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Project Summary

Pollution Prevention Opportunity Assessment: Histology Laboratory Xylene Use Fort Carson, Colorado

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One of the primary ongoing programs for promotion and encouragement of pollution prevention research is a cooperative program between the U.S. Environmental Protection Agency (EPA) and the Federal community at large. EPA's Waste Reduction Evaluations at Federal Sites (WREAFS) Program supports pollution prevention research through joint assessments of problematic areas at selected sites. The three primary objectives of the WREAFS Program are to 1) conduct waste minimization assessments and case studies; 2) conduct research and demonstration projects jointly with other Federal activities; and 3) provide technology and information transfer of pollution prevention results.

A Pollution Prevention Opportunity Assessment of a community hospital undertook an evaluation of xylene and ethanol waste streams generated as the result of tissue processing and staining in the hospital's histology laboratory, and methanol waste pollutions from the hematology laboratory.

Feasibility analyses for solvent recovery, materials substitution, and volume reduction also considered both technical and economic factors. These analyses allowed an "economic of scale" to be constructed to illustrate the net savings and payback periods for these options when implemented in histology laboratories of varying work loads (i.e., tissue sample throughputs).

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

To promote pollution prevention activities in accordance with the national policy objectives established under the 1984 Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act of 1976 (RCRA), the Risk Reduction Engineering Laboratory (RREL) of the EPA's Office of Research and Development is supporting the Waste Reduction Evaluations at Federal Sites (WREAFS) Program. This program consists of a series of projects for pollution prevention conducted cooperatively by EPA and various parts of the Department of Defense, Department of Energy, and other Federal agencies. The WREAFS Program focuses on pollution prevention research opportunities and technical assessments at Federal sites. The present project focused on a pollution prevention opportunity assessment conducted at the Fort Carson Evans Community Hospital (ECH) Histology Laboratory in Colorado Springs, CO.

Results of the pollution prevention opportunity assessment conducted at the histology laboratory identified two pollution prevention opportunities involving materials used for tissue processing and slide staining. The third opportunity that was investigated was volume reduction. At ECH, however, this option had been implemented by installing and utilizing automatic tissue and staining processors, so

the cost savings associated with volume reduction had already been realized and are no longer available.

Pollution Prevention Opportunities

The pollution prevention opportunity assessment was initiated by developing an inventory of the wastes generated at the ECH. Although the waste stream includes small quantities of various chemicals, xylene, ethanol, and methanol are the most significant wastes, with respect to volume, and require disposal as hazardous waste.

The Pathology Department (which includes the histology laboratory) at ECH disposes of approximately 150, 250, and 240 L (40, 66, and 63 gal) per yr of xylene, ethanol, and methanol, respectively. The principal operations involving these solvents include human tissue processing and slide staining for histologic and cytologic evaluations to support clinical diagnoses. The current method of disposal is through a local contractor who transports and incinerates the solvent waste. Chemical Waste Management, located in Henderson, CO, is currently under contract for this purpose. Disposal costs is approximately $160/55-gal drum, including transportation. The generation of these solvent wastes involve the following specific processes.

Tissue Processing

One solvent reservoir of xylene with a volume of 1.5 L and two reservoirs of ethanol with volumes of 3.5 and 0.7 L, respectively, are used in the automatic tissue processing equipment. The xylene and ethanol baths used during tissue processing are discarded and replaced with fresh solvent on a weekly basis. The discarded solvents are currently placed in a hazardous waste storage container. During this procedure, the solvents are mixed (the three chemicals from both the histology and hematology laboratories are not segregated but "pooled" (mixed) in the same drum and disposed together) in 55-gal drums with significant volumes of methanol from the hematology laboratory for eventual transport by a contractor for disposal.

Slide Staining

Two solvent reservoirs of xylene, both with volumes of 0.7 L, and one reservoir of ethanol with a volume of 0.7 L are used in the automatic staining equipment. The ethanol used during slide staining of histologic or cytologic specimens is changed on a weekly basis. Of the two xylene reservoirs (baths), the first reservoir is discarded; the second reservoir is rotated forward; and a fresh xylene reservoir replaces the reservoir that is rotated forward. This is done on a weekly basis. In the hematology laboratory, methanol is used for slide staining and other purposes.

It is important to note that for the purposes of implementing any solvent recovery option, it would be necessary to keep these solvents separate to maximize their recovery and reuse. The hematology laboratory's methanol waste can be kept separate from the histology laboratory's xylene and ethanol waste. Because cross-contamination of the xylene and ethanol baths occur during tissue processing and slide staining, therefore, mixing of xylene and ethanol will always occur in the process of tissue preparation for microscopic examination.

Two pollution prevention options were identified and evaluated for xylene and ethanol waste generated as the result of tissue processing and slide staining activities in the histology laboratory solvent substitution and solvent recovery. These options were also evaluated for methanol waste resulting from staining procedures performed in the hematology laboratory. The technical details of these options are discussed in the full report summarized here.

Solvent Substitution

Example xylene substitutes include Clear-Rite 3®*, Americlear®, Histosolv X®, and Mediclear II®. Adequate discussions of the toxicological profiles of these substitutes are not available to be able to compare their toxicity and safety to that of xylene. A review of the Material Safety Data Sheets shows that the primary hazardous constituent of the chemical substitutes are aliphatic petroleum distillates, which are classified as a D001 (Flammable Liquid) hazardous waste for disposal purposes. Before disposal into the sanitary sewer, the local wastewater treatment authority would need to be consulted for either discharge approval, or permitting, or both. Sanitary sewer districts often grant permission for such discharges for nonbioaccumulative wastes that are in dilute, or low-volume solutions, or both.

When selecting a substitute, a number of criteria must be considered. These include toxicity, physicochemical characteristics, compatibility with other materials, performance, availability, recycling requirements, disposal requirements, and cost.

The ECH has initiated an evaluation of available xylene substitutes. Preliminary results with vendor's substitutes indicated a preference for continuing to use xylene. The primary reason is related to xylene's ability to provide maximum paraffin infiltration of tissues resulting in greater specimen visibility and, thus, enhanced microscopic examination. Further, some of the available substitutes have a citrus odor that was undesirable to laboratory staff, and the staff believed the substitutes did not provide equal or better specimen visibility. The use of vacuum hoods could, however, eliminate the undesirable odors. Xylene substitutes are used in both open and closed processors and have been reported to be nondrying to skin, leave no oily residue for faster and easier slide cleaning, and allow for complete paraffin infiltration rendering tissues less brittle than xylenes. Further information is required, however, with respect to the potential hazards and safe use conditions of xylene substitutes.

Methanol substitutes for use in the hematology laboratory were not identified. Since methanol waste mixed with xylene and ethanol is difficult to separate by distillation, ECH should implement a program to keep methanol waste separate.

Solvent Recovery

Clinical laboratories in general, and histology laboratories in particular, have a large demand for organic solvents. The ECH laboratory is no exception. The histology department is a major consumer of xylene and ethanol. In addition, the hematology laboratory uses a significant volume of methanol. One method for minimizing the amount of these solvents is to recover the solvents with the use of distillation techniques. The histology laboratory at ECH has been considering this option as a possible means of pollution prevention. The initial investment cost of a sophisticated distillation system can usually be recovered in a reasonable amount of time (e.g., 1 yr because less solvent is needed and disposed costs are reduced).

The ECH laboratory mixes xylene, ethanol, and methanol wastes for ease of disposal. The only method to effectively separate these chemicals onsite is by distillation. In distillation, substances are heated to their boiling temperatures when the substance with the lowest boiling point is vaporized. This vapor rises into the condensing portion of the distillation column where it reverts back to its liquid state and is removed from the column. Efficiencies for separating compounds in mixtures have been achieved by using mechanisms de-

* Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

signed to continuously mix the vapor and liquid phases during the distillation process. With these mechanisms, the vapor becomes increasingly enriched with the higher boiling compound, and essentially complete separations can be achieved.

Two different solvent recovery techniques have been developed to enhance the efficiency of solvent separation. One method available for distillation of laboratory solvents (spinning band distillation) uses a motor-driven Teflon band in the distillation column. Another method utilizes an atomized plate technique. Although these distillation methods offer efficient separation, pure ethanol cannot be separated and recovered from xylene and ethanol mixtures. In fact, even if ethanol could be kept completely free of xylene contamination during tissue processing and slide staining, the ability of an alcohol recovery system to produce a virgin grade (95% +) alcohol depends on the system's ability to deal with the azeotropic link between alcohol and water (see number 2 below for explanation of the source of the water) as well as on effective alcohol recovery operational procedures. Effective operational procedures have been recommended as follows:

(1) Either ethanol or methanol (recommended by the tissue processor manufacturer) should be used because of their low azeotrope to water;
(2) All alcohol containers should be filled at the end of each shift; discard the contents of the flush container (normally 70% alcohol) following the formalin container; the alcohol in all remaining containers is put into a storage vessel to be reclaimed later;
(3) The last alcohol container is normally absolute; it should continue to be replaced with absolute alcohol; this will be the only "make-up" solvent necessary to purchase;
(4) The alcohol reclaimed using distillation methods normally has a purity of 95% or greater; this alcohol should be used in the containers between the flush container and the absolute container; there will be enough reclaimed 95% + alcohol left over after filling the middle containers to be blended to 70% purity for the flush container.

Economic Feasibility Analysis

The economic feasibility evaluation includes a preliminary cost analysis of both capital and operating costs. For this study, capital costs include estimates of equipment and materials. The operating costs include estimates of disposal fees and raw materials. Not included were insurance and liabilities costs because they were undetermined and utility use and labor costs because they were considered relatively unchanged. Based on the economic analyses, an economies of scale was developed (i.e., the economics for different amounts of slide production) to illustrate the net savings and payback periods for each of the three options. Scale Level A represents laboratories with monthly slide sample throughput of 8,000 or more slides; Scale Level B throughput of 1,000 to 8,000 slides; Scale Level C throughput of less than 1,000 slides.

In Table 1 the cost analysis data for ECH (i.e., pollution prevention cost assessment factors determining technical feasibility) are summarized: the total capital investment, the net operating cost savings, and the payback period (total capital investment/net operating cost savings per month) for each option, and each level of throughputs. Payback evaluation worksheets for the solvent recovery option are presented in the final report. The payback evaluation was based on solvent waste recovery for xylene and ethanol only because these two solvents can economically be recovered with the use of the same solvent waste recovery unit. Recovering methanol would require a separate unit or the implementation of a solvent waste segregation program. Worksheets for solvent substitution and solvent reduction were not prepared. No savings are realized from the use of solvent (material) substitutes. The data reporting savings from volume reduction from the use of automated equipment are presented only as a case study since ECH already uses an automated system, and no additional improvement is possible.

Conclusions and Recommendations

The technical and economic results of the feasibility analysis phase are summarized in the next column.

Solvent recovery: This option is clearly the most beneficial to ECH, provided that the relatively high payback (97 mo) is attractive to their operations. It can be an effective pollution prevention method for xylene, ethanol, methanol, and other histology solvents; however, solvent waste segregation is important to make this option feasible.

Substitution: Although this option may provide the use of less toxic substances, the relatively high cost of the substitutes and their less effective performance for tissue cleaning (compared with xylene) make their benefit as a waste minimization option less significant.

Volume reduction: ECH, like most laboratories, is currently using automated equipment. This option may provide laboratories using manual tissue processors and slide stainers a significant savings because solvent purchased as well as disposal costs are reduced.

In conclusion, the economy of scale analysis indicates that solvent recovery can be a cost-effective and attractive pollution prevention option to implement in large throughput histology laboratories (8,000 slides/mo or larger) as indicated by the low payback period (11 mo). It is a less attractive option for the smaller scale laboratories having slide throughputs of less than 8,000/mo (payback period 97 mo). The purchase of a solvent recovery unit to allow the recovery of methanol along with xylene and ethanol would increase the economic feasibility of solvent recovery. Material substitution offers the benefits of less toxic material; however, its higher cost (compared with current practice) may not be justified unless considered primarily on environmental grounds. Volume reduction from the use of automated equipment can offer significant savings in laboratories still using manual processors. This option has already been implemented in most histology laboratories, including ECH.

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Table 1. *Summary of Cost Analysis Data for Pollution Prevention Options*

Option Description	Capital Investment	Cost Savings/Month *	Payback Period (Months)
1. Solvent Recovery			
Scale Level A	12,800-18,900	Up to $1,780	11
Scale Level B	8,500-10,900	Up to $120	97
Scale Level C	7,900-8,500	Up to $68	124
2. Material Substitution			
Scale Level A	No capital investment required	None, will increase operating cost by about $384-$2,137/mo.	Costs cannot be recovered
Scale Level B	No capital investment required	None, will increase operating cost by about $72-$401/mo.	Costs cannot be recovered
Scale Level C	No capital investment required	None, will increase operating cost by about $21-$117/mo.	Costs cannot be recovered
3. Volume Reduction †			
Scale Level A	25,500-32,750	Up to $1,190	21-28
Scale Level B	22,200-25,500	Up to $793	28-32
Scale Level C	18,300-22,200	Up to $477	38-47

* These savings were calculated utilizing solvent cost as follows: xylene, $7.50/gal; ethanol, $7.60/gal; and methanol, $2.00/gal.

† Data for solvent volume reductions were provided by a major equipment vendor. The data compare total solvent cost requirements for manual tissue processors and the same requirements for an automatic processor provided with solvent evaporation and fume control. Total savings of $274/wk was reported for the Level A operation (based on Hacker Instruments estimation). Savings on Levels B and C operations were proportioned based on total slide throughput capacity.

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Kenneth R. Stone is the EPA Project Officer (see below).
The complete report, entitled "Pollution Prevention Opportunity Assessment: Histology Laboratory Xylene Use, Fort Carson, Colorado," (Order No. PB92-228 436/AS; Cost: $19.00, subject to change) will be available only from:
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