eight times in one academic year.
- A chemical owner requests EH&S to re-inventory his/her laboratory due to changes in personnel or graduate students.
- A laboratory or building undergoes significant remodeling or upgrading and all chemicals stored inside need to be verified in order to perform a hazard assessment prior to construction/renovation.

The inventory database can be searched and viewed by all chemical users, EH&S and local Fire and Police Departments using the web-based CEMS. For biological agents, or chemicals that can be used to make potentially dangerous or illegal products, chemical owners could request to hide their inventory from being searched by other users. The hidden items, however, could still be viewed by the local Fire Department, EH&S, and the owners themselves.

3. Use

Chemical use for education and research purposes is characterized by a high diversity and low volume pattern. The CEMS does not track consumption of chemicals, just their containers. A

[8] The Chemistry Stockroom has conducted a clean out in January 2003 to identify and dispose chemicals that are no longer needed by researchers. Before the cleanout, the stockroom had over 4,000 chemical containers.

[9] Despite best efforts to educate chemical users on the central receiving arrangement, some researchers still provide their own laboratory address when ordering chemicals because they have failed to separate the chemical part of the order from the lab supplies part. Furthermore, drivers of UPS and FedEx sometimes change and thus some chemicals are being sent to the researchers directly. Although it is hard to quantify, it is believed that up to 5% of newly purchased chemicals could have bypassed the two centralized receiving locations.

container appears to be full in the database until its owner declares it empty through the direct links on the chemical owner's homepage. In addition, the CEMS software allows chemical users to designate unneeded chemicals that can be made available to other users free-of-charge. If a researcher wants to acquire a new chemical, he/she can check the surplus chemical list through CEMS, obtain the contact information of the chemical owner if the chemical needed is found, and contact the chemical owner directly for details about the chemical, such as purity and age.

4. Disposal

Disposal of non-hazardous chemicals is not subject to any regulatory requirement, and therefore is typically handled by chemical users. But EH&S encourages chemical users to remove or obliterate bar-code labels prior to disposal, and report these containers empty through CEMS so that EH&S knows that these chemicals no longer exist on the campus. Hazardous waste chemicals, however, must be taken care of by EH&S. Chemical users can request a pick-up service through their own CEMS homepages. After receiving a request, the Hazardous Waste Coordinator of EH&S will collect the hazardous waste chemical for off-site treatment by their sub-contractor.

Before implementing CEMS, all hazardous waste disposal records were kept on paper copies with the shipping manifests. Now all hazardous waste pick-up records are kept in the database and EH&S and researchers can easily search the disposal records by the type of waste stream, the date of pick-up, name of waste generator, and department. This enables EH&S to easily identify key waste generators and target education programs on waste reduction.

To ensure that chemicals will not stay indefinitely on the shelf, a default 3-year evaluation date is set in the CEMS software. Periodically, the CEMS software will check the date of entry of each chemical, and if a chemical is detected to have stayed in the campus for 3 years, an email will be sent automatically to alert EH&S, who will then request the chemical owner of the long-staying chemical to consider disposal or listing that chemical on the surplus chemical list.[10] By referencing to the date of entry, the 3-year evaluation date ensures that long-staying chemicals are being tracked and managed properly, while keeping data entry for CEMS as simple as possible.

5. EH&S and Emergency Preparedness

Several features of the CEMS information software are designed to improve health and safety in laboratories and facilitate compliance reporting and emergency preparedness:

i. *Regulatory compliance module.* The module for regulatory compliance automatically prompts to notify the responsible people of satellite accumulation areas (SAAs) via email when an inspection is due, and provides a direct link of the regulatory module for creating SAA monthly inspection report in the reminder email. Currently, the CEMS keeps a database with all inspection reports of SAA. The CEMS regulatory module also has similar functions to facilitate reporting for above ground storage tanks (AST) and small quantity generators (SQG), and EH&S is planning to include the chemical fume hood inspection reports and the fire extinguisher reports in the CEMS database.

[10] Note that the actual shelf-life of chemicals is not stored in the CEMS, since management of chemicals with short shelf-life is considered the responsibility of chemical users.

Furthermore, preparation of the University's Tier II report, which had been based on paper records of hazardous chemical inventory, has been progressively easier with a built-in function of CEMS.

ii. *Door signs.* The CEMS stores the hazard information found on the door signs for all laboratories or rooms that have storage of chemicals. The door sign of each room displays the nature of chemicals stored and contact information of chemical owners or laboratory associates in case of emergency. To ensure that laboratory door signs are kept accurate and up-to-date, periodically, CEMS generates emails to remind chemical users to review and update information displayed on the door sign.

iii. *MSDS and chemical fact sheets.* The CEMS database currently has electronic version of MSDS and chemical fact sheets for more than 80% of the chemicals in the inventory. For chemicals with only print copies of MSDSs or chemical fact sheets, chemical users are required to keep the print copies at places where chemicals are used or stored. An electronic MSDS can be viewed on-line by anyone on campus, and it is also provided as a direct link to items residing in the chemical inventory for the benefit of chemical owners, as well as emergency responders. When a new chemical is purchased, EH&S is responsible for requesting new MSDS or the chemical fact sheet from its vendor and upload it to the system. Ultimately, EH&S aims to have MSDS sheets for all chemicals on the campus.

iv. *Allow local Fire and Police Departments access of database.* Each month the local fire and police departments are provided an updated CD ROM of CEMS information. If an accident occurs, Fire and Police Departments can bring the CD on their patrol cars and quickly check the CD ROM using labtops (provided by the University) in their cars to assess the potential hazard of a specific laboratory or room before arriving at the site. The CD contains the entire chemical inventory - sorted by location and hazard - with links to MSDS of each chemicals stored, and the emergency door signs. The Fire and Police Departments also have 24-hour on-line access to the latest information on chemical inventory. Additionally, the latest version of CEMS allows the emergency responders to download the entire inventory/MSDS/door signs onto a CD or zip file at will. This improvement allows them to have the most up-to-date information in the event of a real emergency.

v. *Particularly hazardous chemicals*. The UNH Chemical Safety Committee has established a list of particularly hazardous chemicals that require special attention on the UNH campus. To alert users of the hazardous nature of these chemicals, whenever a particularly hazardous chemical is displayed on CEMS, the type of hazard is shown next to the chemical name and highlighted in red (e.g. If a chemical is a carcinogen, the word "carcinogenic" would be displayed in red next to the chemical name). These chemicals will also be listed on the top of the inventory of a laboratory when it is viewed by Fire and Police Departments through the Emergency Responders module.

vi. *Hiding a chemical from view.* For security reasons, the CEMS allows chemical users to 'hide' the location and type of a chemical that could be used to make potentially dangerous or illegal products, or if the owner does not want to share the chemical information with the rest of the UNH research community, with the approval from EH&S. Only the Durham Fire Department, EH&S and the chemical owners themselves can view the records of hidden chemicals.

vii. *Posting of training and upcoming events.* The homepage of individual chemical users contains a "memos" table, which conveys up-to-date information related to the CEMS, such as scheduled training and vendor visits.

III. Summary of Costs and Resources for Developing and Maintaining Chemical Management at UNH

The CEMS is part of a broader effort to increase EH&S capacity at UNH. Since 1997, the EH&S team has expanded from three to eight full-time technical staff (see Box 1). In this cost analysis, we include labor and capital costs that are dedicated to the design and implementation of the chemical management system, which cover the chemical life cycle stages of inventory, delivery, use, EHS and emergency preparedness (see Figure 1). We have also included the total costs for managing hazardous chemical waste disposal.

Box 1. List of EH&S Personnel at UNH

Before 1997	After 1997
Director	Director
Hazardous Waste Coordinator	Hazardous Waste Coordinator
Chemical Safety Officer	Hazardous Material Coordinator
	Engineering Technician
	Environmental Health and Safety Specialist
	Chemical and Biological Safety Coordinator
	Occupational Health & Safety Coordinator
	Radiation Safety Officer

We have broken down the cost for developing and maintaining the chemical management system into two categories: 1) one-time initial development cost; and 2) ongoing maintenance costs. The one-time initial development cost is defined to be the labor and capital costs for designing and setting up the new chemical management system – including resources for undertaking inventory audits, purchase of ChiM, and programming of the original version of CEMS that was released in January 2001. The ongoing maintenance cost refers to the annual cost required for upgrading and maintaining CEMS, the operation of centralized receiving stations, education and outreach, communication with emergency responders and researchers, etc.

A total initial development cost of $322,000 was estimated for the groundwork for establishing the chemical management system, and developing the original version of CEMS.[11] The cost covers:

1. The EH&S labor cost for conducting the two inventory audits and assisting in the design of the new chemical management system, and
2. Capital costs for purchasing ChiM
3. The RCC labor cost to design the original version of CEMS software
4. Capital costs for equipment to operate CEMS

[11] Note that the original version only possessed some basic functions such as inventory search, reporting and searching of surplus chemicals, posting request for chemical waste disposal. The CEMS software was continuously enhanced and improved after the release of the original version, and the labor costs for upgrading the software are counted under on-going maintenance and enhancement.

Ongoing CEMS maintenance and management involves 1.15 FTE EH&S staff (two-third of the Hazardous Material Coordinator's time and 40% of the Engineering Technician's time), a full-time RCC software designer, and a part-time student for EH&S. The Hazardous Material Coordinator is mainly responsible for overseeing the implementation of the chemical management system, communicating with chemical users, vendors, and emergency responders. He also provides inputs to RCC to upgrade the CEMS software. The Engineering Technician is mainly responsible for chemical receiving, data entry, on-campus delivery and providing training to new users of the CEMS software. The part-time student is mainly responsible for uploading new MSDS sheets into the database. In total, ongoing maintenance of the CEMS costs $160,492/year.

The ongoing maintenance cost should level out over time as the system upgrades become less substantial. Actually, the above cost estimates on ongoing maintenance include the labor cost of RCC and EH&S staff to serve licensees of CEMS, such as troubleshooting, or enhancement of CEMS to cater licensees' needs. Nevertheless, these costs are not separated in the analysis since improvements on CEMS requested by licensees also benefit UNH users.

For management of hazardous chemical waste collection and disposal, the annual labor costs amount to $11,700, while the total cost for hazardous waste disposal totaled $76,300 in 2002.

Details of cost for each activity and key assumptions used are presented in Table 1.

Table 1: Summary of Costs for Developing and Maintaining Chemical Management at UNH

Cost Category	Component	Activities Included and Key Assumptions
One-time Initial Development Cost for CEMS [1] **[$322,000]**	EH&S labor [$181,000]	▪ Supervisor of the Hazardous Material Coordinator: 20% of his time for 3 years for overseeing two inventory audits, and assisting the design of the chemical management system = $60,000 * 20% * 3 * 1.3 = $46,800 (see note 2) ▪ Hazardous Material Coordinator: 0.5 FTE for 3 years for conducting the two inventory audits, and designing and implementing the chemical management system = $20/hr * 1800 hrs/year * 50% * 3 yrs * 1.3 = $70,200 (see note 3) ▪ Part-time students: 10 weeks time for 10 students for conducting each inventory audit = 2 * 10 students * $8/hr * 40 hrs/week * 10 weeks = $64,000 (see note 4)
	ChiM System [$14,000]	Software, hardware and license fees for using ChiM
	RCC labor [$110,000]	1 full-time software designer and part of the time of other RCC staff for planning and programming of the original version of CEMS (see note 5)
	RCC Equipment [$17,000]	Hardware dedicated to CEMS

Annual Ongoing Maintenance Costs for CEMS **[$160,492]**	EH&S labor [$48,892]	Labor costs for: 1) 75% of the Hazardous Material Coordinator's time – overseeing the chemical management system, communicating with chemical users and emergency responders, designing and delivering training courses on CEMS = 20/hr * 1800 hrs/year *0.75 * 1.3 = $35,100 (see note 3) 2) 40% of the Engineering Technician's time – responsible for day-to-day operation of the centralized receiving room and providing training on CEMS to chemical users = 18/hr * 1800 hrs/year * 0.4 = $12,960 (see note 6) 3) 1 part-time student (2 days a week) - searching and downloading MSDS. = 8/hr * 2 days/week * 52 weeks/year = $832 (see note 4) Total labor cost = $48,892
	RCC labor [$111,600]	1 fulll-time software designer for providing general maintenance of the server and upgrading the CEMS. Annual labor costs = $62/hr * 1800 hrs/year = $111,600 (see note 7)
Annual Chemical Waste Collection and Disposal [$88,000]	EH&S labor [$11,700]	Labor costs for: ▪ 10 hours/week of Environmental Health and Safety Specialist = 10 / 40 * 1800 hours/year * $20/hour * 1.3 = $11,700 (see note 8)
	Waste disposal cost	$76,300 (for year 2002)
Total Annual Chemical Management Cost *(exclude procurement)*		**$ 248,492**

Note:

1. Since the CEMS software was continuously enhanced and improved since the release of the original version, the cost for initial development is defined to be the total capital and labor costs for establishing the chemical management system and developing the original version of CEMS (i.e. from 1998 to Jan of 2001).
2. The annual salary of the supervisor is $60,000, and fringe benefits equal to 30% on top of the salary. This position has been eliminated after year 2000.
3. Assumes that an hourly labor rate of $20/hour for the Hazardous Material Coordinator, and fringe benefits is 30% on top of the salary.
4. Assumes that an hourly labor rate of $8/hour for part-time students, and no fringe benefits.
5. The lump sum cost for RCC labor to develop the initial version of CEMS is provided by RCC.
6. The labor rate of the Engineering Technician is not available because of sensitivity of the data. Also, the wage schedule of UNH is not available. The estimation assumes that the fully burdened labor rate for the Engineering Technician is $18/hour. This is based on the mean salary of Academic, Administrative & Technical (AAT) A Grade of Dartmouth College ($24,360) per year, fringe benefits is 30% on top of salary, and 1,800 hours/year for full time staff.
7. According to RCC, fully burdened labor rate (including salary and fringe benefits) of the software designer is $62/hour.
8. The labor rate of the Environmental, Health and Safety Specialist is not available because of sensitivity of the data. Also, the wage schedule of UNH is not available. The estimation assumes that the hourly labor for the Environmental, Health and Safety Specialist is the same for the Hazardous Material Coordinator, i.e. $20/hour, and fringe benefits is 30% on top of the salary.

IV.Benefits of Implementing the CEMS

The information tracking software in combination with the centralized receiving arrangement allows EH&S to track nearly all newly purchased chemicals from the time they arrive at UNH to the point of disposal. The campus-wide accessible chemical information, including storage location, owner's profile, MSDSs, as well as the built in functions of CEMS, enables EH&S to improve environmental performance, and more effectively manage chemical storage, use and disposal in the following ways:

1. *Encourage optimal chemical purchase and reduces waste disposal*

   The CEMS has includes features that facilitate the use of existing chemical inventory, such as allowing chemical users to search the chemicals inventory using various criteria, and allowing chemical users and staff at the Business Service Center to view the availability of surplus chemicals before placing an order. Some researchers are very pleased with these features since they now can obtain a small amount of a chemical from their peer rather than purchasing an entire container that usually will not be used in its entirety. In particular, EH&S noted that the current arrangement for surplus chemicals is better than having EH&S to collect surplus chemicals and redistribute to users, because most researchers have more confidence on the purity of surplus chemicals if they obtain those chemicals from the owner directly rather than from EH&S. Even though EH&S does not track how much reduction in chemical purchases has occurred since the implementation of the CEMS, the overall positive feedback from researchers indicates more researchers are more receptive to surplus chemical exchange or "borrowing" of small amount of chemicals.

2. *Increase Awareness of Hazardous Chemical Use and Encourage Substitution of Less Toxic Alternatives*

   The feature of CEMS that shows the type of hazard in red next to a particularly hazardous chemical whenever it is displayed alerts researchers and their assistants about the serious hazards of using those chemicals. In addition, EH&S has included in CEMS a direct link to a product substitution list developed by EH&S and links to websites on green chemistry, pollution prevention practices in laboratories, microscale chemistry if researchers are interested in reducing toxic chemical use. Even though the final procurement decisions still rest with chemical users, these features of CEMS help to increase chemical users' awareness on the hazard of toxic chemicals they own, and could gradually steer them towards less hazardous substitutes.

3. *Enhance laboratory safety and emergency preparedness*

   The CEMS provides on-line access to chemical inventory information and MSDS / chemical fact sheets database, as well as facilitates maintenance of door signage. These features have been effective in enhancing laboratory safety and emergency preparedness:

   - The updated information of chemical inventory and door signage (including the pictograms and contact information) on the CEMS database enables EH&S and emergency responders to take proper measures in response to accidents that occur at or in proximity to chemical storage areas. The chemical inventory information also facilitates risk assessment for projects works, such as construction works, on the UNH campus.

- The online MSDS / Chemical Fact sheets database provides a convenient pathway for chemical users to maintain the latest version of MSDS / Chemical Fact sheets in their laboratories.
- With the knowledge of researchers that own particularly hazardous chemicals, EH&S can better target training and education to hazardous chemical users.

Improved laboratory safety and emergency preparedness can be highlighted by the following three incidences:

- A faculty member was taken to the hospital with symptoms of heart palpitations. He recalled that while working alone in his laboratory, he saw a cracked chemical container. A search of his inventory revealed the chemical that he was exposed to, and the MSDS provided the hospital with the information needed to treat him.
- A graduate student splashed a chemical in his eyes and was sent to the emergency room. EH&S was able to quickly search the MSDS database and fax the MSDS of that chemical to the emergency room.
- Durham Police Department has used the CEMS database to identify research facilities or areas that are deemed vulnerable to terrorist attacks, and find out who is responsible for each area, and how they can contact them. Tougher measures are now arranged for these high-risk facilities or areas.

4. *Minimize stockpiling of outdated chemicals*

The two campus-wide audits conducted at UNH found that many laboratories have accumulated a significant number of aged and deteriorating chemicals. Before the implementation of CEMS, there were no established programs to facilitate surplus chemical reuse, and researchers generally were not aware of the hazards of outdated chemicals, thus did not make available enough resources to clean out long-staying chemicals. As a result, some chemicals that were only used in small volumes in research and teaching activities were left on the shelves for years.

Ongoing maintenance of an accurate inventory database and the three-year automatic re-evaluation function of the CEMS help EH&S better track outdated chemicals, and avoid them being left unattended. These features minimize accumulation of long-staying chemicals that would eventually become hazardous and be costly to dispose.

EH&S has also suggested that more transparent and easily accessible chemical inventory records, coupled with increased outreach and education efforts, has created a heightened *awareness* of the importance of chemical management and safety. The traditional mentality of researchers that a chemical might some day be useful in research is gradually changing to a new mind set that keeping an unused chemical is unnecessary, might pose a risk on laboratory safety and will be costly for disposal. For some long-time researchers, they are looking at their chemical inventory with a new set of eyes – they now admit that there are some chemicals they did not even realize were in their laboratories, and they could probably do without. Some researchers now use less hazardous methods to accomplish the same tasks.

5. *Ensure compliance with environmental legislations*

   The module for environmental compliance in CEMS has established a system through which chemical owners are automatically reminded of conducting monthly inspection and submitting monthly reports for SAA, SQG, and AST. The feature of the CEMS that allows on-line request for hazardous waste chemical pick-up also provides a simple and easy pathway for chemical users to dispose of unneeded hazardous chemicals. These features of the CEMS designed to facilitate environmental compliance have nicely complemented the formal system developed after the EPA inspection that trains and monitors waste generators' laboratory management practices for achieving regulatory compliance.

All in all, the availability of more transparent chemical information through CEMS, coupled with the design features of CEMS that seek to facilitate chemical management activities of both EH&S and chemical users, has greatly enhanced many aspects of laboratory chemical management at UNH. Actually, the abundant chemical information collected and managed by CEMS has also provided unexpected added values to researchers and laboratories workers. For instance, some faculty are using the CEMS as a teaching tool – MSDSs are used in class to teach properties of specific chemicals (e.g. boiling point or toxicity studies).

V. Key Elements to Success

In the long process of developing and implementing the current chemical management system, UNH has encountered a number of challenges (see Box 2). UNH has found that successful implementing the system relies on the following efforts:

1. Upper management support

It has been a long and laborious process to search for and design a chemical management system that best fits UNH's chemical management needs. Still, the system requires continuous input of staff resources to coordinate implementation, educate and re-educate users, and continue system improvement to fulfill new needs. All these are not possible without full support from top management that helps secure sufficient resources for the development, implementation and ongoing maintenance of the system.

2. Minimizing management burden on individual chemical user

EH&S has learned from the previous hands-off approach to chemical management that it is difficult for researchers to take on the responsibility of maintaining their own chemical inventory, since this is not considered their core responsibility. The CEMS, therefore, is designed in the way to minimize chemical users' responsibility, with built-in functions that help chemical users accomplish management tasks that could only be undertaken by users (such as requesting hazardous chemical disposal, reporting surplus chemicals, etc).

For instance, the centralized receiving arrangement at the Chemical Receiving Station and the Chemistry Stockroom ensures that barcoding and data entry of chemical information (such as responsible person and the storage location) are centrally managed by EH&S. With such an arrangement, information on most of the chemicals purchased is captured at the point of arrival. This arrangement therefore allows researchers to maintain high autonomy on their choice of

chemicals and suppliers, while saving chemical users' time in updating their own chemical inventory information and tagging containers with bar codes.

3. Simple and user-friendly features

The CEMS webpage is designed to be intuitive and easy to learn, therefore, direct links are provided on users' homepages for performing multiple tasks (e.g. requesting hazardous waste pick-up, performing inventory search, preparing SAA inspection report, etc). Such design not only assists EH&S and chemical users to easily perform chemical management activities, it also allows chemical users to better utilize chemical information maintained by CEMS to service their own needs. For example, a researcher was able to keep a valuable employee who became pregnant by demonstrating to her physician that there were no mutagenic or teratogenic chemicals in his laboratory.

Box 2. Challenges Found at UNH

1. Chemical procurement and usage at UNH are highly decentralized – researchers are free to decide what chemicals to use, where to buy them and how they use them. Also, more and more researchers now prefer to buy their own chemicals using p-cards, which makes it even more difficult to track chemical acquisitions. Such a decentralized setting posed a great challenge to establishing and maintaining an accurate and up-to-date inventory database, and establishing links between individual chemical container, chemical owners, and safety reference information (such as MSDSs).

2. Initial implementation of the CEMS was met with resistance and skepticism from some researchers. Some of them consider a centralized chemical management system or any form of control over any aspect of a laboratory intrusive to their research. Some researchers were concerned that a centralized chemical management system may cause delays to chemical acquisition. This can be best illustrated by the fact that, even though the CEMS has been implemented for nearly two years and EH&S has spent considerable resources to promote the new system, some researchers are still reluctant to use it.

3. Chemical use and management in laboratories involves a significant number of graduate students and research assistances that are subject to frequent turnover. Ongoing training is therefore needed to keep up training on EH&S regulations and the proper use of chemical management system.

4. Cooperation from departments

Although the system is designed to minimize required researcher inputs to effectively manage chemical inventories, some tasks still need to be done by chemical owners. Therefore, it is critical to the success of CEMS that researchers make available the time and resources needed for accomplishing their responsibilities. EH&S has dedicated many resources to successfully get buy-in from most chemical users through training workshops and regular communications. For example, EH&S obtains a list of new hires from Personnel Department every month to arrange training course for new users. To better cater chemical users' needs, EH&S continuously seeks researchers' feedbacks on potential improvements to the system, and incorporates them when upgrading the CEMS software.

Given that UNH is a medium-sized university, with about 320 chemical users and 255 laboratory associates, the task for maintaining frequent communications with chemical users does not appear to be particularly daunting - the Hazardous Material Coordinator is currently spending part of his time on this task. For large universities that have more chemical users and with more extensive research activities, a thoughtful communication plan has to be in place to maintain good communications with chemical users.

VI. Conclusions

Chemical management at UNH has come a long way, from a basically non-managed system to the deployment of a well managed and easy-to-use system. UNH has done a phenomenal job in developing, setting up and maintaining the new chemical management system. With the easy-to-access chemical inventory database, and various built in features designed to facilitate better chemical management, the system has greatly improved chemical tracking, reduced the over-purchase of chemicals and waste generation, enhanced laboratory safety, and streamlined regulatory reporting.

Initially designed as a hazardous material tracking system, the CEMS has now evolved to serve much wider purposes, e.g., enhancing emergency preparedness, promoting hazardous waste minimization, discouraging unnecessary chemical purchases, etc. Most importantly, the wealth of chemical inventory information captured by CEMS has helped to raise the overall awareness of the research community and spur the need for a more proactive approach to achieve chemical use optimization and effective chemical management. As a next step to reduce chemical use on campus, EH&S is now leading an effort to promote microscale laboratory technique, and has contributed a significant amount of its operating budget to the purchase of microscale laboratory materials/equipment and training for the Chemistry Department. The feedback has been overwhelmingly positive. This new initiative has led to reduction in the amount of waste generated in the freshman organic and inorganic chemistry labs, thereby reducing disposal costs and lessening the level of hazardous chemical exposure for everyone. As a separate initiative, the Purchasing Office of UNH now includes a statement in new contracts with chemical suppliers that promote the idea of "less is better". The Purchasing Office hopes that this will encourage chemical suppliers to sell chemicals in smaller containers, so that users can buy chemicals in smaller volume to reduce leftover, unusable chemicals, thereby minimizing waste and disposal costs.

However, the above mentioned achievements do not come without a cost. The total resources required for developing the new chemical management system and ongoing maintenance are evident from our analysis in Section III. Of the annual ongoing maintenance cost for CEMS ($160,492), EHS labor cost for managing the system contributes to about 30%. This indicates that, even with an easy-to-use information system, staff resources for continued implementation of the system are still crucial to the success of a system. From our conversations with universities in the course of this project, we have observed that many universities have underestimated the resources required for establishing, deploying and managing a formal chemical management system, leading to under staffing and eventual failure of programs.

In hindsight, the CEMS system should have incorporated chemical procurement activities. Excluding the chemical procurement stage from the CEMS information system makes it extremely difficult for EH&S to track the total chemical expenditure - a strategically important piece of information for accessing the true lifecycle cost of chemical use, and evaluating the effectiveness of the chemical management system in reducing chemical purchases. Centralizing procurement activities and incorporating them into the CEMS can also help EH&S to further pursue chemical use optimization. For instance, the purchasing function of the CEMS can be designed in the way such that every time a user places a chemical procurement order, the system can display information of the requested chemical provided by different suppliers (e.g. size of packaging, purity) and also search whether that chemical is on the surplus chemical list. With this information, chemical users make an informed choice on whether to reuse surplus chemicals or

purchase new chemicals with the right size of packaging. We have seen information systems developed by Chemical Management Services (CMS) providers feature the consolidated procurement function. Even though EH&S has investigated this possibility early on when developing the CEMS, and decided that it was too complicated to develop, we suggest that EH&S to revisit this possibility.

For more information about CSP and the CMS model:
http://www.chemicalstrategies.org

To contact us:
Tom Votta and Freda Fung

11 Arlington St
Boston, MA 02116
Tel: 617.266.5400
tvotta@tellus.org; ffung@tellus.org