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Eliminating Mercury Use in Hospital Laboratories: A Step toward Zero Discharge

SYNOPSIS

In 1996, the Western Lake Superior Sanitary District initiated a Zero Discharge Project to work toward the goal of zero discharge of persistent toxic substances from its wastewater treatment plant. This multifaceted project focuses on mercury, lead, dioxin, polychlorinated biphenyls, and hexachlorbenzene. Here, the author describes a collaboration with local hospitals to eliminate the use of mercury-containing fixatives by histopathology laboratories. Three primary roadblocks to change were identified: (a) technicians' belief that pathologists would be resistant to change; (b) lack of time to research alternatives; (c) lack of awareness of the hospital's role in polluting the environment.

The Western Lake Superior Sanitary District (WLSSD) operates a wastewater treatment plant located on the St. Louis River, in Duluth, MN. It is the largest point source discharger to the St. Louis River and to the US's Lake Superior Basin.

In the late 1980s, mercury was detected in sediment sampling in the lower St. Louis River, MN. Shortly thereafter, in 1990, the International Joint Commission (IJC) issued its fifth biennial report, to the governments of the United States and Canada. The IJC is a binational federally appointed body charged with making recommendations on water quality under the 1978 Great Lakes Water Quality Agreement between the United States and Canada. In its 1990 report, the IJC concluded that "there is a threat to the health of our children emanating from our exposure to persistent toxic substances, even at low ambient levels."[1] One

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of the persistent toxic substances specifically cited was mercury. Mercury released into the environment accumulates in lake bottom sediments, where it is transformed into a more toxic form, methylmercury, which builds up in fish tissue. Wildlife and humans who eat fish may face health risks due to methylmercury contamination.

A specific recommendation in this report was that the US and Canadian governments "designate Lake Superior as a demonstration area where no point source discharge of any persistent toxic substance will be permitted." Two years later, in its sixth biennial report, the IJC strengthened its position by stating that "persistent toxic substances are too dangerous to the biosphere and to humans to permit their release in any quantity."[2]

Together, these signals were a call to action for WLSSD. In 1994, WLSSD institutionalized a commitment to the goal of zero discharge of persistent, bioaccumulative toxic substances within the Lake Superior Basin. In 1995, we initiated a Zero Discharge Project. The goal of the project is to identify and implement pollution prevention strategies for lead, PCBs, hexachlorobenzene, dioxin, and mercury. The hospital-based initiative discussed in the present article is one component of a multifaceted mercury pollution prevention program. We have also worked cooperatively with a local pulp and paper mill to reduce mercury discharges by approximately 98%. We have held mercury fever thermometer "round-ups" at local schools, worked closely with the dental community to develop best practices for management of mercury, partnered with the local university chemistry department to eliminate the use of mercury-containing equipment, and have been conducting an ongoing community-wide education campaign on mercury pollution prevention. In 1997, many of these activities were summarized in WLSSD's guidebook for wastewater treatment plant operators, *Blueprint for Mercury Elimination*.[3]

Mercury Discharge in Hospital Wastewater

The United States recognizes health care facilities, through medical waste incineration, as the fourth largest source of mercury emissions to the atmosphere.[4] Hospitals are also recognized as a source of mercury discharge to the wastewater system. The Palo Alto (California) Regional Water Quality Control Plant has determined that mercury contributions from hospitals represents 4% of its total mercury loading.[5] This estimate is within the range we identified in our investigations at two local hospitals.

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In the spring of 1996, two local hospitals in Duluth (Hospitals A and B) joined with WLSSD in a collaborative effort to minimize their discharges of mercury. As a first step, WLSSD staff took samples from all of the hospital wastewater discharge pipes and analyzed them for mercury.

Wastewater sampling technique. We performed composite wastewater sampling using an ISCO 3700 automatic sampler. With this sampler, both sequential and composite samples can be collected at user-defined time intervals. More than one discrete sample can be collected in a bottle, which allows for the collection of a series of small composite samples. The contents of the bottle then represent an average of the flow during the sample period. For this investigation, samples were composited to represent a 24-hour flow period. All samples were analyzed for mercury at WLSSD using a methodology based on Environmental Protection Agency–approved method 245.1, with a detection limit of 50 parts per trillion (ppt).

Sources of mercury. At Hospital A, the largest mercury concentrations were discovered in the discharge from the west plumbing sanitary system. This system included the discharge from the histopathology laboratory. Almost all mercury-containing equipment had already been removed from the hospital over the previous five to six years—Hospital A had been one of the first hospitals in the US to do so. While the hospital had no formal mercury elimination policy, hospital staff offered a variety of explanations as to why these changes had been made. These included recognition of mercury as a significant spill hazard, the ease and speed of use of electronic thermometers, and awareness through local media of mercury contamination in the St. Louis River in the early 1990s. Through a review of current hospital practices and a written survey, the histopathology lab was identified as the only "source" purposefully using mercury-containing compounds.

At Hospital B, a discharge pattern implicating the histopathology laboratory was also observed.

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Mercury-containing fixatives. WLSSD pollution prevention staff then worked closely with laboratory staff at both hospitals to become familiar with the processes in which mercury-containing compounds were used. The only product used in the two labs in which mercury was intentionally added was mercuric chloride fixative. Two commonly used formulations of mercuric chloride fixatives are Zenkers and B5 solution.

With the assistance of laboratory staff, we identified a variety of pathways through which mercury-containing fixatives could contaminate laboratory processes, the products of these processes, and ultimately wastestreams. We then sampled the wastes from these processes, analyzed them for mercury, and were able to identify and quantify mercury-contaminated discharges. As determined through the work with the two hospitals, and as detailed below, use of a mercury-containing fixative may ultimately lead to mercury contamination of:

- used mercury fixative and its precipitated supernatant;
- rinse waters and alcohol solutions;
- processor wastes;
- still bottoms (residue remaining from distillation and reuse of processor wastes);
- pigment removal waste;
- section shavings;
- tissue blocks.

In addition, any time mercury is purposefully used in a process, the possibility for accidental spillage exists. From a pollution prevention rather than a pollution control perspective, this fact alone should be sufficient to warrant an investigation into mercury-free alternatives.

In the two pathology labs, the first step in the preparation of bone and lymph tissue specimens required immersion of the tissue in B5. Once the tissue specimen was removed from the B5 fixative, it was rinsed in a common laboratory sink, either immediately or after an alcohol rinse. Rinse times ranged from 5 to 20 minutes under running water. We detected a 7 parts per billion (ppb) mercury concentration in the wastewater contained in a new sink trap. (Because the trap was new, the mercury was not from historical sources, such as a broken mercury thermometer, but a result of then-current laboratory practice.) We measured a mercury concentration of 120 parts per million (ppm) in a grab sample of the alcohol rinse, before discharge down a sink drain.

Hospital A. The two hospitals managed "used" B5 (B5 remaining after tissue immersion) in three different ways. At Hospital A, the laboratory collected excess B5 until a sizable volume (typically one liter) was obtained. Through pH adjustment, mercury salts were precipitated according to a procedure described in *Hazardous Materials in the Histopathology Laboratory*[6]; the solution was poured through filter paper (where the mercury salts were collected), and the remaining supernatant was discharged into the wastewater sewer. The filter paper was contained and managed appropriately as mercury-containing hazardous waste. WLSSD staff collected and analyzed 100-ml grab samples of the supernatant on two separate occasions; the concentrations of mercury were 25 ppm and 260 ppm.

A one-liter discharge of the mercury-containing supernatant at these concentrations would represent total effluent mercury concentrations of 0.331 ppm in one case and 3.44 ppm in the other, assuming an average daily flow of 20,000 gallons of wastewater per day at Hospital A. Because hospitals are not considered to be significant industrial users (a federal category of dischargers, defined by flow or potential to pollute or both), WLSSD has not yet decided to regulate hospi-

tals under its wastewater pretreatment ordinance. Industries under the pretreatment program are permitted a maximum discharge of 0.300 ppb of mercury daily. So while these mercury concentrations in the hospital wastewater may seem small, they exceed the mercury discharge limits set for industries under WLSSD's pretreatment program.

Hospital B. The laboratory at Hospital B is physically divided onto two floors. On one floor, laboratory staff appropriately captured and managed the used fixative as mercury-containing hazardous waste, yet one floor above, staff disposed of the excess B5 as infectious waste. Infectious waste is a unique wastestream that by its nature (and law) requires special handling procedures. These handling procedures increase disposal costs of the waste relative to regular solid waste (garbage) considerably. Because medical waste at this hospital is incinerated, the mercury ultimately ended up entering the environment as air emissions. Disposal of mercury-containing compounds in medical waste is not only illegal in Minnesota[7] but adds unnecessary costs to the hospital's management of infectious waste.

Tissue processor chemicals. After a tissue sample is fixed, it is placed in an automatic tissue processor. Both hospital laboratories use the same automated process. The tissue processor is a machine that automates the process of dehydrating a tissue sample and replacing it with paraffin. With paraffin embedded in the tissue, sectioning or slicing of the tissue is facilitated. The processor works by immersing the fixed tissue in a series of stations, or chemical baths. The first three stations in the tissue processor use concentrations of formalin, a formaldehyde water solution. At Hospital A, the formalin from the first two stations (or rinse containers) of the processor is recovered through distillation to allow recycling of the formalin. Contents of the third station are deposited into the wastewater sewer system on a weekly basis. We analyzed the discharge from the third station of the processor on two occasions, finding mercury concentrations of 350 ppb and 1040 ppb.

Distillation of waste formalin from the tissue processor produces both a recovered formalin product and liquid still bottoms. The pathology lab at Hospital A discharges the still bottoms into the wastewater sewer. Two analyses of the still bottoms revealed concentrations of 1230 ppb and >40,000 ppb of mercury. Although we did not examine all potential sources of mercury contamination to the formalin (such as potential mercury contamination of formaldehyde when it is manufactured), the mercuric chloride fixative was the only source in which mercury was purposefully used in the laboratory. Any other source of mercury to the formalin would be from background contamination. Based on the mercury concentrations detected, WLSSD staff concluded that mercury diffused from fixed tissues and contaminated the processor stations at Hospital A.

Because the laboratory procedures at the two hospitals were similar, we assumed a similar contamination pattern would be apparent at Hospital B. We did not sample or analyze processor wastes for mercury at Hospital B.

Other sources. After the tissue specimen has been removed from the processor and sectioned or sliced, the specimen is stained to optically differentiate the tissue constituents by variations in color. When tissue is fixed in mercuric chloride, artefact pigments containing mercury are deposited in the tissue and must be removed before the tissue specimen is stained. These pigments are removed through immersion in an iodine solution, rinsing in water, immersion in a sodium thiosulphate solution, and a final rinse in water. The practice at both hospitals was to discard all these solutions down the drain. We did not analyze the mercury concentration in any of these solutions, but mercury was very likely to have been found in all of them since it was contained in the mercury pigments removed through the process.

Mercury discharge to the environment may also occur when shavings and broken sections from mercury-fixed specimens are thrown either into the solid wastestream (garbage) or regulated medical wastestream. Histopathology labs at all hospitals retain their tissue blocks for an extended period, after which they are disposed of in the solid wastestream. Mercury-fixed specimens would then be introduced to the environment at landfills or during incineration.

MERCURY-FREE ALTERNATIVES

The goal of the WLSSD Zero Discharge Project was to work collaboratively with "partners" in the community to help us identify roadblocks and ways of achieving zero discharge. Hospitals A and B both agreed to become partners and work with us toward this goal. At that point, neither we nor hospital staff knew whether

A switch to mercury-free alternatives can save a hospital potential regulatory and disposal costs.

the goal was possible without compromising the ability of the hospitals to deliver quality care.

By the end of this analytical phase of the investigation, hospital staff and WLSSD staff were able to recognize the role mercury fixatives played in mercury discharge to the environment. WLSSD staff then tried to determine whether mercury-free alternatives existed and whether they were viable alternatives. Through a literature search and discussion with laboratory staff, we determined that mercury-free fixatives are readily available and that hospitals are slowly converting to their use on a national scale. The exact reasons for this conversion are unclear to WLSSD staff, but may be due to the wider availability of mercury-free alternatives in combination with a growing awareness of mercury as a global pollutant and the resultant increase in management costs associated with mercury-containing wastes. (More stringent regulations have increased training, disposal, and reporting requirements.)

WLSSD staff contacted manufacturers of mercury-free fixatives and requested the names of any local hospitals using their products. We made phone calls to labs at three Midwestern hospitals, asking staff members to identify any concerns or problems they had encountered with mercury-free products. The most common concern cited was pathologists' fear that the new fixatives would not provide the same level of detail or work as quickly as the mercury fixative. Typically, these hospitals had implemented a trial period with the mercury-free alternative. All three hospitals recommended mercury-free fixatives as a viable alternative.

In light of this information, in July 1997, WLSSD developed a regulation that prohibited the discharge of any mercury-contaminated waste from hospital laboratories after July 1, 1998. This regulation did not prohibit the use of mercury fixatives but did prohibit wastewater discharge of any product associated with mercury-containing fixatives (such as formalin still discharges, mercuric chloride precipitation wastes, fixative rinse water, and formalin fixative wastes). The year frame provided the hospitals ample time to test and implement mercury-free alternatives or to implement handling procedures for all mercury-contaminated wastes. WLSSD staff then met with administrative staff members from Hospitals A and B and a third hospital (Hospital C) that was not involved in the Zero Discharge Project to explain the regulation and to provide assistance, including the names of manufacturers of mercury-free fixatives and contacts at other hospitals using mercury-free alternatives.

By spring 1998, Hospital A had made the successful conversion to a mercury-free fixative. To undertake this conversion, the hospital formed a histopathology task force. The task force developed a plan in which the pathology staff would rank the various mercury-free alternatives along with the mercury fixative they were currently using. Five mercury-free alternatives were selected. Ten different tissue samples were then fixed in each of the five alternatives and the mercury fixative then in use. The resulting 60 preparations were then ranked. The highest ranking was a tie between the mercury-containing fixative and one of the alternatives. The alternative was chosen as a replacement.

Hospital A lent its 60 slides to the two other hospitals in the community. With the significant work of preparing slides already taken care of, Hospital C eliminated its use of mercury fixatives shortly thereafter. At this hospital, the pathology staff had actually ranked a mercury-free alternative higher than the mercury fixative they had been using; the conversion was straightforward because staff felt they would be getting a better product. This also helped to illustrate how subjective the presentation of a histological section is. Hospital B is currently attempting to minimize its use of the mercury fixative but has not completely made the conversion.

OBSTACLES TO CHANGE

At Hospitals A and B, WLSSD staff identified three primary roadblocks to change as: (*a*) technicians' belief

that pathologists would be resistant to change; (*b*) time constraints; (*c*) lack of awareness of the problem. In order to institute a switch to mercury-free alternatives, it is important to understand and provide solutions to these roadblocks.

Of these, the largest roadblock noted by WLSSD staff was histopathology technicians' belief that a change of procedures in the lab would not be acceptable to pathologists. Preparation of a tissue block is a complex process, and a change to a new process includes the potential for a change in the presentation of histological sections. Determinations of disease are based on subtleties in presentation. The technicians believed that the medical staff would resist any changes that might affect their proficiency in interpreting a histological section.

Another roadblock to change was the lack of time to research alternatives. Lab staff felt that demands on their time would not allow them time to research alternatives, meet with the medical staff, and set up the necessary parallel studies to see how the changes would affect preparation time and the appearance of the new sections. Another time-related concern was the belief that alternative products would not "fix" in adequate time to allow for the turnaround time demanded by the medical staff.

The lack of awareness of the problem was apparent in both hospitals studied. While our sampling data made it apparent that these laboratories were responsible for considerable mercury loading to the wastewater stream, concentrations were at such low levels (ppb or ppt) that most medical personnel probably dismissed them as trivial. While emissions to the air, such as from coal-fired power plants, are a much larger source to the environment overall, even such very low concentrations have an impact on the environment. It was during our work on the project that staff and administration in the hospitals became better educated on the issue and began to gain an appreciation that all sources of mercury to the environment are unacceptable.

Any successful mercury pollution prevention effort will require an understanding by all staff of the hospital's role in polluting the environment, including sources of mercury, the fate of mercury in the environment, and the effects on wildlife and human health. A pollution prevention "team" including both histopathology technicians and medical staff could review the institution's practices and visit with staff of hospitals that have already gone mercury-free. Perhaps most important, though, is commitment from hospital administration. Such a commitment may be facilitated through the Mercury-Free Pledge Campaign, initiated in April of this year by Health Care Without Harm, an international coalition of health care professionals, hospitals, and environmental advocates. Health care providers including Kaiser Permanente, Dartmouth-Hitchcock Medical Center in Lebanon, New Hampshire, and New York's Beth Israel Medical Center have signed the pledge, which outlines steps and formalizes the commitment to mercury-free health care.

Until the use of mercury-free fixatives has been implemented, hospitals can still use management practices that minimize mercury-containing waste. One of these is to reduce the quantity of mercuric fixative used to the minimum volume required to adequately fix the specimen. The use of mercury-free stain is another pollution prevention practice that can be easily implemented. Harris hemotoxylin stain traditionally contained mercuric oxide. Some labs continue to make their own solutions with mercuric oxide, yet mercury-free Harris hemotoxylin stains are widely available. Nearly all histological vendors offer mercury-free stain oxidized with sodium iodate. The laboratories at both Hospitals A and B used a mercury-free hemotoxylin stain.

A switch to mercury-free alternatives can save a hospital potential regulatory and disposal costs. In addition, almost all hospitals have in their mission statements a commitment to community health; a pledge for mercury-free medicine is one large step a hospital can take to honor its commitment to the community and to the medical principle to "First, do no harm." ■

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