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Pollution Prevention and the Work Environment: The Massachusetts Experience

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In 1989, Massachusetts enacted the Toxics Use Reduction Act. The Act defined toxics use reduction, also referred to as pollution prevention, as "in-plant changes in production processes or raw materials that reduce, avoid, or eliminate the use of toxic or hazardous substances or generation of hazardous by-product per unit of product . . . without shifting risks between workers, consumers or parts of the environment." The investigators sought to understand to what extent worker health and safety concerns have been integrated into toxics use reduction activities and how these activities have affected the work environment. The authors reviewed 35 published case studies of toxics use reduction in Massachusetts companies and interviewed key personnel including the staff of the Massachusetts Office of Technical Assistance for Toxics Use Reduction. Overall, between 1990 and 1997, Massachusetts companies decreased their use of toxic chemicals by 24 percent and decreased their volume of toxic by-product by 41 percent. In almost 50 percent of the cases analyzed, improved worker health and safety was cited as a benefit of the toxic use reduction projects. Solvents were eliminated or reduced in 63 percent of the cases. Forty-six percent of the companies profiled introduced water-based chemicals in place of more volatile ones; and acids and caustics were reduced or eliminated in 20 percent of the cases. The investigators concluded that toxics use reduction activities have resulted in improvements to the work environment, but that such improvements were rarely a direct concern of these efforts, thus creating the potential for new negative worker health and safety impacts and missed opportunities to coordinate environmental and worker health and safety improvements. The authors recommend that technical assistance agencies and companies better integrate worker health and safety issues and pollution prevention activities.

Keywords Pollution Prevention, Toxics Use Reduction, Technical Assistance, Prevention, Substitution, Controls

In 1989, Massachusetts established itself in the forefront of environmental policy innovation by promoting a preventive approach to environmental protection. In that year the Toxics Use Reduction (TUR) Act became law—one year in advance of the federal Pollution Prevention Act which also championed source reduction.[1] The Massachusetts TUR Act defined TUR as "in-plant changes in production processes or raw materials that reduce, avoid, or eliminate the use of toxic or hazardous substances or generation of hazardous by-product per unit of product . . . without shifting risks between workers, consumers or parts of the environment." The act also suggested an unprecedented policy approach: coordination and integration of environmental and worker protection. Although preventive strategies top the classic industrial hygiene hierarchy of controls, only a handful of articles have detailed efforts to mitigate work environment hazards by these methods or have described integration of environmental and industrial hygiene preventive practices.[2–6]

The TUR Act opened the door for enhanced prevention of occupational injuries and illnesses in Massachusetts by (1) asking firms to evaluate their operations for opportunities for TUR, such as worker exposure to hazardous chemicals, and (2) instructing them to prevent the shifting of risk to workers while implementing alternatives. This last mandate implied that companies would need to evaluate the proposed less toxic alternatives for their potential impact on the work environment, including their potential for new chemical, physical, safety, or ergonomic hazards. Despite the explicit direction given by the Act to incorporate worker health and safety issues into toxics use reduction planning, some have observed that natural and obvious opportunities to do so have been ignored.[7] Thus, a major question of this research was: "To what extent have companies and technical assistance providers consciously integrated worker health and safety concerns into their TUR activities?"

The second major question addressed by this project was: "In what ways have TUR activities had an impact on the work environment?" In eliminating and reducing the use of toxic chemicals in their operations, companies reduce or eliminate potential exposure to toxics in the air, via chemical handling, in conjunction

with maintenance activities, or during accidents. This is true, *even if companies never consider occupational health or safety issues in the process*. Although measuring this impact in terms of lives saved, injuries prevented, or accidents avoided is not possible at this time, it is possible to scrutinize descriptions of TUR projects to discover probable reductions in exposure to toxics. Another potential discovery would be that TUR projects may create new problems while solving old ones. For example, companies may return to using flammable solvents or other solvents that are not ozone-depleters, but still toxic, or may reduce solvent use by increasing the amount of elbow grease applied to clean a part, thereby increasing musculoskeletal injury risks. This type of TUR practice might result in exposures to new safety, health, and ergonomic hazards. Thus, this research also sought to discover whether such "risk-shifting" had occurred as companies undertook to eliminate or reduce troublesome environmental threats.

METHODS

The role of occupational safety and health issues was examined in the experience of companies and technical assistance providers in Massachusetts following the implementation of the TUR Act. We reviewed case studies of TUR projects undertaken in 35 Massachusetts companies between 1989 and 1997 with the assistance of staff of the Office of Technical Assistance for the Toxics Use Reduction (OTA), a non-regulatory division of the Governor's Executive Office of Environmental Affairs.[8] (See Figure 1 for the industry sectors profiled.) With the permission of these companies, these case studies were written by staff of OTA to promote TUR in the Commonwealth. The case studies varied in length from two–five pages and typically covered the technical and financial aspects of the TUR projects.

Five OTA technical assistance providers were interviewed about these projects, the role of occupational health and safety in their work, company motivations for TUR, their own perceptions of the impact of their work on occupational health and safety, and their training and background in occupational health and safety. These staff were four of the five OTA regional "team leaders." The fifth interviewed individual was the director of technical assistance. All interviewed staff had been with OTA since at least shortly after its founding and, prior to that, had 20 years or more of experience in industry in a range of fields, including chemical processing, finance, ceramic engineering, plant management, and marketing.

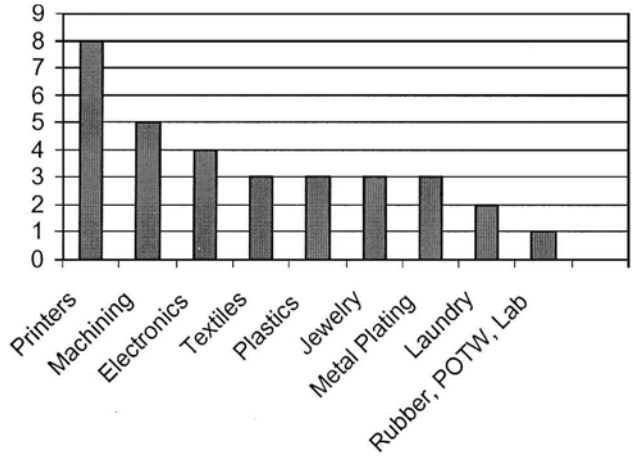

FIGURE 1
Case study industry sectors.

In addition to the interviews with OTA staff, three of the profiled cases were investigated in-depth by conducting interviews with key company personnel and by visiting the site where the projects were undertaken. Two of the companies were visited in conjunction with Demonstration Site Programs sponsored by the Massachusetts Toxics Use Reduction Institute. The cases were selected on the basis of convenience and may not be representative of all cases in the study. Two of these companies were large (>1,000 employees) and have positive reputations with regard to the environment. The third company is small (fewer than 150 employees) and had a neutral reputation.

Interviews were conducted following guidelines for qualitative evaluation research.[9] Interview guides with open-end, theme-based questions were used to draw out complex responses based on the interviewee's experience and knowledge. Interviews took place either at OTA, or on-site at the companies, and varied in duration from 15 minutes to one hour. Interviews were taped and transcripts were analyzed for correspondence with themes, coincidence of multiple respondent opinions, and nonconforming perspectives.

RESULTS

The Case Studies

In 49 percent (17) of the 35 toxics use reduction cases profiled by OTA, improved worker health and safety was mentioned as a benefit of the project. In 26 percent (9) of the 35 cases, the case study described worker health and safety as at least a partial motive for undertaking the TUR projects. Ozone-depleting substances were eliminated or reduced in 37 percent of the cases and all classes of solvents were eliminated or reduced in 63 percent. Forty-six percent of the companies profiled introduced water-based chemicals in place of more volatile ones, and acids and caustics were reduced or eliminated in 20 percent of the cases. These results are summarized in Table I. Table II provides some examples of the TUR projects and their potential impact on the work environment.

The OTA Interviews

Role of Worker Health and Safety

When asked what role worker health and safety played in their work, a common response by the OTA staff was: "everything we do is health and safety." A staff member clarified this statement by saying that he believes that OTA's work to reduce the quantity and toxicity of industrial chemicals consistently and generally improves the work environment. Two staff members

TABLE I
Results of case study analysis

TUR cases studies	% of cases	n (n = 35)
Health and safety benefit claimed	49%	17
Health and safety motive claimed	26%	9
Ozone depleters reduced or eliminated	37%	13
Solvents reduced or eliminated	63%	22
Water-based substitutes introduced	46%	16
Acids/caustics reduced or eliminated	20%	7
Types of TUR projects undertaken (>1 possible)		
Input substitution	86%	30
Preventive maintenance	46%	16
Water conservation or quality	31%	11
In-process recycling	23%	8
Operations and maintenance	20%	7

said that at the request of the firm, OTA staff will, to the best of their abilities, point out potential Occupational Safety and Health Administration (OSHA) violations in a site visit and in recommendation letters. One team leader said that visiting OTA team members would draw a firm's attention to hazards that OTA staff regarded as posing "imminent danger" to employees. But this same individual thought that worker health and safety issues were not a part of OTA's work because the agency would not want to get involved in OSHA compliance issues. Several of those interviewed expressed the general assessment that worker health and safety is not often a primary and conscious concern, but that improvement of the work environment was a supplemental benefit of their work. As one interviewee described it, "We don't particularly look for health and safety, but it is an ancillary thing."

Worker health and safety issues potentially come into play in two specific aspects of OTA's work: as part of OTA's assessment of TUR opportunities at a firm, and in OTA's TUR recommendations. In assessing a firm's options for TUR, OTA has the opportunity to point out potential worker health and safety hazards of firms' current use and handling of toxic chemicals and recommend TUR strategies to limit exposure. Additionally, OTA can evaluate their recommended alternatives for potential impact on the work environment in order to avoid "risk shifting." Most OTA interviewees acknowledged that these activities fit within their role as TUR technical assistance providers. However, they noted that, in practice, the agency's ability to incorporate worker health and safety issues into their work was limited by a number of factors (see Table III), and that the degree of attention to these issues varied with the interest of the staff involved.

Consideration of Risk-Shifting

Interviewed OTA staffers generally believed that their recommendations for TUR eliminated or reduced hazards and did not create significant new ones. However, one team leader said that not everyone who provides technical assistance at OTA put worker health and safety in as prominent a place in the evaluation of alternatives as he did. Indeed, one of his colleagues mentioned that he had never considered risk shifting to workers as an issue in his recommendations. In response to a question about whether an interviewee had considered the potential for inhalation hazards in powder coating—a commonly recommended alternative to solvent-based paint—he said, "I hadn't thought about the particles with powder coating. Whenever I've seen the powder coating operations, it seems to be relatively under control and all the operators were fitted with personal protective equipment—respirators."

Some OTA staffers said that they found that determing the safety of the new process relative to the one it replaces is not always straightforward. Several OTA staffers mentioned that information on the hazards of alternatives is often not available. New products or technologies often have not been evaluated in the work environment or laboratory for their potential impact on workers' health. One staffer summarized:

> There's very little out there as far as evaluating risks of alternatives. I think you have to use common sense, number one, plus experience with industrial processes. For example, if you replace a degreaser with an aqueous cleaner, the chances of it being more harmful than the degreaser are probably minimal.

In another example, an OTA staffer questioned his recommendation to companies that they use n-methyl pyrrolidone in place of methylene chloride in stripping operations, because of his concerns with its toxicity. (There is no OSHA permissible exposure limit (PEL) or American Conference of Governmental Industrial Hygienists (ACGIH®) threshold limit value (TLV®) for it, although it is an irritant, is absorbed through the skin, and may be a reproductive hazard.) He commented on this recommendation: "Whether it's a giant step forward, I don't know. I think it's an improvement. But I'm not sure."

Even if reliable and clear information on the products and technologies is available, several felt that potential hazards are often very difficult to predict. One OTA staffer said:

> If I know that (the change) is going to require some additional personal protection or engineering controls, I certainly will recommend it. But in many cases there is no way to know what the outcome is until they implement it. But in the report, we say 'try it and see.' Maybe they should monitor, with Draeger tubes or whatever.

This OTA staffer gave the following example:

> Occasionally, there are times when you make recommendations that may have a greater impact on the worker. When I've made those recommendations, I've tried to explain to the company what those are. For example, acetone has been de-listed as a VOC (volatile organic compound regulated under the Clean Air Act). We were working with a company that was coating metal parts using toluene as a diluent in painting operations. They were trying to keep under a five ton threshold for VOCs so they wouldn't have to get a permit. One of the options we gave them was to switch acetone for toluene. From a toxicity standpoint, acetone is better to use than toluene. But it has a much higher vapor pressure so there is potentially much

TABLE II
Toxics use reduction case study examples

Industry	TUR project	Potential H&S benefit	Potential new hazards
Printer	Substituted a water-based cleaner for TCA used for cleaning printing plates.	Eliminated TCA exposure.	Unknown hazards of new cleaners. (Originally introduced a terpene-based cleaner that was replaced due to worker complaints.)
Circuit board mfg.	Replaced a solvent spray painting operation with a computer-programmed, low-pressure coating spraying and UV light-cured polyurethane system.	Reduced the volume of coating used from 125 gal/10,000 circuit boards to 4 gal/10,000 circuit boards. Eliminated almost all clean-up solvents. Storage of flammables was eliminated.	UV light and photo-initiating compounds, including possibly isocyanates. Automation replaced skilled workers.
Hat mfg.	Eliminated toluene and methyl ethyl ketone by switching to water-based coatings. Eliminated use of a coating containing formaldehyde and isocyanates.	Eliminated solvent, formaldehyde, and isocyanate exposure.	Unknown hazards of water-based substitutes. Part of production line re-located outside the state. Eliminated "hazard pay."
Industrial control mfg.	Switched from solvent-based paints to powder coating; eliminated CFCs by changing to solder fluxes needing less cleanup; introduced semi-aqueous cleaners; reduced the amount of metal plating and changed the plating process from cadmium-cyanide to zinc-cobalt; reduced waste paint through new work practices; and eliminated methylene chloride by cleaning less, using water-soluble metalworking fluids and using detergents.	Eliminated exposures to solvents, cadmium, and cyanide.	Unknown hazards of new cleaners. New exposures to cobalt and soluble metal working fluids.
Auto part mfg.	Substituted synthetic metal working fluids for sulphurized oil.	The case study noted that "workers no longer suffer from dermatitis problems associated with sulphurized oils."	Synthetic metalworking fluids.
Metal finisher	Replaced ammonia with hydrogen and nitrogen in annealing processes; substituted hot air and water for Freon; introduced a three-step aqueous cleaning station including ultrasonic washes in place of TCE cleaning; switched to a lighter stamping oil requiring less aggressive removal; and instituted a reverse osmosis, closed-loop water treatment process.	Eliminated: ammonia exposure and accident potential; solvent exposure; handling of maintenance chemicals (muriatic acid, sodium hydroxide, and sulphuric acid). The new treatment system reduced the volume of sludge from 4000 to 7 gal/year.	Potential for hydrogen/nitrogen explosion; unknown hazards of new cleaners.
Laundry	Substituted carbon dioxide for sulphuric acid used as a pH adjuster in waste water.	Acid handling was eliminated, as was aerosolized acid mist and hydrogen sulfide production—a by-product of the process.	Potential safety hazard related to pressurized gas storage and handling.

TABLE III
Barriers to integration of health and safety and toxics use reduction

1. Insufficient training of technical assistance providers in worker health and safety.
2. Prevention "double-standard"—prevention focus for environmental harms, but controls and personal protective equipment deemed adequate for workers.
3. New chemistries and technologies presumed safe for workers.
4. Lack of information about substitute chemistries and technologies' potential impact on workers, including musculoskeletal injury risks.
5. Environmental compliance focus inhibits consideration of work environment.
6. Little coordination or communication between environmental and worker health agencies.

> higher worker exposure from it because it's more volatile. When you make a recommendation like that, there's trade offs. What I try to do is explain to the company what the implications are—what the considerations are if they make that kind of change.

In addition to recommending that the firm monitor exposures or implement engineering controls or personal protective equipment, OTA staffers felt that there were other checks on TUR projects that would prevent workers from being harmed. In particular, OTA staffers believed that equipment that is properly designed, installed, and operated will not present hazards. One gave the following example:

> When you talk about going from a solvent-based paint to powder coating, there will be dust issues. But normally, every time something is set up, it will be set up properly. When you make a recommendation, you make the assumption that it will be set up properly. If someone takes a powder coating system and puts it in a room and takes no action to contain the dust or vapors, it could be more harmful, but you have to think that if someone is going to invest the time, effort, and money to bring in a new process, they are going to look at those things.

One staffer felt that another check on the TUR process is that if "something smells worse or different, workers will complain."

Motivation for TUR

Despite the case studies' frequent mention of worker health and safety as a motivation for TUR, interviewed staff contradicted this assertion. The primary motivation for most companies seeking technical assistance for TUR is better compliance with environmental regulations. This is corroborated by the high number of profiled companies who undertook to replace chlorinated and ozone-depleting substances as the restriction dates imposed by the Montreal Protocol and the Clean Air Act drew closer. However, some OTA staff mentioned that they increasingly use OSHA regulations to motivate companies to undertake OTA's recommendations. One team leader observed, "You can make all kinds of recommendations for pollution prevention, but if it's not on their radar screen, they don't care. One way to put it on their radar screen is to put that (OSHA) reg right in front of them." This staffer said that he is investigating what ways OTA can make use of OSHA's Process Safety Management Standard to encourage companies to gather information about their processes and undertake TUR projects. In a further attempt to encourage TUR using OSHA regulations, OTA sent out letters to selected companies advising them of OSHA's promulgation of a strict new methylene chloride standard and OTA's services.

OTA Training in Worker Health and Safety

No OTA staff have specific and comprehensive training in industrial hygiene, although several have some knowledge of the field. They have gained this knowledge through staff meetings, workshops sponsored by the Massachusetts Safety Council and the Commonwealth's Division of Occupational Safety, university classes, and their own efforts to seek out information from worker health and safety resources, such as the National Institute for Occupational Safety and Health (NIOSH). The team leaders said that they felt that they were knowledgeable about worker health and safety and industrial hygiene issues, and that they had disseminated their knowledge to their teams.

OTA and OSHA Collaboration

Some members of OTA staff have referred employers who are curious about their OSHA compliance status to the OSHA consultation service operated by the Division of Occupational Safety in Massachusetts. But one OTA staffer said he would never refer a company because companies are required to rectify violations within a set time frame. The prospect of joint agency visits to selected companies has been discussed, but has never taken place. No formal memorandum of understanding exists between the agencies.

Company Site Visits

Three of the companies profiled by OTA case studies were visited to interview the environmental and/or worker health and safety staff and to tour the TUR projects. Due to space limitations, findings from only one of these investigations are briefly discussed here.

Company A has over 1000 employees and makes more than 3000 rubber specialty products including windshield wipers, o-rings, copier toner blades, golf balls, and respirator face pieces. Their manufacturing processes utilize 4000 different chemicals, although only 30 are used in large quantities. Since 1992, Company A has undertaken several TUR projects that have resulted in the reduction and elimination of solvent use, improved material dispensing, reduction in toxicity of inks, recycling, and water and electricity conservation. The Director of Environmental Health and Safety (EH&S director) for the company has championed these projects as well as an overall system of reducing environmental impact through their ISO 14,000 program, Life Cycle Analysis and Design for the Environment initiatives. (More information on these program frameworks is available at

www.iso.ch and www.epa.gov/dfe.) These projects are popular at the company, in part, because they save an estimated $2 million a year through increased efficiency, elimination of emissions and discharges, and reduction in energy and water consumption.

Being responsible for both areas, the EH&S director has worked to integrate the environmental and worker health and safety programs and to encourage long-range thinking about these hazards. The company's slogan "Committed to a Safe Workplace in a Clean World" expresses this integration and is aimed at building employee support for the program. The EH&S director believes that the worker health and safety regulations of the 1970s mandated local exhaust ventilation that "created" the environmental problems of the 1980s and 1990s and is committed to avoiding such conflicts. This company has elected to include worker health and safety concerns in its ISO 14,000 program, even though worker health and safety is not officially a component of certification. The EH&S director also credits the TUR Planners Course offered by the Toxics Use Reduction Institute with training environmental health and safety personnel to integrate the two areas.

According to a case study written in conjunction with the company's designation as a Toxics Use Reduction Institute Demonstration Site grant recipient, the company's overall objective is "designing products to minimize environmental, health and safety (EHS) impacts in production, use, reuse and ultimate disposal." The company's motivations for setting this objective include creating a positive image with customers and employees, limiting liability, improving compliance with regulations, lowering insurance and accident costs, furthering good community relations, reducing waste, and, most importantly, saving money. The EH&S director also noted that the company "wants people to be happy at their job and be as comfortable as possible, because we know that it affects the output: quantity and quality." Improving worker health and safety has been the primary object of several TUR initiatives, due, in part, to worker participation in the program. Methylene chloride was eliminated because of worker health concerns and because of pending stringent regulations. Additionally, the company is in the process of investigating alternatives to a solvent hand-wiping process that presents a potential fire and health hazard.

The EH&S director believes that one of the benefits of the program is reduced workers' compensation costs. These reduced costs result from fewer claims related to chemical accidents and disease and also from improved worker health and safety program management overall which is an outcome of the TUR and ISO 14,000 program. Prior to the elimination of trichloroethylene, workers suffered dermatitis, had been overcome by vapors and had, on occasion, to be evacuated due to vapor build up.

At this company, proposals for new processes or products, or proposed changes to existing processes, including TUR-related changes, undergo "Advanced Product Quality Planning." This process includes an environmental health and safety review using a special assessment sheet. This form requires that the proposed process or product be scrutinized for potential chemical and mechanical (safety) hazards and required controls. In an unusual move, this process incorporates life cycle analysis principles by asking reviewers to consider impacts of the process beyond the company itself, for example, environmental hazards resulting from vendor activities. Out of this review comes worker health and safety specifications that are imposed on equipment suppliers for electrical safety, noise (below 85 dBA), machine guarding, emissions (chemicals in synthetic hydraulic oils), and others. Additionally, the assessment gives the company an idea of the costs associated with the proposed process. The EH&S director notes that, "Anytime you have a health and safety exposure, you have a cost associated with it—exposure monitoring, potential for accidents, insurance, claims, administrative costs because of tracking with regulations, permit fees, and so on."

The assessment report may describe impacts of proposed new processes, products, or equipment, but it does not include a rating procedure for evaluating alternatives. The EH&S director suggested that there were few choices by the end of a technical and initial environmental assessment process, and gave the example of the company's choice between n-methyl pyrrolidone and dibasic esters as a substitute for methylene chloride. The dibasic esters-based chemical was ultimately selected because it performed better than n-methyl pyrrolidone and it was deemed "safer." In addition to potentially inadequate screening of substitutes, Company A's assessment procedures are only applied to new or changed processes; current hazardous operations may go unscrutinized.

Although this company's assessment tools do not detail worker health and safety criteria, discussion with the EH&S director indicates that the process is comprehensive, even if the evaluation process is not systematic. For example, in addition to TUR aimed at lessening chemical hazards, process changes have occurred to reduce mechanical safety and ergonomic hazards. In place of a hand trimming operation following a power pressing, a cryogenic process was substituted. This eliminated the potential for operator entanglement in the presses and ergonomic hazards due to repetitive motion and forceful exertion with a trimming knife. However, this process did add a burn hazard—liquid nitrogen—and this potential hazard was considered in the change analysis. Ergonomic concerns also found their way into the environmental planning process as the company redesigned their packaging. To reduce waste, cardboard packaging was standardized, and in the processes, redesigned to prevent workers from lifting more than 35 pounds.

DISCUSSION

As was found in an earlier review of pollution prevention case studies, the case studies considered in this study rarely described worker-process interactions or worker health and safety issues.[10] Because these case studies were written by OTA staff instead of company personnel, and with the explicit purpose of promoting TUR (and OTA), the case studies are likely to be biased. This bias is likely to be in the direction of presenting positive results and a practical conformity with the provisions

of the TUR Act, for example, incorporation of worker health and safety in TUR activities. However, the interviews with both OTA staff and company personnel were designed to overcome this inherent bias and the lack of information in the case studies by clarifying and confirming the interpretation of the written materials. Possible limitations of the interview component of this study include the limited number of informants (eight) and the potential bias introduced by respondents shaping their answers to meet the perceived expectations of the (industrial hygienist) interviewer.

While the interviews and site visits raised issues not discussed in the case studies, thereby potentially confounding conclusions based on these cases with the experience of other cases, they also improved the reliability of the case study data via a strategy known in qualitative research as "triangulation." Using multiple sources and the in-depth investigation which is the hallmark of qualitative methods, the investigators were able to produce a rich data set not available to quantitative survey-based research. Because of the ability of these methods to "fill in" the complex work environment context, scientists at NIOSH have called for a greater use of these methods in this field.[11]

CONCLUSION

Reporting under the TUR Act shows that Massachusetts companies have dramatically reduced their use of toxic chemicals since the act took effect in 1990. Companies decreased their use of toxic chemicals by 24 percent and decreased their volume of toxic by-product by 41 percent between 1990 and 1997 (figures adjusted for production).[12] This reduction in toxic by-product includes reductions in fugitive emissions released inside the work environment.

The case studies describe concrete examples of work environment improvements brought about through TUR projects. Especially notable is the work the profiled companies have done to eliminate use of the hazardous chemicals trichloroethylene, methylene chloride, cyanide, and acids. Additionally, many of the TUR projects described resulted in better enclosure and control of hazardous processes, particularly of maintenance tasks that are ordinarily difficult to control. While few of these projects might have been undertaken with the goal of eliminating worker hazards, many of these companies have accomplished this nevertheless. These examples and the statewide figures reported above suggest that worker exposures to toxic chemicals may have substantially decreased as a result of the TUR Act, although measurement has not been conducted to verify this.

The case studies and interviews with TUR technical assistance staff and company environmental, health, and safety personnel uncovered many examples of the lessening or elimination of worker health and safety hazards as a result of TUR projects. However, according to technical assistance personnel, these results are often a happy coincidence rather than the design of TUR projects. The potential therefore exists for this lack of attention to work environment hazards to result in missed opportunities to reduce hazards, or in risk shifting—from the environment to workers, from known hazards to unknown potential hazards, or from chemical to safety or ergonomic hazards.

Agencies that provide technical assistance to companies contemplating TUR activities have a significant opportunity to guide companies toward the elimination and reduction of toxic exposures and chemical safety hazards. Additionally, technical assistance providers can help companies avoid risk shifting between the environment and workers. However, this research uncovered several potential barriers which may hinder the development of integrated preventive worker health and safety and environmental practices (see summary in Table III). The investigators found that additional training across disciplines may be necessary to improve the ability of pollution prevention technical assistance providers to recognize, prevent, or control work environment hazards or potential hazards.

In addition, despite the source reduction focus of pollution prevention technical assistance, technical assistance staff may assume that worker health hazards are appropriately and permanently controlled by standard engineering controls and personal protective equipment. They may also have too much confidence that products and processes deemed good for the environment are incapable of causing harm to workers. In this study we found a lack of consistent evaluation of opportunities in the TUR process to reduce risks to workers and also insufficient attention to the risk shifting potential of new technologies and processes. Of course, TUR advocates face the challenge of inadequate and often inaccessible information on health and safety impacts of substitute chemistries and processes.

Another barrier to consideration of worker health issues in TUR projects may be the environmental compliance focus of firms who request the services of technical assistance agencies. Substitutions for ozone-depleting substances, reduction in emissions of the Clean Air Act's hazardous air pollutants, elimination of metals and solids from waste water discharge—these have been the issues motivating companies to undertake TUR projects. Worker health and safety may be dramatically improved in conjunction with the amelioration of these problems, but finding the easiest and cheapest solution to these specific and urgent environmental problems may dwarf other concerns. Promising TUR projects where the primary focus is improved worker health and safety, but for which there is less regulatory pressure motivating their acceptance, may be ignored altogether. Finally, the lack of working relationships between pollution prevention agencies and OSHA consultation or other occupational health-related agencies may hinder the potential for integration of technical assistance, enforcement, and standards development and interpretation.

On the positive side, companies such as Company A have overcome some of these barriers and demonstrated the benefits of integrating preventive strategies. Company A eliminated several significant worker hazards, including exposure to chlorinated solvents, and saved thousands of dollars doing it. In some cases, new hazards were introduced that required subsequent control efforts. But the integration of the worker health

and safety and environmental programs meant that these new hazards were identified and controlled and that opportunities to eliminate hazards, such as manual material handling, were discovered and implemented in the course of TUR projects. The success of this company in this regard may be attributed to both management vision and, critically, to worker participation in the program. Despite the limitations discussed above, this study concludes that TUR has already had a positive impact on the work environment in Massachusetts and has enormous potential for further improving the health and safety of workers.

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