Technical Assistance Tool: Chemical Safety and Life Cycle Management – Hazardous Chemical Reduction

Dedicated to Promoting Excellence in DOE Operations

Prepared by:

Energy Facilities Contractor Group

Environment, Safety, and Health Working Group

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May 2013

Technical Assistance Tool: Chemical Safety and Life Cycle Management -- Toxic and Hazardous Chemical Reduction

Overview

The Chemical Life Cycle consists of acquisition, inventory, and disposition. Since reduction in the acquisition, use, and disposal of hazardous chemicals continues to be a goal of the Department of Energy (DOE), improved Chemical Life Cycle management should include the identification of chemicals for reduction, substitution or elimination of chemicals in operations. Chapter 1 of this Technical Assistance Tool (Tool) describes strategies for hazardous chemical reduction deemed effective by one or more DOE facilities and should be applicable to a broad cross-section of DOE facilities. The strategies presented in this Tool are not mandated; however, implementation of these strategies should increase the operational safety envelope while reducing operating costs, injuries, chemical use, and generation of chemical wastes. Chapter 2 describes the use of site Environmental Management Systems (EMSs) and Performance Evaluation Management Plans (PEMPs) and Performance Evaluation Plans (PEPs) as emerging strategies to increase management engagement to enhance site chemical management programs. Appendix 1 contains the questionnaire used to elicit the DOE site strategies. Appendix 2 contains case studies for the management of sulfur hexafluoride, SF_6 containing fugitive emissions. Reduced fugitive emissions have been identified as a priority for achieving DOE's greenhouse gas reduction goals for Scope 1 and 2 emissions.

The strategies contained in this Tool are based on literature searches, information from DOE site questionnaires, and follow-on interviews conducted in 2011 by members of the Chemical Safety and Lifecycle Management (CSLM) Subgroup of the Energy Facilities Contractors Group (EFCOG). These questionnaires were sent to DOE personnel and contractor chemical management subject matter experts at 32 DOE sites. From this group, 15 responders were subsequently interviewed. Since the strategies are not attributed to specific sites, if users of this Tool would like additional information they are encouraged to contact the Chair of the CSLM Subgroup of the EFCOG Environmental Safety and Health (ESH) Working Group at http://efcog.org/wg/esh_cslm/index.htm. This document does not promulgate any new requirements and does not include specific regulatory compliance information. Statutory and regulatory compliance information on chemical management can be found in the *DOE Handbook on Chemical Management*, *Volume 3, Consolidated Chemical User Safety and Health Requirements.*[1]

Driving Forces for Chemical Reduction

There are several driving forces for hazardous chemical reduction at DOE facilities. The high cost of chemical management is one. When all lifecycle stages of managing a hazardous chemical are

[1] DOE Handbook on Chemical Management (Vol 3 of 3) Consolidated Chemical User Safety and Health Requirements. http://www.hss.doe.gov/HealthSafety/WSHP/Chem_Safety/library/doe-hdbk-1139-3-2008.pdf.

considered (acquisition, compliance, safety, training, inventory control, storage, disposal, etc.), there is an estimated additional management cost of $1 to $3 for every $1 spent to acquire the chemical.[2]

Under Executive Order 13514 (EO 13214) Federal Leadership in Environmental, Energy, and Economic Performance, (10/5/09), federal agencies must ensure that 95% of all new contract actions require the supply or use of products and services that are non-toxic or less-toxic alternatives. Federal agencies must also promote pollution prevention and eliminate waste by reducing and minimizing the acquisition, use, and disposal of hazardous chemicals and materials while increasing the use of acceptable alternative (less toxic) chemicals and processes. The DOE Strategic Sustainability Performance Plan (SSPP), written to support the implementation of EO 13514, adopts the EO's sustainable acquisition, pollution prevention and waste minimization goals. The SSPP also suggests implementation of sustainable practices to achieve hazardous chemical reductions such as conducting sustainability assessments and promoting higher recyclable content of procured items. The DOE implements the EO through DOE Order 436.1, *Departmental Sustainability*, and to DOE contractors through the Contractor Requirements Document and the Department of Energy Acquisition Regulations (DEAR). These DOE requirements established two new contract clauses 48 CFR 970.5223-7, Sustainable Acquisition Program (Management and Operating (M&O) contracts) and 48 CFR 952.223-78, Sustainable Acquisition Program (non-M&O contracts).

Additionally, pursuant to DOE Order 436.1, DOE sites use their EMSs to establish site-specific hazardous chemical reduction objectives and measurable targets that contribute to DOE achieving its sustainability goals, including hazardous chemical reduction goals. For purposes of DOE 436.1, sustainability has been broadly defined to include "those actions taken to minimize chemical toxicity and harmful environmental releases, particularly GHG while sustaining assigned mission activities".

Finally, many federal, state and local health and environmental regulations require waste minimization and pollution prevention. These regulations often contain regulatory permit limits, and specify storage or use thresholds. These limits often increase permitting complexity or decrease facility modification flexibility if exceeded.

[2] http://www.epa.gov/osw/hazard/wastemin/minimize/cms.htm

Table of Contents

1 Summary of Strategies from Site Interviews

1.1 Strategies for Acquisition: Chemical Purchasing Review and Approval

Chemical acquisition is the purchase, transfer, receipt or hand carrying of hazardous chemicals onto a worksite. Most chemicals on site are a result of a purchase through a procurement system. Chemicals may also be brought on site as samples received directly by researchers, or by subcontractor personnel performing maintenance, testing, or construction. An advanced chemical acquisition review and approval process has the following elements. When a chemical need is identified, the availability of the chemical that may be already on-site is checked. If available, the chemical is obtained by the requester and the chemical tracking system is updated. If the chemical is not available, a review of the order is done to determine the associated hazards and if it is or should be prohibited at the site. If a less hazardous chemical is available, that chemical substitute will be recommended for purchase. If the substitute is unacceptable to the requester, the original chemical, if not prohibited, will be approved for acquisition.

<u>Example 1: Using an Electronic Ordering System</u>

When a chemical need is identified through work planning and control processes, the requester is directed to check the chemical availability using the site's chemical exchange tool. If available, the chemical is obtained and the site's chemical inventory database is updated to reflect the location transfer. If the chemical is not available on-site, a request is made, and the chemical order information is uploaded to a procurement system. A Controlled Items/Service List (CISL) is checked to determine if the chemical requires special approval from a specific organization (e.g., Industrial Hygiene) prior to acquisition. A current Material Safety Data Sheet (MSDS) is obtained and forwarded to chemical management personnel, and the required data from the MSDS is entered into the chemical inventory database.

Once the CISL determination is made, a chemical purchase notification is forwarded to chemical management personnel for review and validation of the chemical purchase information. The chemical is concurrently compared against DOE's Protective Action Criteria (PACs) for Chemicals for safety basis implications. The purchase is placed once all authorizations are obtained. Receiving personnel barcode the chemical containers upon delivery, and use chemical inventory tools to enter required data into the chemical inventory database. The chemicals are then delivered to the end user.

<u>Example 2: Using an Electronic Bill of Material</u>

An electronic bill of material is transmitted to designated reviewers who determine if the chemicals ordered is prohibited at the site; whether a less toxic or less hazardous material is suitable; or whether the procurement might exceed any regulatory thresholds. This strategy is intended to help control hazardous chemical inventories by ensuring that excessive amounts hazardous chemicals are not ordered if they meet one of these conditions.

<u>Example 3: Prepurchase Chemical Management</u>

Chemical management personnel review MSDSs and listed constituents of new products to determine hazards of concern. If a less hazardous product is available, chemical management personnel will recommend that product. Waste designations are assigned for newly requested chemicals so that waste codes identify the hazards associated with the disposition of the product. Chemical management personnel encourage the purchase of only the amount needed for the job, while communicating to chemical purchasers that it may not be cheaper to buy in bulk due to inventory, storage, and waste (chemical lifecycle) costs. Chemical management personnel also encourage the use of chemicals already available on site prior to purchasing new products.

Potential Implementation Issues

- Chemical users may bypass the approval process due to a perceived or actual mission need for a chemical that might not be approved or approved in a timely manner.
- Some chemical vendors only offer case lots so more chemicals are obtained than needed.
- Testing of new methods or new processes may result in only small amounts being used from a large container, leaving the remainder of the product unused.
- Due to resource issues, reconciliations cannot always be performed to physically verify that all chemicals used have been removed or dispositioned prior to acquiring new chemicals.
- Chemical users must be educated to order chemicals that are less hazardous and to purchase only what is needed.
- Chemical inventory databases may be built on old technology systems.
- Not all chemicals are tracked in inventory databases.
- The process is person-dependent; therefore electronic notification/authorizations may not occur. Individuals may also make a judgment call on whether to consult with subject matter experts.

Measuring Success

Successes of these strategies may be measured using metrics of chemical inventory accuracy, the number of chemicals or products that have Material Safety Data Sheets/Safety Data Sheets (MSDSs/SDS), by the reduction in the amount of surplus chemicals, substitutions for less hazardous chemicals, and reduced regulatory liability.

Long Term Effectiveness and Lessons Learned

The example strategies have been in place for several years, and were deemed effective. Lessons learned include the following: It is challenging to break chemical users' habits of using chemicals that are more hazardous simply because they have been used in the past, subjective decisions regarding whether a chemical should be purchased should be minimized, and a clear process should be established for a chemical purchase review and approval system.

1.2 Strategies for Acquisition: Receipt Inspection

An advanced chemical purchase review and approval process has the following elements. A chemical coordinator located in Receiving inspects all incoming chemical orders to ensure the received material matches the product ordered and that any unordered materials are not accepted. Any chemical order that does not match is flagged for further review. The requester is contacted, and if the substitution is acceptable, the order is received. If the substitution is not acceptable, the order is rejected and returned to the vendor.

Potential Implementation Issues
Obtaining prior approval of the Receiving organization and associated personnel is essential to initiating this strategy. Additionally, the chemical coordinator must be identified and funded.

Measuring Success
Success of this strategy can be measured by tracking the decrease in the number of incorrect shipments received.

Long Term Effectiveness and Lessons Learned
DOE sites using this strategy perceive its long term effectiveness to be high. Lessons learned include the following. Incorrect products are sometimes shipped when a vendor is attempting to eliminate unwanted inventory. Such practices must be discouraged by having the vendor incur additional cost for the returned product or by directing purchases to vendors willing to assist in identifying less hazardous substances in order to secure future site business. All orders should contain standard contract requirements stating that incorrect shipments will be returned at the vendor's expense.

1.3 Strategies for Inventory: Tracking Individual Chemical Containers

Each individual container of any chemical with an expiration date is labeled with a unique barcode for tracking and inventorying purposes. This enables early identification of chemicals which may expire due to a low use rate and/or high volume stored. Radio Frequency Identification (RFID) tags can be used in lieu of standard one dimensional barcodes. Containers with a high turn-over rate need not be uniquely coded.

Potential Implementation Issues

- Initial container labeling and database conversion may be time consuming and expensive.
- Barcode labels, especially those on solvent containers, may be obscured if any liquid runs down the side of the container and over the label. This can be easily prevented by covering barcode labels with chemical resistant tape that can be procured from any safety supply source.
- RFID tags will not work well if placed on a metal or wet surface due to signal bleed. This can be prevented by either using special foam-backed (insulated) RFID tags or by placing chemical resistant tape on the container and then placing the RFID tag on the tape.
- RFID tags will not work well when located out of 'line-of-sight' within a metal storage cabinet or on metal storage shelves. The metal in the shelves or in the cabinet will block the RFID signal.

Measuring Success
Success of this strategy may be measured by tracking the reduction in the number of chemicals stored beyond their expiration date.

Long Term Effectiveness and Lessons Learned
Sites using this strategy perceive its long term effectiveness as high. A lesson learned is that the number of chemicals expiring over time is somewhat limited. If this process is applied to all chemicals, not just those expiring, it will significantly increase costs by generating more waste than is required.

1.4 **Strategies for Inventory: Chemical Inventory Reduction**

Chemical inventory reduction is the process of reducing the types and amounts of chemicals on site to limit the chemicals to those required for the mission and mission support. An advanced chemical inventory reduction process targets: chemicals that have been on site for years, “expired” chemicals, excessive quantities of chemicals, chemicals that no longer have a programmatic need, extremely hazardous chemicals, chemicals whose reduction will help a site achieve GHG emission reduction, and chemicals of interest to the surrounding community.

Example 1: Priority Chemical Reduction
“Priority chemicals” are identified for inventory reduction, including high-hazard legacy materials (e.g., corrosive gases, peroxidizables, and alkali metals). Inventory reports of priority chemicals are periodically provided to Line management in support of minimization efforts. Total volumes of priority chemicals purchased are tracked and reported quarterly to senior management. Reports of generated hazardous wastes are also provided to Line management to encourage waste minimization.

Example 2: Chemical Reduction for Legacy Items
A chemical inventory system is used to track and trend legacy items. Targets for disposition are based on the number of years they have been in the inventory. For example: retention exceptions to extend the effective expiration date need to be documented in the chemical inventory system.

Potential Implementation Issues

- The priority chemicals may be needed for customer-specific requirements.
- Clean-out campaigns funded by excess ES&H and site budgets have been found to incentivize the wrong behavior because people tend to wait until the next campaign to dispose of legacy materials.

Measuring Success
Success of this strategy may be measured by tracking the reduction of total volumes of priority chemicals purchased and disposed, e.g., chemicals 10-15 years old should be no more than 15% of total inventory; chemicals greater than 15 years should be no more than 10% of total inventory; and chemicals past their container label expiration date (with approved extensions) should be 0% of total inventory.

Long Term Effectiveness and Lessons Learned
None determined.

1.5 **Strategies for Inventory: Centralized Chemical Storage/Stockroom**

Example 1: Centralized Storage
Each project is limited to one flammable and one toxic storage cabinet in their project area. Chemicals exceeding the amount that can be stored in those cabinets are stored in a consolidated warehouse. Chemical management personnel encourage the use of in-stock chemicals or chemicals available on site from other projects. Chemical management personnel also review and research potential product substitutions. For example, one site found an absorbent that was less hazardous, less costly, and met

the pollution prevention program goal of less product used for amount absorbed. Chemical use training is provided during morning safety meetings.

Warehouse personnel notify chemical management personnel when chemical product orders are received and when warehoused chemicals are sent out to specific project locations. Chemical management personnel update the chemical inventory as chemicals change locations or the status of a product changes to a waste or depleted status.

Example 2: Centralized Stockroom
A centralized chemical stockroom was established to serve all chemical users working within a particular area by transforming an old plating shop. By doing this, chemical inventories in individual laboratories were reduced and consolidated. Stockroom operations help personnel manage chemical procurement, distribution, inventory, glassware cleaning, and waste disposal. The consolidation of these activities reduce the number and/or size of chemical containers (reduce facility inventory), eliminate unneeded or unauthorized chemical purchases, redistribute excess chemicals, minimize inventory in laboratory spaces, reduce legacy containers and improve laboratory space utilization, eliminate glassware cleaning baths in individual laboratories, and consolidate and minimize waste generation. Chemical procurement and inventory management are performed by the stockroom coordinator to reduce R&D scientists' time spent ordering and inventorying chemicals. Stockroom personnel distribute laboratory-scale quantities of chemicals necessary for researchers to perform their work reducing significant quantities of unused chemicals that may become hazardous waste.

Potential Implementation Issues
- Consolidation of chemicals in a central area may result in fire protection issues and excess stock that must be disposed if user needs change.
- Management must fund stockroom personnel positions.

Measuring Success
Success has not yet been measured.

Long Term Effectiveness and Lessons Learned
It is estimated that a fully implemented chemical stockroom could reduce costs related to chemical management and disposal by $50,000 per year depending on the scale of the stockroom.

1.6 Strategies for Disposition: Identification of Unneeded Chemicals

Walk downs of each chemical storage area are performed by the owner of the area and chemical management personnel to identify chemicals that still have a programmatic need. Chemicals that have no apparent programmatic need are sorted by compatibility, and evaluated for dispositioning according to the following reuse hierarchy: return the chemical to the vendor, transfer to other areas within the company that will use the chemical, transfer to another DOE site that will use the chemical, or donate the chemical to local schools, tribes, or other government agencies. If these routes are unsuccessful, the chemical is dispositioned as waste.

Potential Implementation Issues
- The greatest challenge for implementing this strategy is limited resources. Identifying which chemicals need to be dispositioned, collecting those chemicals, and sorting them according to

compatibilities are time-consuming. However, it is ultimately far less expensive to redeploy than simply disposition the chemicals as waste.

- Laboratory chemicals that have been opened are virtually impossible to disposition using any method other than disposal as waste.

Measuring Success
Success of this strategy may be measured in both the number of containers removed and the total amount reused rather than disposed as waste.

Long Term Effectiveness and Lessons Learned
Sites using this strategy perceive long term effectiveness as dependent upon whether other programs to control unnecessary procurement of chemicals are present. If not, the inventory will slowly grow back to its original size. A lesson learned is that personnel knowledgeable of the hazards must be involved in the initial identification of unneeded chemicals. In addition, some chemicals develop additional hazards upon prolonged storage and those hazards must be adequately controlled during this process.

1.7 Strategies for Disposition: Chemical Management Disposition Process

A facility chemical Inventory is sent to applicable managers annually to justify a programmatic need for chemicals in the manager's area of responsibility. Chemicals that have been identified as having no programmatic need are placed into a chemical disposition program. This plan identifies the disposition pathway such as: send items back to vendor, recycle or dispose as waste.

Potential Implementation Issues
Disposition process pathways may be suspended due to lack of funding, but a state of readiness is necessary for an organization to able to disposition as resources become available.

Measuring Success
Success is measured by the number of chemicals disposition as returned product or recycled versus disposed as waste.

Long Term Effectiveness and Lessons Learned
The long term effectiveness of this strategy has not yet been determined. No lessons learned have yet been documented.

1.8 Strategies for Disposition: Chemical Exchange

Unneeded chemicals are identified and advertised internally online at the site. Prior to acquisition of new chemicals, requesters are required to search the website to determine if a product that they can use is available on-site. The website then facilitates the transfer of the chemical to the requestor, usually with no charge.

Example 1: Electronic Chemical Stockroom

The electronic chemical stockroom is maintained as part of a chemical management initiative. It allows chemical owners to disposition chemical containers no longer needed. This example uses Microsoft SharePoint, and was created because researchers needed something easy to use in place of an existing method that was not effective or efficient. Chemical owners post unneeded chemical containers for others to acquire. Chemicals must have the following characteristics: commercially obtained, original container, good condition, unopened or contain a usable quantity, intact and legible label, lid/container not compromised, and be free from ANY contamination (radiological and otherwise). Valuable features of the system/process include: a mobile packing van that comes to a facility free-of-charge to categorize, package, provide shipping papers, and transport the container to its new location. Help with this process can be requested by phone or email. Multiple containers can be posted via an Excel spreadsheet upload. There is also an online discussion forum. Once posted, chemical owners agree to take responsibility for the post, including responding to emails and keeping the container's status up-to-date. If agreement is reached with a new owner, current chemical owners must formally transfer ownership within the site chemical inventory system.

Example 2: Chemical Exchange Program (CEP)

The CEP is a web-based module that allows chemical users to browse for chemicals, submit surplus chemicals, and request chemicals online. Chemical owners can submit chemicals to the CEP by entering unique bar codes into the CEP application. They are asked to verify location of the chemical, whether the container has ever been opened (the CEP accepts open containers), and must certify that the chemicals meet acceptance criteria (e.g., no gases, explosives, or organic peroxides). Emails are sent on a weekly basis listing the available chemicals through the CEP. A chemical availability posting can reside up to six months in the CEP, at which time the chemical owner has the option to keep the chemical or dispose of it. CEP personnel will pick up chemicals from the chemical owner and transfer them to the requester to complete the exchange.

Potential Implementation Issues

- Some users never perceive their chemicals as surplus due to a real or perceived future need.
- Some users are reluctant to use opened chemicals due to a real or perceived quality control issue.
- Resources are necessary to build and maintain the web-based exchange software
- Resources are necessary to provide user awareness, user training, and chemical transport.

Measuring Success

Success of this strategy may be measured either by tracking dollars saved by using chemicals listed on the exchange rather than procuring new chemicals, tracking the number of chemical containers successfully placed with new owners or by disposal costs avoided.

Long Term Effectiveness and Lessons Learned

Sites that have used this strategy perceive its long term effectiveness as high. This program works best with office supplies which typically do not fall into the hazardous category. Laboratory chemicals that are opened are rarely, if ever, used by others since these products have a questionable pedigree and purity, thus chemical users are not willing to use them. Better success has been observed with janitorial chemicals, paints, and lubricants where quality assurance issues are limited.

1.9 **Strategies for Chemical Substitution**

Chemicals and chemicals products that are highly hazardous or especially toxic are often good candidates for substitution with a less hazardous chemicals or products. Potential substitutions may be identified by the user, or the site may have a review process designed to help users identify substitutions.

Example 1: Replacement of a hazardous solvent with a less hazardous solvent
Personnel successfully replaced p-xylene with the citrus-based "green" solvent d-limonene in degreasing operations. D-Limonene has low toxicity, is biodegradable, and is sustainable (i.e., requires no hydrocarbon feedstock during manufacturing).

Example 2: Green Custodial Chemicals
Custodial staff incorporated "Green Seal[3]" cleaning compounds and updated cleaning practices in a phased approach throughout the site. This included a Pulse Mopping Kit designed to control the amount of chemicals used during mopping, a Walk-Behind Corded Carpet Cleaner that uses water only, eliminating traditional cleaning, and dilution equipment that allows Green Seal products (and others) to be purchased in bulk. When processed through the dilution equipment, chemicals are accurately measured for distribution to the custodial staff.

Example 3: Green Tools and Processes
Links to Green Chemistry tools are available on the DOE sites' Environmental Management System webpages, Pollution Prevention webpages, and chemical inventory webpages. A list of chemicals targeted for 'use reduction' and is evaluated at routine intervals. A janitorial shop has replaced several cleaning chemicals with Green Seal cleaners. The motor vehicle fleet uses E85 fuel and a number of Ford Fusion Hybrid vehicles, and buses run on hydrogen fuel.

Example 4: Identifying Chemicals for Substitution by Analyzing Waste Streams
Upon completion of the biennial Hazardous Waste Report[4], or a state hazardous waste report, waste streams with generation rates of over 200 kilograms per year are evaluated for potential hazardous chemical reduction opportunities.

Potential Implementation Issues

- Criteria must be established to determine when a product is sufficiently hazardous to be a candidate for substitution.
- Users may be reluctant to change products.

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[3] http://www.greenseal.org/

[4] The biennial Hazardous Waste Report required by Resource Conservation & Recovery Act (also known as the"Biennial Report") (form 8700-13A/B) must be submitted to the authorized state agency or the EPA Regional Office by March 1st of every even-numbered year. The form includes the quantity of hazardous waste sent to each Treatment Storage Disposal Facility (TSDF) in the U.S. and the manner in which the waste was treated. http://www.epa.gov/osw/inforesources/data/biennialreport/faq.pdf

- Many products that are sufficiently hazardous do not have appropriate substitutes. For example, laboratory chemicals may have specific properties that are required by the researcher's experiment.
- It may be expensive to determine if a substitute is acceptable and whether reduced yields may occur.
- Using substitute chemicals in weapons systems is not allowed without approval from the design agency.

Measuring Success

Success of this strategy can be measured by tracking the reduction in the use of hazardous chemicals and tracking an increase in the use of less hazardous substitutes.

Long Term Effectiveness and Lessons Learned

Effectiveness starts off quickly as the "low hanging fruit" is identified and substitutions are found and used. While smaller gains are made over the following years, they are stable and long lasting. Lessons learned include the following: These products are typically janitorial products although substituted fuels such as E-85 may be added to the measurement. The next greatest opportunity of implementing this strategy is when new facilities are constructed, especially in the case of production facilities.

1.10 **Strategies for Elimination: Use of Analytical Chemistry Upgrades**

A survey of analytical services typically performed in the company's analytical laboratories is conducted to determine if there are any methods available to reduce the use of hazardous chemicals, such as conversion to use of microassays, changing instrumentation to incorporate new technologies, and modifying analyses to use non- or less-hazardous chemicals.

Potential Implementation Issues

- Converting to microassays may require the procurement of new equipment including new instrumentation that would require smaller sample sizes, and may require retraining analysts. Equipment cost may be defrayed by increased efficiencies and throughput.
- Converting to new analytical procedures that use less hazardous materials requires assurance that they consistently produce results with an acceptable degree of accuracy (no false positives and no significant interferences). The conversion should not create additional difficulties such as undue increases in the use of personnel or time, the use of expensive reagents, or the dependence upon a single supplier of reagents.

Measuring Success

Success of this strategy may be measured by tracking a reduction in the amount of hazardous chemicals used in analytical services.

Long Term Effectiveness and Lessons Learned

Sites using this strategy perceive its long term effectiveness as excellent. One lesson learned is to ensure that the process measures what it is intended to measure, that it provides no increase in false positives, and does not have any significant interferences.

1.11 Strategies for Lifecycle Cost Determination

An annual wall-to-wall inventory of all barcoded containers is performed. A number of metrics are employed to determine the accuracy of the chemical inventory. A number of regulatory reports are prepared for submission once the annual inventory is complete.

A number of web-based tools are available to update the inventory and to assess regulatory and safety basis limits.

A lean six sigma improvement effort was completed to more accurately assess lifecycle cost of maintaining chemical inventories. One of the conclusions is that the cost of maintaining the chemical on the shelf is not the most significant cost associated with chemical management. The complete results of these efforts will guide future inventory reduction initiatives.

Potential Implementation Issues

- Non-barcoded chemicals are entered into the database. Line management must reconcile any missing barcoded containers and certify their inventory. More than one web-based tool may result in inaccurate inventory.

Measuring Success

Success is measured by the number of chemical inventory items that have current MSDS information (currently at approximately 97%).

Long Term Effectiveness and Lessons Learned

It is expected that identification of non-barcoded chemicals to result in a move towards a centralized organization responsible for buying all chemicals.

2 Emerging Strategies for Reducing Hazardous Chemicals

2.1 Use of Site Environmental Management Systems

An EMS is a management tool enabling an organization of any size or type to:

- Identify and control the environmental impacts of its activities, products or services,
- Improve its environmental performance continually, and
- Implement a systematic approach to setting environmental objectives and targets, to achieving these objectives and targets, and to demonstrating that they have been achieved.

As discussed in the Overview, pursuant to DOE Order 436.1, DOE sites are to use EMSs as a platform for establishing programs with objectives and measurable targets that contribute to the Department achieving its sustainability goals. These EMS objectives and targets serve as the basis from which the Site Sustainability Plan (SSP) is formulated.

Hazardous chemical use reduction typically fits within a site's EMS objectives and measurable targets since disposal of hazardous waste is a common significant environmental aspect with associated regulatory requirements and liabilities. Equally important, with the issuance of DOE Order 436.1, hazardous chemical use reduction is recognized as a goal in the Departmental SSPP. As a continuous improvement (plan-do-check-act) process, an EMS requires measurement of progress against the goal and action for further achievement. If sites leverage their EMSs by aligning the hazardous chemical use reduction goal and EMS objectives and measurable targets, then progress toward this goal will also be monitored and measured. Additionally, there will be increased management visibility of the hazardous chemical use reduction goal due to the EMS requirement for site (DOE and contractor) management resource commitment and periodic performance review. The site chemical management program should be integrated within the site EMS by having the chemical management Subject Matter Expert be a participating member of the site EMS Team. This would ensure an EMS hazardous chemical use reduction effort with objectives and measurable targets is established, potentially utilizing the strategies discussed in Chapter 1.

2.2 Performance Evaluation and Measurement Plans

Section 5.e. of DOE O 436.1 directs DOE Field Managers to ensure that appropriate quantifiable sustainability goals and targets are integrated in contracting documents such as the Performance Evaluation and Measurement Plan (PEMP) or equivalent (e.g., Performance Evaluation Plan (PEP)). Use of sites' PEMP or PEP to incentivize sustainability and address hazardous chemical use reduction can serve as a viable means to help DOE sites get recognition and reimbursement for their contributions to the Department's achievement of its sustainability goals.

In a site's PEMP or PEP, objectives and performance-based notable outcomes are developed for a specific requirement or goal. Implementation of a notable outcome for hazardous chemical use reduction may include a pilot of a sustainable practice but it also needs to demonstrate there has been a reduction in the purchase, use or re-use, and disposition of hazardous chemicals and materials. At the year-end reporting, sites are also encouraged to submit a notable outcome as a sustainability accomplishment and/or award. Following an examination of DOE PEMPs and PEPS, a performance measure related to hazardous chemical reduction is given as an example.

Objective 1: Advance chemical management at the site to contribute to the achievement of Departmental sustainable goals.

Notable outcomes: Conduct sustainability operations assessments of chemicals used in processes at the site to identify non- and less-toxic and safer substitutes. This will result in the reduction of hazardous chemicals being used and hazardous waste being generated and disposed.

1) Implement those sustainable practices that result in substitution of non- and less-hazardous and safer chemicals.
2) Implement those sustainable practices for determining changes in site process(es) which result in a lesser amount of a hazardous chemical being used.

Objective 2: Advance sustainability of the site's supply chain (sustainable chemical vendors and/or suppliers).

Notable outcomes: In order to secure DOE's continued business, vendors and/or suppliers will support the site with sustainable acquisition practices.

1) Vendors and/or suppliers will flag purchases of hazardous chemicals and identify effective, life cycle cost-effective, non- or less-hazardous, and safer chemical products.
2) Vendors and/or suppliers will provide or maintain records of environmentally sustainable purchases for the purpose of the DOE site's sustainability performance reporting.

NOTE: Purchase agreements will need to be developed or modified to establish sustainability expectations for all parties.

3 Appendix 1 EFCOG Questionnaire

QUESTIONNAIRE: Please fill in and/or check all that is applicable. Email the completed questionnaire to Dina Siegel, Los Alamos National Laboratory, dinas@lanl.gov Submit

1. How do you manage your hazardous and toxic chemicals?
   a. Databases(s)
      i. Computer-Based System
         - ◯ None
         - ◯ Word document
         - ◯ Excel spreadsheet
         - ◯ Microsoft Access
         - ◯ Commercial "Off the Shelf Product name [ ]
         - ◯ Modified "Off the Shelf" Product name [ ]
         - ◯ Home grown: Oracle
         - ◯ Home grown, Other Describe [ ]

      ii. Number of chemical containers
         - ◯ <100
         - ◯ 100-5000
         - ◯ 5000-10000
         - ◯ 10000-20000
         - ◯ >20000

   b. Resources (personnel) dedicated to chemical management
      i. Number of FTEs
         - ◯ <1
         - ◯ 1-3
         - ◯ 3-10
         - ◯ >10

2. How well are your chemical acquisition and chemical management processes integrated? (examples below)
   - Work planning and control allow for identification of chemicals and amounts prior to work
   - Process for identifying less toxic alternatives prior to acquisition of chemicals
   - Process for purchasing only what is needed for a job/project
   - Useful data management tools
   - Process for identifying potential waste disposition prior to procurement of chemicals

○ Not integrated

○ Somewhat integrated

○ Well integrated

○ Very well integrated

Briefly describe your approach to chemical acquisition.

3. How well are your chemical inventory and chemical management processes integrated? (examples below)
    - Real-time updates
    - Process for managing "old" or chemicals that could become unstable
    - Process for managing chemicals no longer needed
    - Regular inventory review with accuracy metrics appropriate to the site
    - Pharmacy or crib
    - Process for minimizing hazardous waste

◯ Not integrated

◯ Somewhat integrated

◯ Well integrated

◯ Very well integrated

Briefly describe your approach to chemical inventory. Include whether you use the pharmacy concept.

4. How well are your chemical disposition and chemical management processes integrated? (examples below)
    - Process for, re-use, recycling
    - Identification and segregation of "cold" waste vs. "radiological" or "mixed" waste

◯ Not integrated

◯ Somewhat integrated

◯ Well integrated

◯ Very well integrated

Briefly describe your approach to chemical disposition.

5. How well are your chemical substitution and chemical management processes integrated? (examples below)
   - Process for janitorial/maintenance chemicals
   - Process for research/analytical chemicals
   - Process for Building materials
   - Process for fuels

○ Not integrated

○ Somewhat integrated

○ Well integrated

○ Very well integrated

Briefly describe your approach to chemical substitution.

6. What does your training program consists of?

☐ Classroom

☐ Online

☐ In the field

☐ Other Describe

The authors of the guide would like to ask you these specific questions in a follow up telephone call or email.

1. What strategies do you employ to reduce or eliminate the acquisition of toxic and hazardous chemicals and materials?
2. How did you implement these strategies?
3. What metrics do you use to measure the success of these strategies?
4. Were there any caveats or roadblocks to implementing the strategies?
5. Do you have any success stories?
6. How does your Environmental Management System intersect with Chemical Management?

Name:

Site:

Role in Chemical Management:

Phone Number:

Email:

Thank you very much for your time!

Sincerely, the members of EFCOG Chemical Safety and Life Cycle Management

Submit

4 Appendix 2 Case Studies for Management of Fugitive Emissions with Sulfur Hexafluoride (SF_6)

Overview

In response to Executive Order (E.O.) 13514, DOE has committed in its Strategic Sustainability Performance Plan (SSPP) to a combined Scope 1 and Scope 2 greenhouse gas (GHG) emissions reduction goal of 28% by 2020 as compared to the fiscal year 2008 baseline inventory.[5]

When calculating the 2008 DOE GHG emissions baseline inventory, DOE was surprised to discover that "non-combustion fugitive gas emissions" comprised 15% of the DOE Scope 1 and 2 GHG emissions inventory. Industrial fugitive emissions comprised slightly more than 14% of this total, while other fugitive emissions (from landfills and wastewater treatment) contributed less than 1%.

Driving Forces for Managing Fugitive Emissions

Fugitive emissions are, for the purposes of GHG accounting, emissions that are not physically controlled, but result from the intentional or unintentional releases of GHGs. They commonly arise from the production, processing, transmission, storage, and use of fluorinated chemicals, often through joints, seals, packing, and gaskets. Fugitive emissions can also include releases of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from on-site waste water treatment facilities, on-site landfills and other industrial uses. CO_2, CH_4, and N_2O emissions from combustion activities are not considered fugitive emissions.

Sulfur hexafluoride (SF_6) is one type of industrial fugitive gas. SF_6 is stable, non-toxic, and has been used for many years as a dielectric material in accelerators, switch gear, and high-voltage power supplies across the DOE complex. Prior to implementation of E.O. 13514 in October 2010, there were no requirements for DOE sites to manage or account for emissions of fluorinated GHGs. In 2008, SF_6 missions accounted for 90% of the industrial fugitive GHG emissions, or 14% of the total DOE Scope 1 and 2 GHG emissions inventory. As a result, DOE identified reducing fugitive emissions, especially SF_6 emissions, as a priority for achieving the 28% GHG reduction goal for Scope 1 and 2 emissions by 2020. The actual quantities of fugitive emissions are often relatively very small; however, most of the fluorinated gases have very high global warming potentials (GWPs) and, thus, a relatively high impact on the overall GHG inventory. GWP is a measure of how much global warming impact a given mass of GHG will have over a certain period of time, relative to the same mass of CO_2. GHG emissions corrected for GWP are expressed in units of CO_2-equivalent (CO_2e). For example, a 10 lb emission of SF_6 is expressed as 239,000 lbs CO_2e.

[5] DOE's 2011 Strategic Sustainability Performance Plan is available at http://www1.eere.energy.gov/sustainability/pdfs/doe_sspp_2011.pdf

A.3 Summary of Strategies for Managing SF6 at Sites

The 2010 DOE Scope 1 and Scope 2 GHG inventory is 4.1 million metric tons (mT) of CO_2e. The fugitive GHG emissions inventory, 426,295 $mTCO_2$e, is approximately 10% of the total 2010 DOE Scope 1 and Scope 2 GHG inventory.

Fugitive emissions decreased by 39% between 2008 and 2010, and SF_6 emissions are reported at 362,928 $mTCO_2$e for 2010 (85% of the total fugitive emissions). This is a 42% decrease from the 2008 SF_6 emissions inventory of 629,425 $mTCO_2$e. This success is the result of SF_6 emission management efforts across the DOE complex. Many of these management efforts incorporate source reduction, process changes, and recycling activities. The successes at individual sites are described in greater detail in the following selected case studies.

Example 1:

In FY 2010, an SF_6-user group was formed to evaluate opportunities for emissions reduction. Argonne hopes to achieve a 90% reduction in SF_6 emissions compared to FY 2008 within one or two years through investment in recovery/reclamation equipment, in more advanced leak detection equipment, and through effective repair procedures.

Example 2:

Since 1997, Flash X-Ray (FXR) system operators at one DOE site have reduced annual SF_6 usage from approximately 5,280 lbs to 115 lbs. Other SF_6 users have noticed the success in reducing SF_6 and are planning to install similar systems elsewhere. Several steps since 1997 led to SF_6 emission reductions:

- Step one (1997) of this process installed an SF_6 reclamation system and replaced polyvinyl chloride (PVC) and chlorinated PVC (CPVC) pipes with copper pipes to minimize leaks.
- Step two (2000) installed a recirculation and purification system. This system cleans the SF_6 and removes any breakdown products created during operation. With the recirculation system in place, the highest quality gas is consistently available for operations without needing to replace the used SF_6 as often.
- Step three (2010) installed electronic scales for more accurate measurements of SF_6 usage and electronic pressure system monitors. The new monitors are tied into a computer and trigger a facility alarm when pressure drops allowing for quick identification of a problem resulting in SF_6 release.
- Step four (2011) installed new valves close to filter locations to further reduce the amount of SF_6 lost during filter exchanges. By moving the valves closer to the filters, operators will be able to minimize the amount of SF_6 available in the piping system for release when performing maintenance.

Example 3:

When informed of the large contribution SF_6 emissions were making to the overall inventory, SF_6 end users took ownership of the problem and implemented changes. The changes implemented for the emissions reduction process included: purchasing new leak detectors (<$200), using detectors to find the leaks, fixing leaks, improving the inventory process, and re-engineering some of the SF_6-containing components, including the high capacity SF_6-recovery system. A portable gas recovery system is available on site for use during maintenance of the smaller systems, including the ion source repair shop, the test system, and sometimes the 138 kV tanks in the main switch yard. The Dilo Mini Plus D-320 Portable Recovery Cart can be operated easily by one person and has operated for over 10 years without any major problems – only a flat tire.

Example 4:

SF_6 purchases, inventory, and location are tracked through an online Chemical Inventory System (CIS). The CIS is an integrated chemical inventory and Material Safety Data Sheet document-management system, which tracks the containers of SF_6 at the site by barcodes. Although this method of tracking based on purchased and disposed containers does not necessarily provide accurate short-term use quantities, it is extremely valuable for tracking chemicals and for estimating long-term usage. SF_6 purchases decreased 77% between FY 2008 and FY 2009 and then increased 101% between FY 2009 and FY 2010. Between the baseline year of FY 2008 and FY 2010, purchases decreased 55%.

The potential for SF_6 alternatives and the associated reconfigurations was assessed for high voltage and other applications. Currently there is not a reasonable alternative to SF_6 without major reconfiguration of equipment and processes. One identified option is to retrofit the pulsar chambers to use air instead of SF_6; however, cost estimates are between $10,000 and $15,000 per chamber. It is unclear whether the accelerators can be converted to run with air as a substitute for SF_6.

Example 5:

In 2009, a leakage rate of 1.1% was achieved. SF_6 is emitted by leaky breakers. Overall, there are more than 2,000 individual SF_6-containing breakers with combined SF_6 nameplate capacity of 173,362 lbs. Both the quantity of breakers and the SF_6 nameplate capacity are continuing to increase as old breakers, including oil-filled and old leaky SF_6-filled breakers, are replaced with new SF_6-filled breakers.

At the beginning of the SF_6 reduction effort, the Electric Powers Research Institute (EPRI) was hired to visit each breaker location and SF_6 leaks were identified using laser cameras. Leaks are repaired by crews using multiple common plumbing techniques. Each crew develops best management practices and reports their SF_6 usage for the calendar year. SF_6 usage is determined by weighing the SF_6 bottles before and after maintenance activities and summing the quantities used to top-off the equipment. One crew has put together a trailer that keeps their SF_6 gas recovery cart, SF_6 bottles, scale, and maintenance equipment and supplies in one convenient and easily transportable location. While the central office does not mandate any specific operating procedures (other than annual reporting), presentations are made to the various crews annually during which ideas may be conveyed to the crew foremen.

A-4 Measuring Success

DOE sites have used a range of strategies to reduce SF_6 usage and avoid emissions. They have had considerable success in implementing leak detection and repair procedures. For example, one site hired a consultant to develop leak detection and repair procedures, and after less than a year of implementation, reported 73% fewer SF_6 emissions in FY 2010 as for FY 2008. Another site dramatically decreased SF_6 purchases after identification and repair of significant leaks in one of the photo injectors. A similar approach led to no associated SF_6 losses with the electrical breakers at another site in FY 2010. Other sites have avoided emissions through utilizing recapture equipment. One example of such equipment is a bladder system, which has been recovering significant amounts of SF_6 since 1997 avoiding approximately 900,000 $MTCO_2e$ and saving $1.5 million (2010 dollars).

A-5 Long Term Effectiveness and Lessons Learned

While implementing SF_6 management strategies across the complex, many lessons were learned, a selection of which are categorized and shown below:

1. **Addressing leaks through changing practices**. A DOE site evaluated leak sources and found that changes in practices could reduce acute leaks from user error. Lessons learned include letting the high voltage tanks vacuum pump overnight to bring the pressure down as low as possible before opening, and identifying the valves that can be opened and which ones should not be to avoid venting SF_6. The site also evaluated the source of chronic leaks and isolated those parts from the recovery system.

2. **Emission inventory**. Sites have different approaches to managing their SF_6 inventory, and several are using their chemical management systems to track SF_6 movement around the site during purchases, deliveries, and contacts. While infrared video cameras are used to detect leaks in utility equipment, top-off maintenance records and bubble detectors are used to identify smaller leaks on-site. One site improved its inventory process by purchasing a scale and changing the process to record the actual weight of the cylinders before and after use on-site. One pound of SF_6 makes a large difference in the overall inventory, so the extra time it takes to weigh the cylinders and to record the data were determined to be well worth it.

3. **Integrated systems approach to emission management**. Over several years, another site has implemented a comprehensive strategy of emission capture, recirculation, purification, monitoring, and leak minimization. In 1997, installation of a reclamation system and copper pipes decreased annual SF_6 usage from approximately 48 cylinders (115 lbs each) to eight cylinders per year. In 2000, installation of a recirculation and purification system enabled SF_6 reuse reducing annual usage from approximately eight cylinders per year to only one cylinder per year. With improved system monitoring installed in 2010 and new valves installed close to filter locations in 2011, further reductions are anticipated.

4. **Cost benefit analysis of recovery equipment**. In addition to evaluating GHG reduction benefits, costs should be considered when implementing emission management strategies. Initial considerations for SF_6 recovery equipment at one of the national laboratories determined that purchasing recovery equipment for one of the research programs could avoid emitting approximately 13,700 $mTCO_2e$ SF_6 annually at a cost of $1.50 per $mTCO_2e$. The research program consumed approximately 1,300 pounds of SF_6 per year during the standard operation

of laboratory equipment, and the acquisition of SF_6 cost the program approximately $12,000 each year. As the estimated cost of SF_6 recovery equipment for this program is $20,000, recovering the SF_6 emissions would avoid SF_6 purchases by the program that resulted in a simple payback in less than 2 years.

5. **<u>Design changes and consideration of SF6 alternatives</u>**. Several sites have explored redesigning equipment and SF_6 alternatives to reduce emissions including one that explored options to retrofit the pulsar chambers to use air instead of SF_6. Cost estimates for the retrofits were between $10,000 and $15,000 per chamber. It was unclear whether the accelerators could be converted to run with air as a substitute. A second site implemented design changes in research equipment to reduce emissions including redesigning the electron gun so that it does not use SF_6, re-machining O-ring seals, and converting single-pass systems to closed loop and adding a collection device. Some challenges associated with substitution are that alternatives may also include GHGs, have increased safety hazards, or require significantly higher operating pressures. Substitution often also requires recalibration and significant equipment substitutions.

6. **<u>Establish user groups</u>**. Several sites have established SF_6-user groups to advance the identification and dissemination of best practices for minimizing releases of fugitive emissions. The groups can assist in identifying where and when SF_6 leaks occur, the time involved in mitigating them, and the estimated quantity of gas released by each incident. This information can assist management in prioritizing repairs, purchasing reclamation equipment, or implementing other mitigation strategies.