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Health and Safety – Pollution Prevention in Hospitals
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Final Report

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ABSTRACT

Numerous initiatives and government, industry, labor, and community-based partnerships have recently been established to foster pollution prevention in hospitals and other healthcare facilities. A major focus is to replace medical products, materials and work practices that generate pollution with those that are more environmentally-sound. Thus far, many of these pollution prevention initiatives are applied without considering their impact on workers, even though it is well-known that changes in materials and work practices can have significant effects on occupational safety and health (OSH). Traditionally, occupational and environmental health and safety hazard assessments and interventions have been conducted separately. The purpose of this work was to develop an integrated approach to assess occupational and environmental health and safety in hospitals and use the approach to: 1) identify and implement effective intervention strategies to replace the use of conventional materials and products with more environmentally-sound, healthy and safe alternatives; and 2) to evaluate the impact of the alternatives on worker health and safety.

An integrated approach was developed by worksite observation and by adapting elements of existing pollution prevention and OSH survey methods including production process mapping, process hazard analysis, and job-task hazard analysis. The survey consists of multiple, nested questionnaires that begin at the level of the entire health care facility and progress to more specific levels of work organization, concluding with a detailed analysis of the tasks associated with the use of a hazardous material or product targeted for the intervention. The survey assesses OSH risks in five categories: safety, chemical, biological, physical, and ergonomic. The survey also includes environmental impact and cost analyses of the conventional material and its alternative. The survey is conducted pre- and post-intervention and the results compared.

Twelve interventions were implemented and evaluated in 7 hospitals, including: replacement of formaldehyde from an anatomical pathology laboratory, xylene from histology laboratories, glutaraldehyde from endoscopy, wet film processing to digital imaging in radiology, and mercury-containing equipment and reagents from clinical laboratories.

This project showed that occupational health and safety and environmental protection are closely linked because the hazards share a common source in the production process. This intervention study was aimed at replacing hazard sources with safer and more environmentally sound alternatives. When these changes were implemented, whether for pollution prevention or technological improvements, there were impacts on worker health and safety. It is concluded that the methods developed here can be used to analyze future changes in materials and work practices in hospitals and to evaluate OSH impacts so they can be managed effectively.

SIGNIFICANT FINDINGS AND ACCOMPLISHMENTS

Occupational health and safety and environmental protection are closely linked because the hazards share a common source in the production process. This intervention study was aimed at replacing hazard sources with safer and more environmentally sound alternatives. This project found that any type of change in materials and work practices is likely to affect worker health and safety. When these changes are implemented, whether for pollution prevention or through technological improvements, worker health and safety must be evaluated as part of the change process. On balance, all of the interventions performed in this project improved worker health and safety. In addition, it was found that if occupational health and safety precautions were better applied, environmental emissions would generally be reduced. This project had the following major accomplishments:

- 12 interventions were conducted in 7 hospitals. In addition to the 3 interventions in 3 hospitals (9 interventions) that we originally proposed, we accomplished 3 more interventions.
- Comprehensive intervention assessment methods were developed.
- Numerous technical bulletins and fact sheets were developed and disseminated to hospital personnel and government agencies and community groups involved with the healthcare industry (see www.Sustainablehospitals.org).
- Detailed case studies of interventions and the lessons learned were developed (see Appendices A, B, and C and www.Sustainablehospitals.org).
- A doctoral dissertation was written by the doctoral student research assistant, Thomas P. Fuller. The dissertation, "Technological change and environmental health and safety in hospitals", was successfully defended in spring 2003. It includes 3 papers on 1) the impacts of technologic changes in radiologic imaging on worker health, safety and the environment; 2) assessing the effectiveness of interventions for replacing xylene in hospital histology laboratories; and 3) the development of environmental health and safety performance indicators for hospitals.
- 8 presentations at occupational safety and health professional conferences. NOTE: The AIHA 2002 poster presentation by the masters student research assistant, Anila Bello, won a prize as the top presentation in her technical session and one of the top four at the entire AIHA 2002 conference.
- Numerous presentations to industry, labor and community groups.

USEFULNESS OF FINDINGS

This project has produced numerous materials for hospital administrators and staff, for occupational and environmental advocacy groups, and for state and federal agency staff to use to evaluate hospital materials and processes for their health, safety and environmental impacts. It has also produced a large body of information on safer, more environmentally sound hospital products and materials. This project has been very effective in disseminating these to hospital personnel and others who can best use for health, safety and environmental improvements. The survey instruments developed in this project can be used as a tool for evaluating change in hospitals by industrial hygienists, ergonomists and safety professionals.

SCIENTIFIC REPORT

Background for the project

Overview. In response to new regulatory and community-based initiatives, many U.S. hospitals are developing plans to change their waste management and materials use practices. This rapid introduction of new materials and work practices will have significant implications for the occupational health and safety of hospital workers, particularly if these workplace changes intended to improve the ***ambient*** environment are not brought about using sound ***work*** environment practices. This project used the opportunity provided by the environmental incentives for hospitals to develop active pollution prevention plans to work with three hospitals to develop specific, integrated methods for implementing occupational health and safety-pollution prevention (OHS-PP) intervention strategies. The objective of this work was to develop workplace intervention strategies to reduce the use of polyvinyl chloride (PVC)- and mercury-containing materials in hospitals while improving the occupational health and safety of hospital workers.

Pollution Prevention in Hospitals. Recent regulations promulgated by the U.S. Environmental Protection Agency (EPA) will strongly encourage pollution prevention efforts in hospitals within the next two years. The new requirements will significantly restrict emissions from medical waste incinerators and will require all facilities that have medical waste incinerators to develop their own waste reduction plans (U.S. EPA 1997a). The EPA regulations will also require each state to develop incinerator emissions plans which include standards that are at least as stringent as the federal standards. The currently available emissions control technologies needed to meet the new regulations are so costly that it is expected that most hospitals will close their onsite incinerators and hospitals that purchase off-site incineration services will experience a considerable increase in costs. The EPA acknowledges that the cost of installing new emissions control technologies on hospital waste incinerators will be so expensive that alternative waste treatment options will be cheaper (MRI 1996). Accordingly, the new regulations also promote waste reduction strategies to reduce the need for waste treatment.

Before these new regulations, there had been little regulation of the approximately 2,400 medical waste incinerators in the U.S. that burn approximately 846 thousand tons of waste each year (U.S. EPA 1997a). Yet medical waste incinerators have been classified by the EPA as among the top three and four anthropogenic sources of both mercury and dioxins in the atmosphere (U.S. EPA 1997b; IARC 1997).

Dioxin production can occur during incineration of polyvinyl chloride (PVC) plastic, one of the most common types of plastic used in medical care. It is cheap, relatively easy to produce and, with the use of plasticizers, can be formulated to exhibit a wide range of properties. These properties enable the use of PVC plastics in virtually all hospital clinical areas, such as dialysis and respiratory therapy, and support areas such as laboratory services, medication preparation, and facilities. PVC plastic is used in such common hospital clinical products as blood, urine, and intravenous (IV) bags, tubing used for nearly all clinical purposes, ventilation masks, pressurized cuffs, and patient identification bracelets. It is also used in a range of patient care products such as pillow and mattress covers, shower curtains, basins, and bed pans.

Human health concerns have been raised about both chlorine and the plasticizers used in PVC. PVC plastic has a high chlorine content (56.7% of the molecular weight) and the incineration of PVC can lead to the formation of dioxins which are then emitted in the air. The group of chemicals known as dioxins has been designated as a known human carcinogen by the International Agency for Research on Cancer (IARC 1997). Phthalates are commonly used as plasticizers in PVC plastics. There is evidence that phthalates leach from IV bags, tubing, and dialysis equipment into patients (Jaeger and Rubin, 1972; Nassberger et. al., 1987). The health consequences of this leaching are now being questioned because DEHP (di(2-ethyl-hexyl)) phthalate), the most commonly-used plasticizer, has been classified as "reasonably anticipated to be a human carcinogen" (U. S. Department of Health and Human Services, 1998). There is also evidence suggesting that phthalates may have weak estrogenic activity, although additional studies are needed (Sharpe et al., 1995).

It has been estimated that hospitals contribute one-fifth of all mercury in solid waste (New Jersey Department of Environmental Protection and Energy, 1993). Further, the incineration of medical waste accounts for 10 percent of the estimated 158 tons of mercury emitted each year into the atmosphere from human activities (U.S. EPA, 1997b). In certain regions of the U.S., such as the Northeast and Great Lakes, limited fish consumption is advised because of its high mercury content. The limitations are very strict for certain populations such as children and pregnant women. Mercury contamination in fish results from air as well as water pollution. Mercury is used in a variety of hospital equipment and supplies. Mercury thermometers are still being used in many hospitals, even though digital thermometers that do not contain mercury are available. For years, many hospitals have given out mercury thermometers to mothers of every new baby. A few states, such have Minnesota, have recently passed laws prohibiting this practice. Mercury is also found in thermostats, blood pressure monitors, microscopes, batteries, fluorescent lamps, dental amalgam, medicines, tissue preservatives, stains and reagents, and solvents and degreasers.

In response to concerns about both the incineration of medical waste and the use of potentially hazardous materials such as PVC plastics and mercury in hospitals, Health Care without Harm: The Campaign for Environmentally Responsible Health Care was organized in 1996. This campaign is an international collaborative effort to eliminate pollution from health care practices without compromising safety or patient care. Over 80 organizations, including physicians', nurses', and other health care professionals' groups; women's, labor, and religious organizations; community health advocates and environmental groups, are part of this environmental and public health endeavor.

Hospitals are beginning to respond to these regulatory and community group initiatives by re-organizing their waste management strategies, by using alternative products that do not contain mercury or PVC, and by changing workplace practices. Several U.S. hospitals, including Beth Israel in New York City, Dartmouth Hitchcock in New Hampshire, and Fletcher Allen Health Care in Vermont, have successfully reduced their total waste stream as well as the components that are incinerated or specially processed and have managed to do so at cost savings. The nurse and waste manager that lead the successful program at Fletcher Allen Health Care and has subsequently developed curricula and delivered training to many other hospitals and members of American Nurses Association will advise the proposed intervention study.

A recent survey of 50 leading hospitals in the U.S. found that 80% have mercury reduction programs in place (Environmental Working Group/Health Care Without Harm, 1998). However, hospitals are just beginning to address their use of PVC plastics. The same survey found that only 20% of these leading hospitals have programs to minimize purchasing of PVC plastic. The California Medical Association (1997), the Minnesota Hospital and Health Care Partnership (1997), and the American Public Health Association (1996) have each passed resolutions that call for the eventual elimination of PVC plastic in health care products. These resolutions are consistent with hospital pollution prevention plans in many western European countries including Germany, which has banned PVC use in hospitals; Denmark, which is considering a PVC phase out in hospitals by the year 2000; and Sweden which has a policy to phase out PVC use country-wide by the year 2007.

Occupational Health and Pollution Prevention. These legislative and community-based initiatives to reduce hospital materials that generate pollution are calls to control environmental hazards by changing the workplace and work practices. It is well-known in the field of occupational health and safety that changes in materials and work practices can have significant effects on job health and safety. Thus far hospitals have introduced alternative materials by using a "top down" approach: the products are procured by purchasing managers and then distributed by the materials management employees. Seldom is an explanation given to workers in the clinical areas about why a product was changed or how its application might differ from the old one. The introduction of new materials very often requires changes in the associated work practices. Often these changes can affect health, safety, and job quality and satisfaction with potentially serious implications for hospital workers and patient care.

Factors related to health, safety and/or job satisfaction may also be significant determinants of whether an alternative product and associated work practices will be introduced and implemented effectively (Karasek 1990). An interview with an environmental regulator for the Massachusetts Water Resources Authority gave the example of a mercury-containing tissue preservative solution that was recently replaced with a non-mercury substitute by a hospital purchasing department. Months after the preservative solution was delivered to the pathology unit, it was discovered that a pathologist was buying the old mercury-containing brand outside of the hospital and bringing it in for employees to use. No one in the hospital had explained why the alternative product was introduced and the sudden change without getting input from the pathologist and other employees in the unit was considered an unacceptable infringement. It was also learned that, while the product specifications for the new product were similar to the old, the new product did not do the job as well. In addition, no industrial hygiene monitoring or workplace assessment had been conducted to determine whether use of the mercury-containing solution in that particular lab presented worker health risks. Interviews with several other environmental regulators have indicated that the new development of non-polluting, alternative materials is important but that in many cases alternatives already exist. The problem is that there are workplace barriers to using the alternatives. Environmental government agencies, community groups, and even hospital management are not equipped to identify or address the workplace conditions that create those barriers. It is the field of occupational health and safety that is well-equipped to address the introduction of new workplace materials and the work practices associated with their handling and application.

There is evidence from occupational intervention studies that workplace changes are brought about most effectively if they are evaluated within the context of the overall workplace goals with the participation of the employees who perform the work (Loewenson et al. 1994; Hugentobler et al, 1992). For example, Moir and Buchholz (1996) have developed participatory methods to introduce successful changes in materials handling and other work sites in the construction industry. Garg and Owens (1992) have applied participatory intervention methods to effectively reduce back strain among nursing home personnel. In the field of organizational management, participatory methods have been used to change rigid, hierarchical management structures to more flexible ones that are able perform more highly specialized work required by the global economy (Forrant 1997; 1998). The proposed in-hospital intervention teams will be based on these participatory methods.

Recent research in occupational health and safety provides evidence that reduction in ambient pollution and improvements in workplace health and safety efforts can simply shift the risks from one to the other when the two are not considered in concert (Ashford et al. 1996). This risk shifting can occur in either direction. For example, a health and safety officer in a large hospital in Maine recently reported that they have two cases of compensable wrist injuries in nurses because the brand of intravenous (IV) bag was switched to reduce PVC use without notifying the nurses of the new work practices needed to use them properly. The new bags required different methods to puncture the needle port. The nurses whose jobs required them to use many IV bags in one day began experiencing wrist pain from the increased repeated forceful action they needed for the new IV bags. Two nurses actually lost time from work. Risk shifting from the occupational setting to the environment has occurred with the use of PVC gloves to replace latex. This is happening on a large scale because of the strong concern for latex sensitization in hospitals. An integrated OHS-PP approach would seek latex glove alternatives that are non-polluting.

The reasons for integrating OHS-PP concerns in a single approach are not only about *avoidance* of risk shifting. A hypothesis of the proposed work is that *improved* pollution prevention strategies will be developed when health and safety are considered along with pollution prevention. Currently separate regulatory structures and professional cultures divide issues related to environmental quality and occupational health and safety. This division has created a significant gap in our understanding of the full range of options for comprehensive pollution prevention (Quinn et al., 1998). An objective of the proposed work is to begin to bridge this gap by evaluating the relationship between occupational health and safety and pollution prevention in the hospital industry.

The Structure of the Hospital Industry. The hospital industry has a complex structure with several organizational levels having a potential role in the change of hospital materials, clinical procedures and work practices. Virtually all individual hospitals belong to Group Purchasing Organizations (GPOs) which negotiate lower prices with member medical equipment and supply distributors. Both hospitals and medical supply distributors pay to join GPOs. Large GPOs, i.e. those representing many and/or large hospitals, have considerable negotiating power. Hospitals have significantly lowered their materials purchasing costs by joining GPOs but have found that they may be limited to certain types or brands of equipment or supplies. In preliminary interviews, managers of large GPOs have said that it is possible for any single hospital to change a particular supply, but it is usually discouraged by the GPO. The role that GPOs have in hospital health and safety and pollution prevention has not been well-defined, however it is clear that the GPO is a part of the hospital industry structure that must be accounted for when considering effective OHS-PP intervention strategies. The president of a New England regional GPO has agreed to participate on the Advisory Board for this project, and so should help integrate the proposed work into the activities of this important sector of the healthcare industry.

Although individual hospitals differ somewhat in their organizational structures, typically each has a hospital-wide committee on standards and procedures with the responsibility of maintaining quality control. Most hospitals also have hospital-wide health and safety committees, although the structure of the committees varies. Both the standards and procedures and the health and safety committees usually have representatives from the hospital administration as well as from the clinical departments. Hospitals are divided in departments for clinical specialties such as internal medicine, pediatrics, and cardiology. Departments of Facilities or General Services typically manage the hospital waste handling and disposal. A division within the Facilities Department, often called Environmental Health and Safety, addresses concerns for hospital employee health and safety as well as environmental management. Several hospital health, safety and quality control professionals have agreed to assist us by serving on the Advisory Board.

Within the broad level of the hospital department (for example the Department of Internal Medicine), there are multiple subunits that perform specific clinical functions (for example dialysis). These subunits represent the basic "production process unit" in the hospital and are the level at which the proposed work site analyses will be conducted. For the purposes of this proposal, these subunits will be called "clinical areas." Workers in these areas include physicians, nurses, other clinicians, and administrators. Materials, such as PVC plastic tubing or intravenous (IV) bags, may be used in many different clinical areas throughout a hospital, however the *manner* in which the material is used and the work practices surrounding the use of the material are primarily defined at the level of the clinical area by the job requirements and clinical procedure performed there. Employees from the division of Environmental Health and Safety come to the clinical area to remove sharps containers and to oversee the handling of hazardous waste. Employees in the Department of Materials Management generally distribute new supplies to a clinical area and employees in the Facilities Department remove and dispose of the waste from the clinical area. In this project, these employees are referred to as "support" for the clinical area with regard to materials handling. "Clinical and support area" refers to the functional group of employees that includes materials purchasing, distribution, application, and disposal.

Hospital waste is usually segregated into infectious ("red bag"), hazardous (radioactive waste) and regular (composition similar to that of an office building) waste. Red bag waste must be specially treated for infection control; it is usually either incinerated or autoclaved and shipped to a landfill. In many hospitals the segregation of the red-bag waste is not done very efficiently and it is common to find all types of materials, such as PVC plastic packaging from supplies, in the red bag waste. Often toxic substances, such as mercury-containing materials, are also found in the red bag waste. These material become airborne during incineration. Management and work practices at all levels of the hospital industry determine how a material will be handled in a particular clinical area. Communication among these various levels of the industry is not always well coordinated and the goals and expectations that motivate the various levels can differ. These circumstances can also affect decisions about what material is introduced and how it is used, handled and disposed. Ineffective waste management can greatly affect a hospital's operating costs. Intervention strategies to reduce hospital waste must be aimed at multiple levels of the hospital industry structure. A multidisciplinary assessment team is needed to address the numerous factors that affect OHS-PP. In addition to having training in the technical health and safety disciplines, the assessment team should have capabilities in economics and organizational management so that health and safety interventions developed are cost-effective and compatible with the organizational structure of the workplace. The investigators of the proposed study comprise such a team.

Specific Aims

The specific aims were to:

1. Establish the multidisciplinary, in-hospital occupational health and safety-pollution prevention (OHS-PP) intervention teams for three hospitals and finalize the establishment of the OHS-PP Intervention Study Advisory Board.
2. Finalize the selection of three clinical areas within each of the three hospitals and conduct interviews with individuals or small groups of hospital managers, clinicians, and waste handling and disposal employees to identify the important dimensions of the OHS-PP problems in each clinical area.
3. Develop and deliver a curriculum and educational materials for in-hospital OHS-PP intervention team training.
4. Develop and conduct a pre-intervention OHS-PP walkthrough survey and job analysis (the "pre-intervention *walkthrough survey*") for three clinical areas in each of the three hospitals.
5. Conduct pre-intervention workplace analyses with the in-hospital intervention teams to analyze work procedures, jobs and materials in each clinical area (the "pre-intervention *workplace analysis*") to identify possible interventions and intervention strategies for reducing environmental and/or occupational health and safety hazards.
6. Research specific intervention strategies for hospital materials and work practices to replace existing hazards.
7. Conduct a worksite orientation to the OHS-PP intervention strategy and implement the intervention.
8. Conduct the post- intervention OHS-PP walkthrough survey and job analysis (the "post-intervention *walkthrough survey*") of each of the three clinical areas in each hospital.
9. Conduct post-intervention workplace analyses with the in-hospital intervention teams to re-analyze work procedures, jobs and materials in each clinical area (the "post-intervention *workplace evaluation*") to evaluate the effectiveness of specific interventions and intervention strategies for reducing environmental and/or occupational safety and health hazards.
10. Analyze the data collected and compare the study findings for each of the clinical areas, within

each hospital and among the three hospitals.
11. Develop and distribute the final products summarizing the study findings: a specific OHS-PP plan for each hospital, an instructional manual and model OHS-PP plan for hospitals nationwide, and OHS-PP case studies for hospital administrators and for occupational safety and health professionals.

Methods

Aim 1. Established an Advisory Board. The advisory board for the Sustainable Hospitals Project was established in 1998. It consists of eight members representing a range of health care labor, management, occupational and environmental professionals, and community health and environmental advocacy groups:
• Debbie Augustine, Environmental Affairs Coordinator, New Hampshire Hospitals Association
• Evelyn Bain, Associate Director, Occupational Health and Safety Specialist, Massachusetts Nurses Association
• Mike Belliveau, Executive Director, Environmental Health Strategy Center, Maine
• Letitia Davis, Occupational Surveillance Program, Massachusetts Department of Public Health
• Kathy Gerwig, National Manager of Resource Conservation, Kaiser Permanente, California
• Bill Ravanesi, Boston Campaign Director, Health Care without Harm, a coalition of more than 200 hospitals, unions, and environmental and health advocacy groups
• Janice Stecchi, Dean, College of Health Professions, University of Massachusetts Lowell and Chair of the Board of Directors, Saints Memorial Medical Center, Lowell
• Susan Wilburn, Senior Specialist, Occupational Health and Safety, American Nurses Association

The main function of the advisory board was to provide independent consultation to the P.I. and intervention study team staff regarding all aspects of the study. The study team communicated regularly with individual advisory board members via the telephone and e-mail throughout the 4 year study period. As educational materials, reports to hospitals, and case studies were developed, drafts of these were sent to 1 or more advisory board members for review and comment. A large group advisory board meeting was held in 1999 to review and comment on the materials being developed to begin the intervention study and to guide the selection of hospitals and areas of the hospitals for implementing the interventions. They met again in 2001 to review the data collected and the intervention study progress. The advisory board also helped us recruit the hospitals for the study. The advisory board also assisted us to disseminate our findings in forms most accessible to hospital workers, managers, and the government agencies and community groups involved with health care institutions. Based on the advisory board recommendations, we established the Sustainable Hospitals Project website with practical information regarding more environmentally-sound, healthy and safe materials, products and work practices. The website information about these workplace alternatives is sufficiently complete that a hospital administrator can evaluate a potential alternative and learn how to obtain it.

Aim 1. Established in-hospital multidisciplinary teams. When the investigators proposed establishing formal workplace teams to participate in the intervention and change process, the workers indicated that they did not have time to become involved so intensively, even if given release time from work. They asked that the investigators perform the research to identify alternatives and work with supervisors to select the final interventions, after consulting with workers. In the end, there was a participatory process in each intervention, but these did not take the form of formal teams with regular meetings. Rather, the employees at all levels of the hospital organization involved in the change process were identified and consulted periodically throughout the process.

Aim 2. Selected hospitals for study. To select the hospitals, the OSH-PP intervention study team met with high level hospital managers including vice presidents and division directors, department supervisors, staff within departments and hospital representatives from nursing and technical staff unions. From these meetings it was found that, once the hospital vice presidents or directors had agreed to participate, the key person in the hospital organization to work with regarding the implementation of a specific intervention was the manager of a particular department along with members of the department staff. During this initial hospital selection step, 5 hospitals indicated at least some interest in participating in the study, but all said that they needed further information about possible interventions and that they wanted to department managers to select the intervention(s).

Interviews with the managers of selected departments were then conducted to identify specific OSH-PP interventions. Because the OSH-PP intervention methods had never been applied before, a decision was made to focus the study on hospital departments that did not have responsibility for urgent patient care. Instead, diagnostic and facilities departments were chosen including histology, pathology, other clinical laboratories, radiology, phlebotomy, and environmental services. The OSH-PP study team had a list of interventions that recent national and state pollution prevention initiatives had targeted such as mercury containing equipment and chemical solutions and polyvinyl chloride (PVC) plastic medical products. However, results of these interviews showed that the OSH-PP approach could be used to re-frame many traditional occupational safety and health hazards in hospitals by linking them to their environmental concerns and then identifying practical alternatives (the interventions) and the procedures to implement them. In addition, it was learned that health care facilities are often engaged in some type of materials, product, or work practice change with the potential to improve OSH or PP, if OSH-PP considerations are included at the beginning of the change process. However, the significance of these changes for OSH-PP often goes unnoticed and OSH-PP considerations are seldom part of a hospital process or materials change. To encourage health care managers to recognize more explicitly the role that such changes could have on OSH-PP, we developed a list of OSH-PP initiatives (interventions) that a health care facility can undertake. Many of the OSH-PP interventions identified during these interviews were workplace changes that the hospital managers and/or staff wanted to make but lacked the time and personnel to implement. More than 40 possible OSH-PP interventions were identified.

Next, the full list of potential OSH-PP initiatives was reviewed with the managers of the diagnostic and facilities departments in each of the 5 hospitals that had expressed an interest in participating in the study. If one or more departments in a hospital agreed to participate in an intervention, then the hospital was enrolled in the study. After the hospital and department recruitment steps, work with the hospitals proceeded in 2 ways. The first was with a group of hospitals that requested information related to 1 or more OSH-PP interventions and that often let our intervention study team come onsite to observe current work practices, but for a variety of reasons, were not able to engage in the full pre-and post-intervention study. In these cases, our study team provided basic technical support to encourage a future workplace OSH-PP intervention, including offering recommendations for improving OSH-PP. In the second group of hospitals, the full pre- and post-intervention study was conducted. This group included 7 hospitals in which 13 OSH-PP interventions were implemented and assessed. The hospital and department recruitment steps were repeated throughout the first 2.5 years of the study in order to: cultivate a pool of hospitals to draw from for the full intervention study, raise general awareness about occupational safety and health - pollution prevention in healthcare, and create a network to disseminate the study findings on more healthy, safe, and environmentally-responsible alternatives and work practices beyond the hospitals that participated in the full intervention study. Over the 4 year period of the study, this network included 14 hospitals.

Aim 3. Developed and delivered curriculum and education materials. Instead of a formal curriculum, technical bulletins, workplace assessment tools, and specialized technical reports and presentations were developed for specific interventions. The investigators developed a procedure for the overall change process and presented this to the department managers. To help the manager decide what she/he wanted to target for intervention, the investigators prepared technical bulletins on some of the most urgent occupational safety and health topics such as latex, glutaraldehyde, and the implementation of safe needle devices. These were identified through interviews with managers (see Aim 2 above). The investigators also designed "mini-surveys" and other tools that hospitals could use in this process. For example, a survey on glutaraldehyde use was developed for one hospital and then made available on the Sustainable Hospitals Project website for other hospitals to use (www.Sustainablehospitals.org).

Once the intervention was selected, the investigators researched possible alternatives using the healthcare, scientific and engineering literature; telephone interviews with manufacturers and distributors and with personnel in other hospitals known to have made the change; healthcare and medical device websites;, and internet discussion groups for relevant healthcare professions (for example "histonet," a discussion group for histologists was consulted). The study team summarized the alternatives, and their advantages and disadvantages for the department manager and presented their findings to managers and staff in the departments.

Aims 4 - 9. Developed survey instrument and methods for pre- and post-intervention impact evaluation. To evaluate the impact and effectiveness of the intervention, a survey with several components was developed. The survey was designed to be used by the study team industrial hygienists and ergonomists to conduct onsite observational walkthrough surveys, job analyses, and interviews of hospital employees involved in the intervention. Managers and workers upstream and downstream from the process targeted for the intervention were also observed and interviewed to evaluate the impact of the change on the flow of the alternative through the entire hospital. These included purchasing agents and materials managers (upstream) who are responsible for the procurement and distribution of the product and housekeeping and facilities managers (downstream) who are responsible for the clean up and disposal of the product. The survey was conducted pre- and post-intervention and the results compared.

Survey Development. A major objective of the study was the development of the survey and a protocol for administering it. The results of this effort are given in the Results and Discussion section, below. The survey was developed by the study team conducting industrial hygiene and ergonomic walkthrough evaluations in 2 hospitals not included in the final intervention study. In addition, survey elements were drawn from previously published worksite evaluation tools.

Survey Administration. The surveys were used to assist a structured worksite observational analysis conducted by the study team in each department of each hospital. In addition, survey information was collected by interviewing hospital staff and administrators. The full survey and worksite analysis required numerous visits to each hospital.

Aim 10. Analyzed data and compared study findings within and among hospitals. Protocols and timetables for implementing the interventions were developed by the study team with department managers and staff. The OSH-PP intervention survey was used to map the work processes where the intervention was to be introduced and a second map of the materials input and output for each process step was created. A matrix of all the jobs and tasks associated with each process step was then developed and the tasks directly affected by the intervention were identified. These tasks received the most detailed level of the OSH-PP pre- and post-intervention assessments which evaluated the impacts of the interventions on the workers who performed these tasks with respect to biological, chemical, safety, ergonomic and physical hazards. The OSH-PP intervention assessment survey was conducted again after the intervention was implemented. Changes that occurred at the level of the area, process, and task, were of particular interest. The type of change, and whether it had a positive, negative or neutral impact on worker health and safety and the environment was noted. The most detailed change analysis occurred at the task level. Table 1 lists the 13 interventions conducted in the 7 hospitals along with a summary of some of the major health, safety, and environmental impacts of each intervention.

Aim 11. Disseminated materials for hospitals. Eight presentations at occupational health and safety professional conferences were made. Numerous other formal presentations were made at meetings and conferences for government agencies, unions, hospital, and business groups involved with the health care industry. Scientific journal articles on the intervention study methods and a case study of the formaldehyde intervention in the pathology laboratory are being prepared by the P.I. Additional publications are being prepared as part of the doctoral student research assistant's dissertation. The dissertation includes 3 papers on 1) the impacts of technologic changes in radiologic imaging on worker health, safety and the environment; 2) assessing the effectiveness of interventions for replacing xylene in hospital histology laboratories;

and 3) the development of environmental health and safety performance indicators for hospitals.

Numerous technical bulletins and case studies were also developed (see www.Sustainablehospitals.org). The main vehicle for disseminating the study findings to practitioners including environmental and occupational health and safety professionals, hospital managers and staff, and government agencies and community groups involved with the health care industry is the Sustainable Hospitals Project (SHP) Clearinghouse and Website.

The strength of the clearinghouse is in presenting the information in ways that allow hospital staff to make immediate use of the information quickly. This is done in several ways:

- http://www.sustainablehospitals.org is the SHP clearinghouse website. This serves as an electronic filing cabinet and a repository of key information on alternative products and practices. While this is often considered the flagship of the SHP, the website is merely a portal to the SHP staff's research and technical support.
- Technical fact sheets are developed and disseminated via the website, at conferences, in mailings, and by other organizations. These are 1-2 page cogent summaries on timely topics such as mercury, environmentally preferable purchasing, glutaraldehyde, latex, and safe needle devices.
- A technical support hotline is available by both phone and email to answer questions from health care practitioners.
- SHP presentations are routinely offered at New England health care conferences and meetings.

Results and Discussion

There are 2 major categories of results. First, the methods development for the survey and protocol and second, the interventions performed in the hospitals.

Survey instruments and protocol. The survey consisted of multiple, nested questionnaires that begin at the level of the entire health care facility and progress to more specific levels of the organization concluding with a detailed analysis of the health care workers' tasks associated with the use of a material or product targeted for the intervention. The questionnaires were administered onsite by the intervention study team. The information was collected by interviewing workers employed at various levels of the organization, by industrial hygiene walkthrough evaluations, and by observational evaluations based on industrial hygiene, ergonomics, and safety process, job and task hazard analyses. The following is a list and brief description of the questionnaires:

- The Facility Survey: collects demographic data about the organizational structure that can impact occupational safety and health and pollution prevention throughout the health care facility. For example, it determines whether the employees are represented by a union, whether there is a health and safety committee, and if there are hospital-wide policies related to OSH or PP issues such as latex control or mercury reduction.

- The Area Survey: an area may correspond to a clinical department, such as clinical lab services, or to a single, physical space within a department, such as an anatomical pathology laboratory within the larger department of clinical lab services. This questionnaire is used to identify all of the processes that occur in the area and the employees and job titles and basic duties.

- <u>The Process Survey</u>: is conducted for each process identified within an area, for example, histology and cytology may be located within the area of the anatomical pathology lab. Information is collected about the overall process and the physical conditions in which it is performed such as air and lighting quality as well as about waste generation. The process is then broken down into basic steps and each step is evaluated using five hazard categories: chemical, biological, physical, safety, and ergonomics. The evaluation is performed by scoring each process step for each of the hazard categories with a score of 0 = no, 1= low and 2 = high. The process survey is used to create a map of all processes in a particular area. It is then used to create a more detailed materials input and output map.

- <u>The Task Survey:</u> Each task associated with a process step is evaluated for the same five hazard categories as the process steps using the same scoring system. This is the most detailed and therefore the most time-consuming component of the assessment. Part of the analysis of the task survey involves linking the workers through their tasks and jobs to the process steps. This is one way that the intervention study integrates OSH and PP. Conventionally, OSH focuses on jobs and tasks and PP focuses on processes, materials, products, and waste streams. While there is some overlap, these are not fully linked and thus it has been difficult to evaluate the relationship between OSH and PP, their impact on each other, and ultimately to find better solutions to workplace and environmental problems.

- <u>The Employee Survey:</u> Because the task survey data are very detailed and collected by the intervention study team, a general post-intervention questionnaire is used to ask workers whether, overall, they liked, disliked, or were neutral to the intervention. They are also asked to describe in an open-ended format any positive or negative changes that in their jobs that resulted from the intervention.

- <u>The Post-Change Survey:</u> is aimed at evaluating the factors that brought about the change within the health care facility. Our research indicates that change in health care facilities happens or not for a variety of reasons, many of which do not follow from standard health care management dogma. One aim of the intervention study is to evaluate systematically how and why OSH-PP change occurs within a health care facility.

• The Cost Analysis Survey: Positive OSH-PP change in the health care industry cannot be encouraged without accounting for costs. The purpose of the cost survey is to systematically evaluate the direct costs associated with a change, such as the cost of the new material or equipment, and also to account for some of the indirect costs related to OSH-PP that often are not considered. The hidden costs of using a toxic material include those associated with:

- worker training and hazard communication
- purchase and maintenance of personal protective equipment, including respiratory protection
- installation and maintenance of engineering controls
- air and water monitoring to meet occupational and environmental regulations
- surveillance and incident reporting
- hazardous material storage
- waste handling and disposal
- medical monitoring
- emergency response
- regulatory fines

For this study, it was not possible to quantify the costs of occupational illness and injury associated with the use of hazardous materials. However, the topic was discussed with hospital managers in an effort to raise awareness.

Results of hospital interventions. Twelve interventions were carried out in 7 hospitals (Table 1). The original proposal called for conducting 3 interventions in 3 different hospitals. These were accomplished, and 3 additional interventions were also carried out. The following is a description of the interventions:

* Xylene replaced by an aliphatic fixative in 3 histology laboratories. Xylene, a toxic aromatic hydrocarbon, is used in histology laboratories to fix tissue for the preparation of diagnostic slides. Xylene is known to be toxic, and is a suspected carcinogen. It is regulated by OSHA and the EPA. The motivation for this change came from histology staff who complained of respiratory and mucous membrane irritant symptoms, headaches due to the strong odor and dermatitis. The intervention was a new alternative tissue fixative, Histosolve, which is an aliphatic hydrocarbon that does not contain hexane. Other alternatives that required major equipment expenditures, such as tissue fixation using microwaves, were also considered. However, the chemical "drop in" replacement was chosen by the hospital staffs because it required less work reorganization and time to implement. The intervention was successfully implemented in all 3 hospitals, and 6 months after the interventions, the hospitals were continuing to use the alternative chemical. The overall result was that xylene was either completely or significantly reduced in these laboratories. Specific examples of the health and safety and environmental impacts are given in Table 1.

* Mercury reduction policy and plan in 3 clinical laboratories. In these hospitals, the intervention was a written policy and plan for the reduction and eventual elimination of mercury in the clinical laboratories. Mercury occurs in obvious sources such as thermometers, sphygmomanometers, and thermostat switches, but it is also present in small quantities in many laboratory reagents. Most of

these reagents are disposed in the sink. With input from the laboratory managers and staff, a mercury elimination policy was developed and a plan to meet the policy was written. The policy and plan were implemented by laboratory staff with the assistance of our study team. In 2 of the hospitals, the mercury policy was also implemented hospital-wide. The introduction of a successful mercury reduction plan required breaking myths about the need for mercury-containing equipment. Many clinicians feel strongly that mercury thermometers and sphygmomanometers are better than digital ones. For most applications, our research showed otherwise. We also found that mercury spills happen often, and spill procedures are often lacking or not followed.

* Wet chemical film processing to digital imaging in 3 radiology departments. This change was undertaken by the hospitals to introduce new technologies. We recognized that this technologic change could have significant impacts on OSH and the environment, and so we applied the same methods to evaluate these impacts. Interestingly, until we spoke with staff and managers in these radiology departments, none of them recognized the potential OSH-PP impacts. It was found that chemical exposures and musculoskeletal hazards such as repetitive motions awkward postures and heavy lifting were eliminated or reduced. There were increased musculoskeletal hazards related to VDT use. There were significant positive environmental impacts, including reduced chemical and plastic waste and water use. The shift from wet to dry imaging in radiology could result in a loss of jobs. However, with adequate planning and retraining, not only were jobs not lost, but workers were able to move into higher skill jobs with greater job satisfaction (change from film filing clerk to computer database manager).

* Formaldehyde replaced by a less toxic chemical in one hospital. Formaldehyde used for tissue preservation and fixation was replaced in a pathology laboratory. The alternative was a less toxic aldehyde. In this case, the hospital asked our study team to assist with an intervention after they were fined for water pollution violations because of their formaldehyde waste water discharge. In order to convince the pathologists that the alternative product performed as well as formaldehyde, pathologic specimens prepared with formaldehyde were compared to specimens using the alternative in a double blind side-by-side split sample study. The results showed that the alternative performed equivalently on most, but not all, tissues.

* Safe needle device introduction in one hospital. Safe needle devices were introduced in the phlebotomy department, motivated by the OSHA bloodborne pathogens standard. In addition to the decreased risk of infection from needle sticks, there was increased ergonomic strain related to the introduction of the devices because their use involved awkward hand and wrist movements. This problem was heightened during busy shifts. Solid waste was also increased.

* Glutaraldehyde replaced with a less toxic chemical in 2 hospitals. Glutaraldehyde was replaced by Cidex OPA, a less toxic aldehyde, for sterilizing equipment in endoscopy. The motivation for this intervention was to reduce worker asthma risk and dermatitis. The glutaraldehyde was eliminated in this department, thus reducing worker exposure and water pollution.

Intervention	Department or Area	Hospital ID, characteristics	Motivation for Change	Examples of health & safety impacts	Examples of environmental impacts
Xylene → aliphatic fixative	Histology	1. small, urban 2. small urban 3. medium, urban teaching	worker irritant symptoms	↓odor, headaches, skin irritation, toxicity	↓chemical waste
Hg reduction policy & plan	Clinical Labs	1.small, urban 2.small, urban 3.medium, urban teaching	water pollution	↓spill hazards, toxicity	↓water pollution
Wet → digital imaging	Radiology Radiology Emergency Radiology	1.small, urban 4. large urban teaching 5. large urban teaching	new technology	↓chemical exposures ↓ repetitive motions, awkward postures, ↓ lifting ↑ VDT hazards	↓ chemical waste, ↓ water use, ↓ plastic waste
Formaldehyde → glyoxal	Pathology	3.	water pollution	↓toxicity, odor, skin irritation	↓water pollution
Safe needle device	Phlebotomy	3.	bloodborne pathogen standard	↓risk of infection, +/- ergonomic strain	↑solid waste
Glutaraldehyde → less toxic aldehyde	Endoscopy	6. medium suburban 7. large public	reduce worker asthma hazard	↓toxicity	↓water pollution

Table 1. Summary of 12 OSH-PP interventions completed in 7 hospitals (numbered 1 - 7). Down arrow indicates a reduction, up arrow an increase, +/- indicates both increase and reduction in health, safety and environmental impacts comparing pre- and post-intervention.

Conclusions

This project showed that occupational health and safety and environmental protection are closely linked because the hazards share a common source in the production process. This intervention study was aimed at replacing hazard sources with safer and more environmentally sound alternatives. Any type of change in materials and work practices is likely to affect worker health and safety. When these changes are implemented, whether for pollution prevention or through technological improvements, worker health and safety must be evaluated as part of the change process. On balance, all of the interventions improved worker health and safety. In addition, it was found that if occupational health and safety precautions were better applied, environmental emissions would generally be reduced. For example, a well-managed chemical hygiene plan in a clinical laboratory reduces chemical discharges to the environment. However, only substitution permanently resolves both health and safety and environmental hazards.

Linking occupational to environmental issues was found to be an effective way to get hospitals to address occupational health and safety because most hospitals have in their mission statements a "good neighbor" clause, and being environmentally responsible meets this mission. The focus on alternatives is also seen as constructive to hospital managers compared to the conventional OSH "control" approach. To managers, the search for alternatives represents progress and innovation, even if the change process requires work. Alternatively, control of hazards represents an obstacle to progress and productivity, something that hospital managers feel they simply cannot afford, given the current economic pressures in the healthcare industry.

The strongest influence on a hospital deciding to make a change was whether another hospital had already successfully made the change. This was found for every intervention in the study. Due to this finding, it was decided that the dissemination of the study research on alternatives, methods for implementation of the intervention, and results, should first be on a website designed for hospital personnel and later be published in professional journals. Hospital personnel wanted to know that other hospitals had already tried the intervention, and then they wanted to contact the person who tried it. They trust professional contacts and consultation over publications. This was especially true for physicians.

Our research documented that using toxic substances in the workplace is costly. For example, in the formaldehyde intervention in pathology, the major costs included:

- The water resource authority fines for discharging excess formaldehyde (>$75,000)
- The cost of required water and air monitoring required to insure compliance with environmental (EPA, water resource authority) and occupational (OSHA Formaldehyde) standards.
- Hazardous waste disposal costs paid to an outside contractor to remove the liquid effluent containing formaldehyde (approximately $70,000 in the last year. Similar annual costs expected thereafter, if formaldehyde is not reduced.)
- Engineering and plumbing costs to control the liquid formaldehyde (approximately $40,000 initial investment with annual maintenance thereafter.)

- Laboratory fume hood operation and maintenance costs to control airborne formaldehyde emissions in the lab.
- Personnel time associated with hazardous chemical management programs, employee training, and hazard communication related to the storage, handling, disposal, and emergency response in the event of a spill or fire.
- The cost of implementing selected portions of the OSHA respiratory protection standard facilities workers were required to wear a respirator during chemical waste transfer).
- Potentially high costs resulting from spill clean up.

The interventions showed that there was a strong preference for another chemical that could be "dropped into"an existing process, rather than equipment or work organization changes that involved reorganization of work processes and jobs. For example, for the intervention to change formaldehyde use in pathology in hospital 3, several alternatives were identified by the intervention study team. Two candidates were: 1) involved substituting formaldehyde with a less toxic aldehyde (glyoxal, a dialdehyde). The glyoxal was essentially a "drop-in" replacement, in that it was used in a manner similar to formaldehyde and did not require re-organizing the work process or associated work practices and equipment; and 2) microwave tissue fixation process and equipment, the intervention preferred by the investigators because it replaced formaldehyde thus eliminating occupational and environmental chemical exposures.

When there was a hospital employee champion for implementing an intervention, initial complications involved with introducing any process change could be overcome fairly easily. But when there was no champion, it was difficult to overcome obstacles in the change process. In hospitals 1 and 2 for example, there were positively motivated "champions" of the xylene intervention in the histology departments. But in Hospital 3, the lab manager, our study contact, agreed to participate in the intervention to avoid environmental fines, which she felt to be unreasonable. Although she endorsed the intervention, she did not feel real ownership and consequently the intervention was much more difficult to implement and took longer than the xylene histology intervention in hospitals 1 and 2.

Finally, the experience with the chemical interventions highlighted the need for better alternatives. For example, formaldehyde and glutaraldehyde were replaced with less toxic aldehydes. It would have been preferable to replace fixative chemicals entirely or switch to a different and less toxic chemical class. The methods described here can identify where innovative research and development of new materials and products are needed and can be used to motivate hospital staff to seek safer alternatives from their product suppliers.

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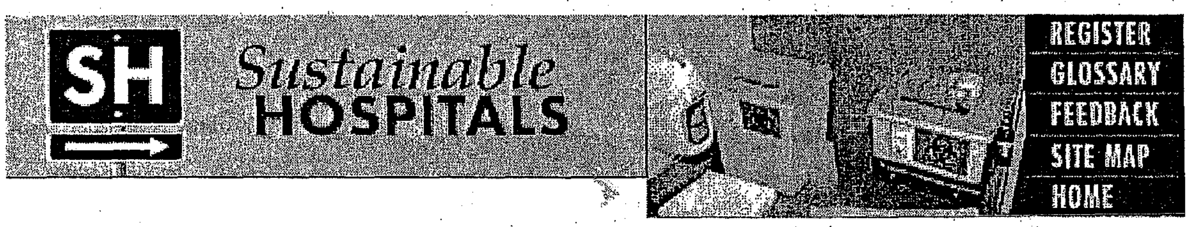
Appendix A

Case Study:
Reducing Formaldehyde Use in a Hospital Clinical Laboratory



DRAFT

Case study: Reducing formaldehyde use in a hospital clinical laboratory

Purpose

This case study provides a model for hospital clinical laboratories to replace formaldehyde with less toxic materials. The case study shows how one hospital histology lab used a project team to assess where formaldehyde was used, find and evaluate alternatives, and introduce a formaldehyde alternative.

Case background and objectives

A 200 bed teaching hospital in the Boston area was cited for repeated violations of the formaldehyde limit in its hospital wastewater. The hospital receives its water and sewer services from the Massachusetts Water Resource Authority (MWRA) and is subject to MWRA Sewer Rules and Regulations for industrial dischargers. (Hyperlink to MWRA website http://www.mwra.state.ma.us/) It was found that the formaldehyde was coming from the sinks in the hospital clinical laboratories and being discharged to the sewer system. The hospital was able to trace the formaldehyde to the labs by sampling effluent at a port connected directly to the laboratories, prior to the lab wastewater being mixed with other areas of the hospital. The clinical laboratories included hematology, microbiology, chemistry, cytology, and pathology-histology.

The hospital's initial response to the formaldehyde violations was to remove all known formaldehyde sources from the sewer line, including:

- most of the laboratory analytic devices were taken off the sewer system by re-piping to 55-gallon drums that were disposed of as hazardous waste.
- a large collection tank was installed to collect all of the pathology rinse water, which contained a considerable amount of formaldehyde, for collection and disposal as hazardous waste.

This resulted in the annual collection and disposal of approximately 8,000 gallons of formaldehyde-containing hazardous waste. In spite of these actions, the laboratories continued to exhibit formaldehyde in the effluent that went to the sewer. Hospital personnel and their plumbing consultant were unable to identify how the formaldehyde was getting into the sewer system and the hospital risked another violation of its sewer permit and a costly fine.

The hospital and MWRA worked to find a timely and mutually acceptable resolution of the formaldehyde problem. Part of the resolution was

(Methods) Step 1. Defining the problem

The main focus of this step was to identify where formaldehyde was being used and how it might continue to reach the sewer system even after the plumbing controls had been implemented. The "how" portion of this step considered not only the physical aspects (e.g. plumbing, chemicals used) but also took into consideration "soft" contributions such as work practices, training, maintenance, and management programs. The SHP conducted the following assessments:

- Mapping of the processes performed in each functional area of the labs to identify the overall work flow and all equipment associated with each process step
- Mapping of the materials used in each process and the types of waste streams produced (e.g. liquid, air, solid, hazardous) and their destination (e.g. sink-sewer, hazardous waste drums, medically regulated biological waste, regular trash)
- Analysis of the tasks and work practices associated with each process step
- Review of existing environmental and occupational health and safety monitoring data and applicable regulations, and
- Review of management programs, policies and procedures for the use and handling of formaldehyde and other chemicals and for disposal of waste streams containing formaldehyde. Whenever relevant, the review compared the activities with applicable industry standards (e.g. Joint Commission on Accreditation of Health care Organizations - JCAHO; College of American Pathologists - CAP; National Fire Protection Association - NFPA) and regulations for environmental, occupational health and safety, and public safety practices.
- Review of financial data to account for the costs associated with using formaldehyde in the histology lab.

With the data in hand, the project team could then describe the formaldehyde situation in a formal "problem statement". The problem statement clearly defined the current situation, the impact of the problem and the desired state. (It did not include causes or solutions). Using the problem statement as a tool served several purposes:

- gain agreement as to what the real problem was,
- provide a clear explanation of the problem to people outside the team,
- demonstrate the adverse effects of the problem,
- provide a baseline that would be used to assess whether a potential solution satisfactorily addressed the problem, and
- make clear the criteria for deeming the problem solved.

Click here for more information on establishing a project team and problem statement.

(Methods) Step 2. Identifying Potential Corrective Actions

The problem statement and assessment completed in the first step were used by the team to prioritize the areas for abating formaldehyde. Once this prioritization was completed, information about alternative products and practices was sought in several ways:

- by doing a web search and reviewing the scientific literature (i.e. publications and journal articles)
- by seeking information and literature from manufacturers about their formaldehyde free fixatives. This was done by contacting manufacturers of currently used (formaldehyde containing) products and by searching the internet for other fixative manufacturers

After the pilot established that the alternative satisfactorily met the criteria, team members presented the results of the pilot to the vice president of the hospital and proposed that the alternative be phased in for full scale use. A plan was developed for continued evaluation over the next few months.

If the outcome of the pilot had not met the criteria specified by the team, the plan was to repeat the exercise of reviewing possible alternatives and piloting another approach or a modification of the initial pilot.

Results

(Results) Step 1. Defining the problem

The process and material mapping, shown in Figure 2 (MAH Pathology Process Steps), Figure 3 (MAH Histology Process Steps), Figure 4 (MAH Pathology Inputs/Outputs), and Figure 5 (MAH Histology Inputs/Outputs), identified the flow of work and materials in the clinical laboratories. Despite the plumbing/engineering controls installed by the hospital, this comprehensive, systematic assessment of formaldehyde use identified several ways that the formaldehyde was still being discharged directly to the sewer system. These included:

- Waste from some analyzers tested positive for formaldehyde, even though chemical solutions and cleaning products used did not have formaldehyde listed as a component. This reflected two possibilities: 1) if the formaldehyde level is lower than 1% the manufacturer is not required to list it on the MSDS or 2) formaldehyde may have been generated in the process. (Unfortunately 1% formaldehyde (10,000 ppm) can be well above some regulated wastewater limits). The waste from these analyzers was routinely collected as a hazardous waste, but the residue from weekly maintenance of one analyzer was poured into the sink.
- Equipment that used or generated formaldehyde was still discharged to the sewer. This reflected two shortcomings: there were no MSDSs available and the discharge composition was not analyzed. The equipment tended to be used intermittently and often on non-standard work shifts, such as weekends. This resulted in intermittent discharges that could explain formaldehyde spikes in the effluent.
- Some workers or contractors were unaware of products containing formaldehyde and were observed pouring these down the sink in the clinical laboratory, especially during cleaning and maintenance tasks. (In this case, the MSDS clearly called out the presence of formaldehyde).

In addition, the assessment found that there were several occupational safety and health (OSH) standards and guidelines related to formaldehyde and other chemical usage that, had they been implemented more effectively, would likely have controlled the environmental formaldehyde problem. These OSH standards and guidelines, shown in table 3, cover work practices related to chemical storage, handling, monitoring, disposal, emergency response and worker training.

Table 3. OSH Standards and Guidelines

1. Chemical alternatives
2. Technological alternatives (equipment, process)
3. Recycling

A summary of the alternatives is shown in Tables 4a-c. Many of the alternatives were chemicals that could be used as a "drop-in" replacement for formaldehyde; that is, approximately the same amount of alternative chemical could be used following the same clinical procedures as with formaldehyde (Table 4a). One technological alternative (microwave fixation) was identified as well as a technological alternative in combination with a chemical (microwave plus a chemical fixative) (Table 4b). Bench top formaldehyde recycling equipment also was identified (Table 4c). While recycling does not eliminate the hazard at its source, it can reduce the total amount used in a lab.

Team members deemed that a key criterion was that the alternative be a "drop-in" chemical substitute, because it would:

a. require very few changes in the clinical lab procedures and work organization,
b. require no additional space, and
c. require no major capital expenditures.

In keeping with this criterion, the chemical alternatives were the ones selected for further consideration.

Three chemical alternatives were compared to formaldehyde, looking at the physical and chemical characteristics relevant to environmental and occupational health and safety (Table 5). The clinical lab manager and her team selected the alternative Glyo-fixx to pilot, based on the comparison in Table 5 and on information that other hospitals had implemented it successfully. (Of the chemical alternatives, "Glyo-fixx" was used most frequently by other hospitals). A review of the advantages and disadvantages of formalin versus Glyo-fixx is given in Table 6. Table 7 shows the amount and cost of the formaldehyde used in the histology lab compared to that of Glyo-Fixx.

(Results) Step 3. Piloting Likely Solutions

Over a four month period, six pathologists in the histology lab reviewed and compared the diagnostic quality of the slides preserved with Glyo-Fixx to slides preserved with formaldehyde. The most important criterion was good diagnostic quality because it was essential that the hospital maintain high quality patient care. The pathologists made the final determination as to whether Glyo-fixx was an acceptable tissue fixative.

All six pathologists read each slide, scored the slide as either "pass" or "fail" and recorded their subjective comments regarding the diagnostic quality of each slide. The pathologists discussed their findings with other histology staff and the clinical lab manager. Histology staff contributed important information related to the performance of Glyo-fixx during preparation of the slides. A sample data collection table is shown in Table 8.

During the first few trials the lab staff reported that the Glyo-fixx was acceptable, although not as easy to use as formaldehyde. As more experience was gained over 4 months, the histology lab staff became more adept at using Glyo-fixx and ultimately deemed it a favorable alternative.

Conclusions and Lessons Learned

1. Formaldehyde is widely used in hospital laboratories in spite of its occupational and environmental risks. Many hospitals are now becoming aware of the drawbacks and are seeking alternatives to formaldehyde containing products. The methods in this case study can be used as a model and guide for reducing formaldehyde expediently and in a cost effective manner.

2. The hospital in this case study initially attempted to control its discharge of formaldehyde by collecting laboratory effluents in drums, which were then removed as hazardous waste. This "end of pipe" solution failed for several reasons:
   - Unrecognized sources of formaldehyde continued to be poured into the sink, including formaldehyde-containing lab chemical solutions and cleaning products whose MSDSs did not list formaldehyde as a component.
   - Equipment that used or generated formaldehyde was still connected to the sewer. In these instances, MSDSs were unavailable and the waste had not been analyzed for formaldehyde. Since this equipment tended to be used intermittently, it could explain formaldehyde spikes in the lab wastewater.
   - Workers or contractors unaware of product composition continued to pour formaldehyde-containing liquids down the sink, especially during cleaning and maintenance tasks. The MSDSs clearly showed the presence of formaldehyde.

3. The "end of pipe" approach to pollution prevention, such as drumming the formaldehyde waste, incurs higher costs and is less effective than eliminating the hazard at the source. Source reduction, i.e. reducing or eliminating the hazard as it comes in the door, is the best control because it is forgiving of human error and equipment failure. End-of-pipe control typically involves collecting waste and trying to clean, filter, alter, or segregate the waste for disposal as hazardous waste. The drawbacks of end-of-pipe approaches include:
   - end-of-pipe controls incur high ongoing costs that do not add lasting value or contribute to the productivity of the hospital
   - removing hazardous waste is costly, not only in disposal cost but also in personnel time and record management
   - there are hidden costs that include personal protective equipment, spill containment, testing and monitoring, worker training, disposal, and potential fines or liabilities for uncontrolled releases.

   In contrast, source reduction employs the hospital's resources in a way that prevents problems from occurring in the first place and allows staff to focus on the jobs for which they were hired.

4. Source reduction of formaldehyde-containing lab products is challenging, but this case study provides key resources to get started or to enhance existing efforts. The barriers include:
   - information about environmentally-sound, healthy and safe alternative products and work practices is initially difficult to find
   - good criteria for evaluating the impact of alternatives on quality, and environmental health and safety are not readily available.
   - procedures for evaluating and introducing new products and practices need to be learned
   - hospitals do not generally have a culture of continuous improvement, a value that comes from senior management down, that facilitates the process of improving environmental and occupational health practices and helps workers through the inevitable problems.

   To overcome these barriers, hospitals must utilize and, by doing so, help develop the existing resources for change:
   - Use case studies such as this one to guide your efforts.
   - Visit the Sustainable Hospitals website, http://www.sustainablehospitals.org, for a listing of alternatives.
   - Network with hospitals that are considering or have made similar changes. Research shows that practitioners will be receptive

	allows one to search for human health effects from exposure to various substances in the environment.
	http://chemfinder.cambridgesoft.com This website allows one to enter a chemical name and find all physical and chemical properties, MSDSs, and pertinent regulations.
	http://www.chemrest.com This website by Best Glove, a manufacturer of industrial gloves, provides assistance in selecting gloves with the appropriate protection for a particular chemical.
Alternative Product & Process Information	http://www.sustainablehospitals.org The Sustainable Hospitals Project (SHP) website provides technical information and tables of alternative products to help hospital reduce occupational and environmental hazards.
	http://www.histosearch.com/histonet.html This is an online discussion group for clinical laboratory practioners.

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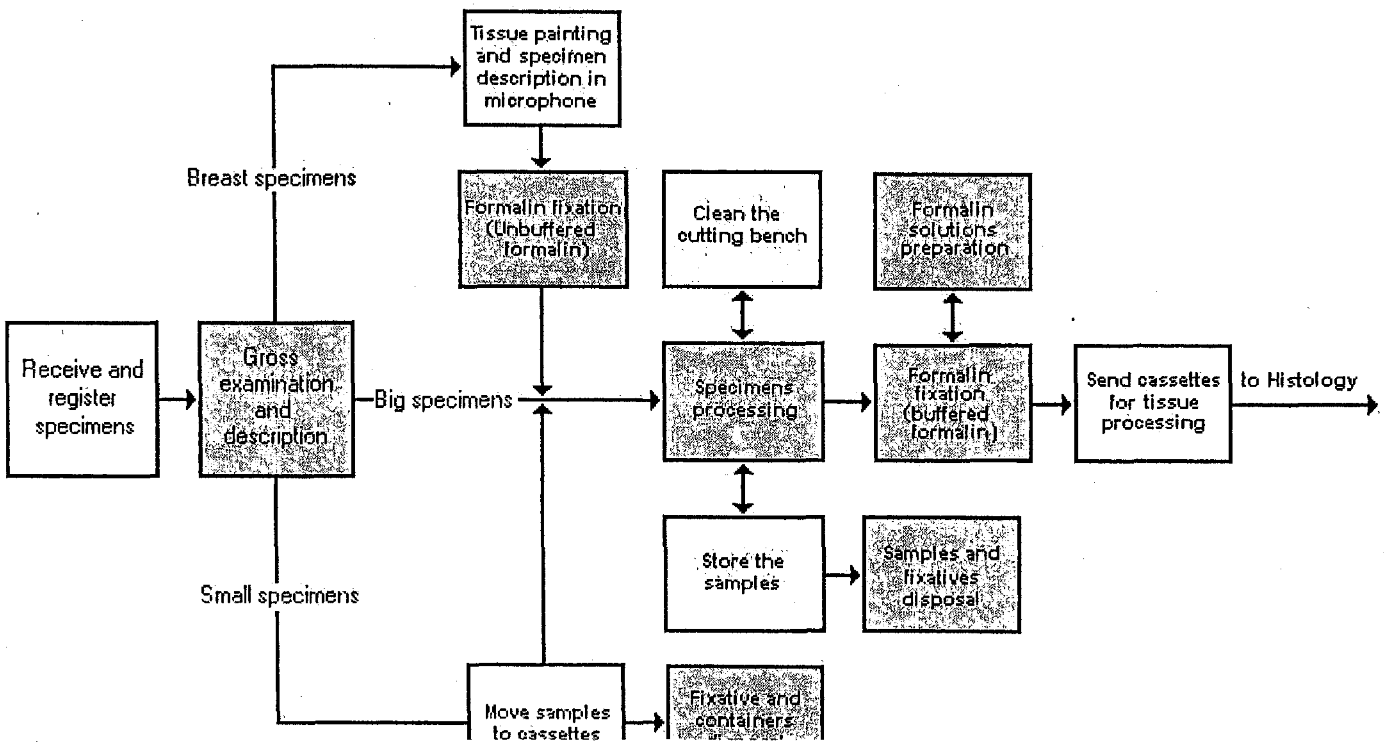
Figure 2. MAH Pathology Process Steps



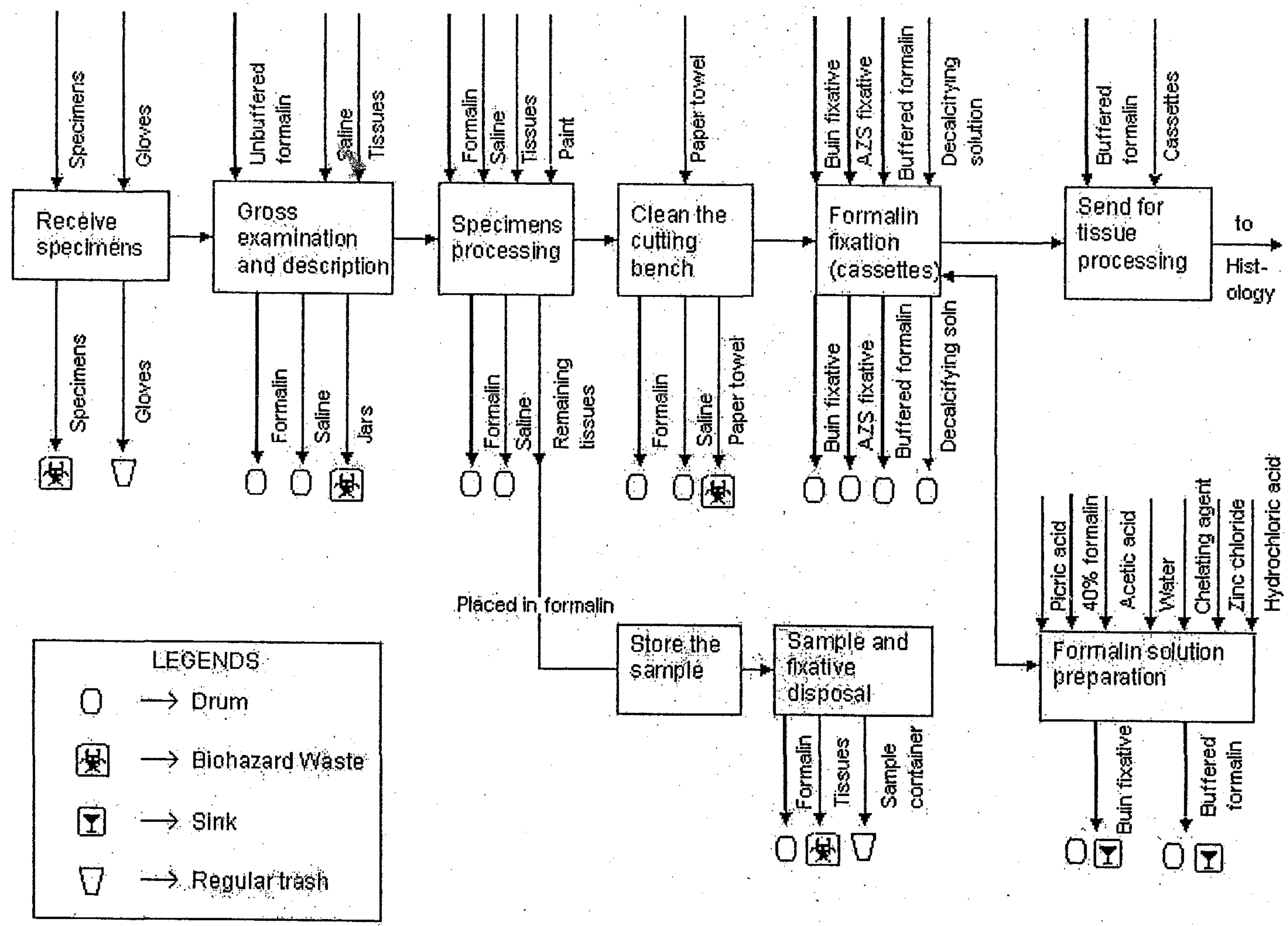


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Figure 5. MAH Histology Inputs/Outputs

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Table 4a. Chemical Alternatives

Alternative & Supplier	Advantages	Disadvantages
Glyo-Fixx Contains: ethanol, glyoxal, buffer, water Thermo Shandon 800-245-6212 x4026	Glyoxal has a low vapor pressure. It is not a sensitizer and not a carcinogen. Can be disposed in the drain. Reduces disposal costs. Comparable to neutral buffered formalin.	Glyoxal causes irritation of the skin and eyes. There are not enough data on glyoxal toxicity and impact on environment and human health. This product cannot preserve red blood cells. Price per gallon of glyoxal is higher than formalin
Prefer Contains: Glyoxal as active ingredient Anatech, LTD 1-800-anatech	Performs better than formalin. Antigenic sites and DNA are unaltered. Fix all types of specimen. (Same as glyofixx)	Tissues cannot be stored longer than two weeks. Prefer is more expensive than formalin.
NoToXhisto Contains: Aqueous alcoholic solution with other hydroxlated compounds Scientific Device Laboratory 1-847-803-9594 or scidev@aol.com	Not carcinogenic and is exempt from EPA regulations. All sizes of tissues can be fixed in this product. Tests have shown better results than formalin. Price is comparable to formalin. No change of existing procedures needed and ready to use.	None listed on the manufacturer's information.
HistoFix Contains: methanol 5% Trend Scientific, Inc 1-800-328-3949	Contains no aldehydes and mercury. Comparable with formalin. Reduces disposal costs. Preserves immunoreactivity for immunohistochemical procedures.	None listed on the manufacturer's information.

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Table 4b. Technological Alternatives

Alternative & Supplier	Advantages	Disadvantages
Microwave stabilization of unfixed tissues. Equipment: H-2800 microwave oven. Energy Beam Sciences Tel:1-800-992-9037	No need for chemicals. Eliminate exposure to toxic chemicals. Fixation cannot extract important component of the tissues, whereas during formaldehyde fixation up to 40% of protein can be lost	Shrinkage, sponginess of tissue and breakdown of red cells.

Fixative Solutions	**Formalin**[a]	**Glyo-Fixx**[a]	**NoToXhisto**[b]	**Histo-Fixx**[c]
Ingredients	**Formaldehyde 37%** Methanol 12-15%	Ethanol 20% **Glyoxal 5%** 2-Propanol 1% Methanol 1%	Alcoholic solutions + hydroxlated compounds	Methanol 5%
OSHA: PEL (TWA)	F - 0.75 ppm M - 200 ppm	E - 1000 ppm G - None P - 400 ppm M - 200 ppm	None listed	200 ppm
ACGIH: TLV (TWA)	F - 0.30 ppm M - 200 ppm	E - 1000 ppm G - None P - 400 ppm M - 200 ppm	None listed	200 ppm
NIOSH: REL	F - 0.016 ppm M - 200 ppm	E - 1000 ppm G - None P - 400 ppm M - 200 ppm	None listed	200 ppm
Vapor pressure	67-88mm Hg at 20°C	Glyoxal: Very low	Not applicable	92mm Hg at 20°C
Water solubility	Complete	Complete	Soluble	Complete
pH	2.8-4.0	3.75-4.25	N/A	2.0
Boiling point	214°F	185-312°F	165°F	212°F
Flash point	185°F	104°F	118°F	340°F
Flammability	(OSHA) Class II	Non-flammable: glyoxal Flammable: alcohols	None known	Non-flammable
NFPA	2,2,1	N/A	N/A	1,3,0
Health effects	Carcinogen and sensitizer	Irritant to skin, eyes and respiratory system	None known in final concentration	Irritant to respiratory system, skin and eyes
Odor	Yes: Pungent odor at low concentrations	Yes: Mild alcoholic	None	Yes: Mild at 100 ppm
Ecological and	High acute toxicity on	Rapidly biodegradable	N/A	Rapidly biodegrade in

	Formaldehyde	Glyo-Fixx
Cost ($/gal)	5.62	20.02
Use Before Change (gal/yr)	226	
Use After Change (gal/yr)	0	>226
Waste Before Change (gal/yr)	8,000*	
Waste After Change (gal/yr)	0	0
Waste Costs Before Change ($/yr)	18,936.22	
Waste Costs After Change ($/yr)		0

Note: The disposal of the hazardous waste, which is stored in containers under the histology lab fume hoods, costs on average $1,114.00/month.
The disposal of the hazardous waste from the cutting bench waste container: $2,186.63/month average cost.
Waste collected ~ 6 weeks.
* Formaldehyde plus other liquids.

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Table 8. Sample Table for the Collection of Pilot Study Data
Formaldehyde Alternative (Glyo-Fixx) used in trials with conventional tissue processing and staining chemical (xylene)

DATE:______

Tissue Type	Trial	Fixation/ Tissue Processing Chemicals Used[a]	Tissue Processing Chemicals Used[a]	Staining Chemicals Used	Sample Quality Description[b]	Pass	Fail
Tonsil	1	Glyo-Fixx	Xylene	Xylene	Fine, nice, good, like formalin	6	
Placenta	2	Glyo-Fixx	Xylene	Xylene	Grayish hue, pale	3	3
Thyroid	3	Glyo-Fixx	Xylene	Xylene	Good, bright pink colloid, well-cut	6	
Adipose	4	Glyo-Fixx	Xylene	Xylene	Poorly fixed, slightly pale	5	1

	Skills & Characteristics*					
Potential Team Member	**Good communicator**	**Knows plumbing & sampling**	**Has data on effluent testing**	**Knows lab chemicals & processes**	**Able to identify alternatives**	**Can effect change**
Margaret			X			
Tom	X			X		
Ani	X	X			X	
Catherine	X					X

* Examples of skills and characteristics:
Good communicator
Knows the lab plumbing system and effluent sampling system
Has timely data on effluent testing results
Knows chemicals, reagents, fixatives and processes used in lab
Able to identify formaldehyde-containing products
Has authority to effect organizational change
Knows laboratory staff functions
Knows laboratory management functions
Knows laboratory housekeeping and maintenance functions

Problem Statement ("A problem well stated is half solved")

A formal problem statement clearly spell out a problem, its impact, and the desired state. It does not include causes or solutions.

Why bother?

- A problem statement helps a team or organization gain consensus on what the problem is. Lack of agreement can lead to different expectations for problem-solving and even to efforts that contradict each other. In the pilot study, the problem statement, the basic steps for problem-solving, and the timetable were part of a detailed legal agreement between the hospital and the MWRA.
- It provides a clear explanation of the problem to people outside the team
- It demonstrates the adverse effects of the problem; and benefits of solving it
- It defines how the team will know when the problem is solved

The problem statement has 3 parts:

Appendix B

Mercury Reduction in the Mount Auburn Clinical Laboratories

MERCURY REDUCTION IN THE MOUNT AUBURN HOSPITAL CLINICAL LABORATORIES

PURPOSE

This case study describes the investigation of sources of mercury in the clinical laboratories of a moderately-sized, urban teaching hospital. The effort was prompted by an unintended discharge of mercury into the sewer, via laboratory waste water. The goal of this work was to identify sources of mercury and help the hospital develop a plan to prevent mercury from being discharged in waste water. Recommendations for mercury reduction are given along with the hospital's mercury reduction policy for the clinical laboratories.

INTRODUCTION

The Massachusetts Water Resources Authority (MWRA) is a Publicly-Owned Treatment Works (POTW) that provides water and sewer services to the Greater Boston area. Industrial users of the sewer system, including hospitals, are prohibited from discharging mercury into the sewer. MWRA has established a discharge limitation of 1 microgram of mercury per liter of waste water (μg/l), as measured in waste water samples. That is, a waste water sample found to have $\geq$ 1 μg/l of mercury will prompt MWRA to take regulatory action against the facility. (Note: 1 μg/l = 1 part per billion or 1 ppb). In June 2001 the MWRA issued a Notice of Noncompliance and Order to Take Corrective Action to the Mount Auburn Hospital (MAH) in Cambridge, MA for mercury in their effluent. Records indicated that MAH effluent tested at 8 ppb of mercury, well above the 1 ppb discharge limitation..

Because of the piping and location of waste water sampling ports, it was evident that the mercury-laden waste water was coming solely from the MAH clinical laboratories. The waste water pipe and its sampling port were directly downstream from the hospital clinical laboratories and were completely separate from waste water piping in other areas of the hospital. The hospital clinical laboratories include hematology, microbiology, chemistry, cytology, and pathology-histology.

As part of negotiations between MAH and the MWRA, the Sustainable Hospitals Project (SHP) of the Lowell Center for Sustainable Production at the University of Massachusetts Lowell was asked to assist the hospital to identify and suggest corrective action for possible sources of mercury in the clinical laboratories. The SHP provides technical support to assist hospitals in developing pollution prevention initiatives aimed at reducing materials, products, and work practices with potentially harmful effects on human health and the environment.

BACKGROUND

Mercury is an extremely hazardous metal that can cause severe environmental damage and human health effects at very low levels. At room temperature, mercury is a silvery liquid that readily evaporates. It is deemed a persistent bioaccumulative toxin (PBT). This means that mercury doesn't hospital labs and potential alternatives and control practices.

It was known that each of these approaches had shortcomings that would allow mercury to go unrecognized. However multiple avenues of investigation increased the likelihood of revealing sources of mercury in the hospital laboratories.

RESULTS

- Policy – At the outset, the hospital did not have an overall mercury policy nor did the clinical labs have a specific mercury reduction or elimination plan. Hence this was not an avenue for identifying sources of mercury. Most staff in the clinical labs were under the impression that mercury thermometers and other mercury devices had been replaced with non-mercury alternatives per informal agreement.
- Process Evaluation – The process evaluation yielded a list of reagents, chemicals, and cleaning products used in the laboratories. The laboratory staff members were very helpful in identifying not only routine operations, but also described infrequent procedures and maintenance activities. The list of products was compared with a list of known mercury-containing products, obtained via the web and literature search, and this identified some mercury containing products used in the labs. Recommendations for finding mercury has been summarized in a separate SHP fact sheet, "Removing Mercury From Hospital Labs" Reference: (available online at http://www.sustainablehospitals.org/HTMLSrc/IP_mercury_factsheets.html)
- MSDS Review – A review of available MSDSs failed to identify the presence of mercury. Several shortcomings were readily apparent with this approach:
  1. Of the products used in the labs, some MSDSs were not readily available for review.
  2. The likelihood of finding mercury listed on an MSDS sheet is very small. Manufacturers are only required to list ingredients that are health hazards and which comprise $\geq 1\%$ or more of the chemical or reagent mixture (0.1% for carcinogens). Unfortunately, for mercury, 1% (10,000 ppm or 10 ppb) is well above the MWRA mercury limit.
- Physical Inspection - During the process mapping and inspection of the lab, it was noted that mercury thermometers were being used or were stored in several areas of the labs. Employee interviews suggested that an attempt had been made by staff in the clinical labs to buy only mercury-free thermometers to be used in the lab refrigerators, however a telephone call to the manufacturer (Streck Laboratories, Inc.) revealed that it is necessary for the purchaser to specify that only mercury-free thermometers may be included in their order. Otherwise it is possible that a mercury thermometer could be substituted.
- Literature and Web Search – The search showed that there is a wealth of information available on mercury products, alternatives, and health effects. A list of resources used is included at the end of the report.

LESSONS LEARNED AND RECOMMENDATIONS

Three areas were suggested for immediate action. It was recommended that:

- Mercury thermometers be removed from the laboratories wherever possible
- A mercury reduction policy be established by the hospital
- A plan to implement the mercury reduction policy be developed and implemented for the clinical laboratories.

strong mercury control effort:

- Mercury reduction coordinator for the clinical laboratories - The reduction and eventual elimination of mercury in the clinical labs involves the coordination of many activities including purchasing, assessment of materials and work practices, spill control and clean up, waste disposal, and staff training. It is recommended that the lab assign a mercury reduction coordinator to oversee these activities. This responsibility could be combined with those of the Chemical Hygiene Plan Administrator.
- Identify mercury-containing lab reagents and other products –A list of mercury containing products will allow the department to recognize where mercury exists, as well as its concentration and relative volume, to prioritize its mercury reduction efforts.
- Establish a plan for replacing mercury-containing products – Using the list of mercury containing products as a basis, the mercury plan will state the priority and timeline for replacing or reducing its use of mercury containing products. There will be different factors considered in the plan; for example priority and target date may reflect ease of change (e.g. thermometers), urgency (e.g. likelihood of a spill or inadvertent drain disposal), or even professional interest (e.g. a colleague at another hospital has recommended an alternative product).
- Develop procedures for purchasing mercury-free reagents and products - When new reagents and products are purchased for the lab, the lab representative and purchasing agent should routinely ask the manufacturer whether the product contains mercury, even if it is not reported on the MSDS or in technical literature. This effort can be aided by strong purchasing language that specifies the customer's requirement for mercury-free products and how the vendor will meet the requirement, for example by providing a Certificate of Analysis for a reagent showing that analytical testing demonstrated no detectable mercury.
- Procedures for proper control of mercury containing products – It is likely that some mercury-containing reagents and products will be used for the foreseeable future. Therefore the policy should spell out controls that will ensure safe and appropriate handling of mercury-containing products. This includes how workers are educated and reminded about which products contain mercury, how to properly handle and dispose of the products, how to perform maintenance and repairs on equipment using mercury reagents or components, and how to respond to a mercury spill or release.

Based on this recommendation, the Clinical Laboratories developed a mercury reduction plan that is included in Appendix A.

Although it is not specific to mercury, the investigation revealed that the laboratory needs to obtain a complete set of material safety data sheets (MSDSs) for reagents, chemical, and other products such as cleaning and disinfecting agents used in the labs. This is required by the OSHA Hazard Communication Standard. Having readily accessible MSDSs will also assist the lab in managing the environmental impact of the materials used and evaluating the relative impact of new products. Obtaining and maintaining a complete set of MSDSs can be difficult; although manufacturers are required to provide an MSDS for their products, they do not always do so. When reagents and other products arrive in the labs from the receiving area of the hospital without an MSDS, it is very time-consuming for lab staff to track down an MSDS. It is recommended that purchasing policies require that the vendor submit an MSDS prior to the evaluation or delivery of new products and the MSDS should be provided to the clinical labs in advance of product or sample delivery.

Hospitals for a Healthy Environment (H2E) website:
http://h2e-online.org/pubs/mercurywaste.pdf
Hospitals for a Healthy Environment (H2E) is a collaborative effort sponsored by the Environmental Protection Agency (EPA), American Hospitals Association (AHA), American Nurses Association (ANA), and Health Care Without Harm (HCWH). The H2E website provides tools for hospitals, including best practices and model plans for waste management and reduction. The H2E website address above connects directly to H2E's comprehensive "Mercury Waste Virtual Elimination Model Plan."

The MASCO Mercury Workgroup Site:
http://www.masco.org/mercury
This site includes a comprehensive Mercury Management Guidebook (under "Phase II Reports") to help hospitals understand the process of identifying, reducing, and eliminating sources of mercury; provide information on methods for monitoring and treating mercury discharges; and present case studies on mercury sources and successful control programs. The Guidebook is the outcome of a joint effort by 28 Boston hospitals and the Massachusetts Water Resource Authority (MWRA).

Minnesota Technical Assistance Program
http://www.mntap.umn.edu/health/GPOletter.pdf
This link contains a sample letter for a hospital to request that its Group Purchasing Organization (GPO) identify products on contract that contain mercury and PVC and to supply less toxic products.

http://www.mntap.umn.edu/A-ZWastes/fs13-g70.htm
This fact sheet describes "Questions for Your Supplier When Changing Brands or Products".

The Department of Veterans Affairs, Edith Nourse Rogers Memorial Veterans Hospital,
200 Springs Road, Bedford, MA 01730
Supplemental Environmental Project: Mercury Reduction Program
As part of an agreement with the Massachusetts Department of Environmental Protection, the Edith Nourse Rogers Memorial Veterans Hospital in Bedford, MA developed and conducted a hospital-wide mercury reduction project with two goals:

- to facilitate the elimination of mercury and products containing mercury from the hospital's waste stream within one year, and
- to establish a model pilot program that will qualify as a Best Practice for use by other hospitals on a national level.

The mercury reduction program has been compiled in a manual that includes samples of employee training materials, hospital policies, a mercury inventory and minutes of the meetings of the mercury reduction challenge committee. This practical guide for hospital administrators is available by writing to the Environmental Care Specialist at the veterans hospital address given above or by contacting the Massachusetts Department of Environmental Protection, Metropolitan Boston – Northeast Regional Office, 205A Lowell Street, Wilmington, MA 01887.

Appendix A. Clinical Laboratories Mercury Reduction Plan

MOUNT AUBURN HOSPITAL – DEPARTMENT OF PATHOLOGY
CAMBRIDGE, MA 02238

MERCURY REDUCTION PLAN

PURPOSE:

The purpose of this plan is to identify the means by which the Clinical Laboratory will meet the Hospital's policy to reduce and eventually ban the use of mercury and mercury containing products at the hospital.

SCOPE:

This plan will apply to all Clinical Laboratory sections.

BACKGROUND:

Mercury is a toxic substance and keeping it out of our water and atmosphere
Is critical to our health and safety. Humans are exposed to Mercury primarily through ingestion of fish that contain Mercury. By eliminating Mercury usage at the hospital we are preventing it from getting into the environment and our food supply.

STEPS TO BE TAKEN:

Purchasing:

Vendors will be asked to provide Material Safety Data Sheets (MSDSs) on all chemicals and reagent systems prior to purchase. Vendors will be asked to report reagents that may contain mercury at levels below those required for an MSDS. Justifications for the purchase of items and/or reagents containing mercury will be provided to the Laboratory Administrator and the Laboratory Medical Director before purchase is approved. It is assumed that the only basis for approval would be medical necessity and lack of an alternative. In an emergency supply situation, purchase of a mercury containing reagent may be approved by the Lab Administrator or the Medical Director.

Mercury Identification:

A complete set of Material Safety Data Sheets will be maintained in the clinical laboratory to assist in the identification of reagents and chemicals that contain mercury. The Laboratory Administrator, as Laboratory Chemical Hygiene Officer, will require that an annual review of MSDS's for mercury containing chemicals is completed within each laboratory section. The Laboratory Administrator, Meetings have been held with the Clinical Laboratory staff to discuss the mercury issues at the hospital and reduction goals.

Written by: ____________________ Date: ________________

Approved by: ____________________ Date: ________________

Reviewed by: ____________________ Date: ________________

____________________ Date: ________________

____________________ Date: ________________

Appendix C

Pilot Study of Alternatives to the Use of Xylene in a Hospital Histology Laboratory

PILOT STUDY OF ALTERNATIVES TO THE USE OF XYLENE IN A HOSPITAL HISTOLOGY LABORATORY

Summary

This work focuses on identifying and evaluating alternatives to xylene used in a hospital histology lab as a solvent and clearing agent.

Hospitals in the Boston area are subject to very strict limits for the amount of xylene that may be discharged as effluent into the Massachusetts Water Resource Authority (MWRA) sewer system. The hospital in this case study exceeded the 1.0 milligrams per liter (mg/l) xylene limit and it was determined that the source of xylene was the hospital's histology laboratories. As part of the corrective actions agreed upon by the hospital and the MWRA, the Sustainable Hospitals Project (SHP) of the University of Massachusetts Lowell Center for Sustainable Production was asked to facilitate resolution of the problem. The SHP's expertise is in helping healthcare facilities reduce environmental and occupational hazards.

Although this action resulted from a violation of the hospital's sewer use permit, many hospitals are pursuing xylene alternatives because of xylene's adverse health and safety characteristics and to reduce hazardous waste disposal. High levels of exposure to xylene can cause renal failure, respiratory failure, hemorrhages, and necrosis of the brain, liver, kidneys, and heart. Other effects of high level exposure include agitation, headaches, light-headedness, eye irritation, dysphasia, shivering, and respiratory tract irritation (Harbison 1998) Chronic effects of workers exposed to xylene have shown decreased peripheral nerve function. (Ruijten, 2001) Xylene is also suspected of causing hearing loss and may result in other Central Nervous System symptoms. (Harbison, 1998).

The hospital histology laboratory and the SHP worked together to:

- Identify where xylene is used in the histology departments
- Identify potential alternatives for xylene applications in the histology departments
- Select and pilot two alternative (i.e. xylene-free) products
- Document the pilot process as a case study to be used as a model for other histology labs

Two alternatives were evaluated in the laboratory. Overall, the alternatives appear to be a favorable alternative to xylene. There were a few applications in which xylene was preferable, but even so the hospital was able to considerably reduce its xylene use. The product that was ultimately selected proved to be a "drop in" alternative; that is, the histology processes and conditions of use were unchanged and the alternative product was easily incorporated into the lab's operation. As with many new products, questions arose which made communication with the manufacturer's representative and other labs using the product instrumental to the product's acceptance and successful use.

2. Identify Xylene Alternatives

Chemicals that can be used to perform the functions of xylene in the histology laboratory but have less damaging effects on environmental health and safety were identified through a combination of the following methods: 1.) Literature and the internet search and review with respect to the use of xylene and alternative chemicals for histology operations. Identification of other hospital pilot studies and change processes evaluations; 2.) Preliminary studies at other histology laboratories at two other regional hospitals; 3.) Interviews conducted with manufacturers to discuss the applications and benefits of their alternative products; and 4.) Interviews with representatives from histology departments at other hospitals that have successfully implemented alternative chemicals to the use of xylene in their laboratories.

3. Pilot Two Alternative Products

Once the alternatives were identified, criteria were developed to determine which were the best xylene replacements. Methods were developed to pilot the xylene alternatives. This was done by:

1.) Reviewing the toxicological and environmental literature to identifying criteria for evaluating the alternatives and comparing them to xylene (i.e. Health effects, safety, environmental impacts, regulatory climate),

2.) Developing a pilot protocol based on a.) interviews with workers and pathologists and, b.) the review of laboratory management, pathology, and histology literature,

3.) Creating a data collection form to tabulate and consolidate the results of the pilot trials in a manner that could be used to compare the quality of the histological slides produced using xylene to those made with the xylene alternatives, and

4.) Implementing the pilot protocols to collect data for the chemical alternative comparisons table and documenting the pilot results in terms of diagnostic quality, environmental benefits, and economic benefits or consequences. Six department pathologists reviewed seven different tissue samples prepared using the alternative chemicals in a total of 22 different combinations to make a determination of diagnostic quality.

The chief pathologist instructed the assistant pathologist what samples to collect and then he communicated directly with the histology supervisor to assign which chemicals would be applied to these samples under what steps of the processes. As a result, the tissues were tested with various combinations of the alternative and xylene in different phases of the histology processes. Each of these combinations is identified on the data matrix, along with the quality results indication of the combinations.

During the evaluation the histology supervisor kept track of all the samples and processing chemical combinations. She was the only person in the lab who had the combination key.

The histology workers who processed the samples were also interviewed regarding the use of the alternative chemicals. They offered very helpful feedback on advantages and disadvantages of both new and old chemicals. The workers' comments are included in Table 1.

Table 1. Advantages and disadvantages of xylene and the alternatives in histology laboratory

	Advantages	Disadvantages
Xylene	• Known product • Produces high quality slides	• Noxious smell • High toxicity • Possible carcinogen • Classified as hazardous waste due to flammability and toxicity • Flammable • Causes dermatitis, penetrates skin
HistoSolve	• Less toxic • Produces high quality slides • Uses same procedures *Workers' feedback* • Acceptable consistency • Did not affect/compromise stain quality • Lack of offensive odor • No process modifications required, including amount of solvent process time, process temperature • Volume of waste and effluents unchanged	• Not well known • Classified as hazardous waste due to flammability • Slightly more expensive *Workers' feedback* • Incompatible with currently used cover slipping media due to bubbles in slides[1] • During cutting processes, it was noted that the tissues felt dry and brittle and it was hard to open wrinkled sections
ClearRite 3	• Less Toxic • Produces adequate quality slides • Uses same procedures *Workers' feedback* • Did not affect/compromise stain quality • Lack of offensive odor • No process modifications required, including amount of solvent, process time, process temperature • Volume of waste and effluents unchanged	• Not well known • Classified as hazardous waste due to flammability • Slightly more expensive *Workers' feedback* • Very oily • More difficult to work with than xylene. • Incompatible with currently used cover slipping media due to bubbles in slides[1] • During cutting processes it was noted that the tissues felt dry and brittle and it was hard to open wrinkled sections

The Chief Pathologist indicated that he felt that the Histosolve alternative to xylene was comparable to xylene in the preparation of histology slides. The Chief Pathologist's opinions regarding the alternatives concur with analyses of the pilot study data collected from all six pathologists

Environmental health and safety benefits

Histosolve is comprised of a variety of isoalkanes (C9-C12). These isoalkanes exclude hexane and are not associated with the significant nervous system and respiratory irritant health effects of hexane. These chemicals are typically less toxic to both humans and biota than xylene. They do not tend to persist in the environment due to their high vapor pressures and they do not tend to bind or attach to sedentary environmental media. Histosolve has the disadvantage that it must be disposed of as a hazardous waste. This is because of its flammability, not toxicity.

The health benefits to workers using Histosolve in place of xylene are first characterized by the lack of noxious odors in the lab. Many workers are irritated by the noxious fumes in the workplace, even at low levels. Histosolve has no bad odors and does not seem to illicit irritation responses in lab workers.

Recommendations

In this pilot, the data indicated that for a large number of tissues and tests, the change to Histosolve is acceptable and feasible. The primary criterion, acceptable diagnostic quality, was achieved with the exception of the coverslipping process.

Recommendations for future work

- *Recognize that this was a small sample size and there is need to proceed cautiously with larger sample sizes and longer times*
- *Establish ongoing discussions with manufacturer and other hospitals to identify and/or resolve routine questions*
- *Proceed cautiously to other tissues not covered in this pilot*

References

Harbison, R. D., Ed. (1998). Hamilton & Hardy's industrial toxicology. St. Louis, Mosby.

Ruijten, M. (2001) "Neurobehavioral effects of long-term exposure to xylene and mixed organic solvents in shipyard spray painters." Neurological Toxicology 15: 613-620

OMB No. 0925-0159
Approved for use through 12/31/8?

DEPARTMENT OF HEALTH AND HUMAN SERVICES

FINAL INVENTION STATEMENT AND CERTIFICATION

(FOR GRANT OR AWARD)

DHHS GRANT OR AWARD NO. 5 R01 OH03744-03

A. We hereby certify that, to the best of our knowledge and belief, all inventions are listed below which were conceived and/or first actually reduced to practice during the course of work under the above-referenced DHHS grant or award for the period 09/30/98 (original effective date) through 09/30/02 (date of termination).

B. **INVENTIONS** (Note: If no inventions have been made under the grant or award, insert the word "NONE" under Title below.)

NAME OF INVENTOR	TITLE OF INVENTION	DATE REPORTED TO DHHS
N O N E		

(Use continuation sheet if necessary)

C. **FIRST SIGNATURE** — The person responsible for the grant or award is required to sign (in ink). Sign in the block opposite the applicable type of grant or award.

TYPE OF GRANT OR AWARD	WHO MUST SIGN (title)	SIGNATURE
Research Grant	Principal Investigator or Project Director	Margaret M. Quinn
Health Services Grant	Director	
Research Career Program Award	Awardee	
All other types *(specify)*	Responsible Official	

D. **SECOND SIGNATURE** — This block **must** be signed by an official authorized to sign on behalf of the institution.

TITLE: Director of External Funding	NAME AND MAILING ADDRESS OF INSTITUTION: University of Massachusetts Lowell, 600 Suffolk Street, Lowell, MA 01854
TYPED NAME: Louise G. Griffin	
SIGNATURE:	DATE: 5/16/03

P.O. No.	Date	Dept ID	PS Project	Model No.	Serial No.	Tag No.	Tag Date	Item/Description	Accountable Person	Location	Cost	Cond	Verification	Remarks
79606	12/9/98			G6-350	0011937620	1	12/15/98	Gateway E-3200 350 Computer	Quinn, Magaret	*Home	$1,436.00	A-2	4/2/2001	*Margaret Quinn, 45 Shore Rd, Magnelia, MA 01930 (978) 525-3762
79606	12/9/98			700-069EV	17004A809713	2	12/15/98	17" Monitor for above computer	Quinn, Magaret	*Home	$0.00	A-2	4/2/2001	*Margaret Quinn, 45 Shore Rd, Magnelia, MA 01930 (978) 525-3762 - Cost of monitor incl in [illegible]
79606	12/9/98			G6-350	0011937621	3	12/15/98	Gateway E-3200 350 Computer	Quinn, Magaret	Kitson 200	$1,436.00	A-2	4/2/2001	
79606	12/9/98			700-069EV	17004A809716	4	12/15/98	17" Monitor for above computer	Quinn, Magaret	Kitson 200	$0.00	A-2	4/2/2001	Cost of monitor incl in above price

.try Date	Date	PO #	Vendor	Vendor #	Order Placement	Requisitioner	Project	LineReq	Est. Total	Comments
12/9/98	12/9/98	79606	Gateway 2000 Major Accounts	12615		Quinn /	16-08173-W	10 T	$2,872.00	(2) Gateway computers, 17" Monitor

OW