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INTEGRATION OF POLLUTION PREVENTION AND OCCUPATIONAL HEALTH AND SAFETY

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Integration of Pollution Prevention and Occupational Health and Safety

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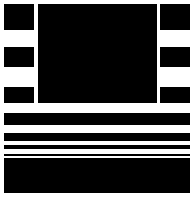

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University Research in Sustainable Technologies

The University Research in Sustainable Technologies program is a joint project of the Toxics Use Reduction Institute (TURI) and the Center for Environmentally Appropriate Materials (CEAM) at the University of Massachusetts Lowell, with support from the Commonwealth's STrategic Envirotechnology Partnership (STEP).

The program taps the research capabilities of the University of Massachusetts to advance the investigation, development and evaluation of sustainable technologies that are environmentally, occupationally and economically sound. The program provides research funding to UMass faculty from all campuses, annually, on a competitive basis and encourages faculty/industry partnerships and cross-campus collaboration. Industry partners provide guidance, propose applications for new technologies, and, in some cases, evaluate and/or adopt processes and technologies resulting from research.

Following is a list of the Fiscal Year 2000 projects.

- **Diffusion Dialysis and Acid Recovery in Metal Working and Finishing -** Prof. Francis J. Bonner and Prof. Alfred A. Donatelli, UMass Lowell, Department of Chemical Engineering

- **Solar Fuel Cell System -** Prof. John Duffy, UMass Lowell, Department of Mechanical Engineering, Solar Engineering Program

- **Optical Information Processing with Environmentally Friendly Organic Materials** - Prof. D.V.G.L.N. Rao, UMass Boston, Department of Physics

- **Developing and Analyzing Lead-Free Soldering Processes for Printed Wiring Boards** - Prof. Sammy G. Shina, UMass Lowell, Department of Mechanical Engineering

- **Environmentally Benign Control of Polymer Solubility: Photoresist Materials Using DNA Mimics** - Prof. John C. Warner, UMass Boston, Department of Chemistry

- **Integration of Pollution Prevention and Occupational Health and Safety** - Prof. Rafael Moure-Eraso, UMass Lowell, Department of Work Environment

- **Synthesis of Conjugated Polymers and Molecules Using Sugar Reagents and Solventless Reactions -** Prof. Daniel J. Sandman, UMass Lowell, Department of Chemistry

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ABSTRACT

Pollution prevention, considered primary prevention, is based in technologies that prevent the possibility of harm from chemicals in industrial processes. Secondary prevention, on the other hand, only reduces the probability of harm from an industrial process. Traditional occupational health practice predominantly utilizes secondary prevention strategies, including disease surveillance and medical treatment in public health, and "end-of-pipe" controls in exposure reduction.

Occupational and environmental health issues are not always considered simultaneously when attempting to reduce or eliminate hazardous materials. Methods to decrease exposure to hazardous chemicals in the workplace frequently lead to increased exposure in the environment and to the community outside the workplace. On the other hand, controls placed on emissions of hazardous chemicals into the environment can lead to increased exposure to the workers inside the plant. There are government regulations in place that ensure a safe work environment or a safe outside environment; however, there is little integration of both approaches when considering the public's health as a whole.

Pollution prevention, as primary prevention, has the ability to shift occupational health strategies from control to prevention, where exposure prevention precedes exposure control. There is a need to address the relationship between environmental and occupational health, requiring a reevaluation of industrial hygiene control activities from a perspective of primary protection. There has been a fundamental change in the methods of environmental health management, from end-of pipe pollution control to comprehensive pollution prevention interventions. A way to develop the same fundamental change of methods in occupational health management (i.e., from exposure control to exposure prevention) needs to be explored.

This study focuses on aspects of the relationship between pollution prevention (P2) and occupational health. It evaluates the effects of pollution prevention intervention programs (i.e., toxics use reduction) on worker safety and health at three Massachusetts printed wire board manufacturing facilities. Most important, it focuses on primary prevention (in the form of P2) and how this model benefits both the environment and the worker. In addition, it provides useful feedback on what motivates companies to approach environmental and occupational compliance issues as a single concern.

I. BACKGROUND

Historically, on the federal level, OSHA standards have focused on worker exposure and conditions inside the plant, while EPA standards have focused on releases to the environment outside of the facility and on "end-of-pipe" control methods. Compliance with traditional environmental regulations generally results in major expenditures which have little if any positive impact on worker exposure and in some cases may actually

increase exposure by shifting toxics from one environmental medium to another (e.g., air and water pollution control devices generating increased quantities of hazardous waste which workers must process).

Recently, through the Pollution Prevention Act of 1990, the EPA shifted its focus from end-of-pipe controls to reducing exposures at the front end of the process. This has resulted in much greater regulatory involvement in the manufacturing process and it has moved EPA's purview inside the plant where its actions clearly have a much greater potential to have a positive impact on worker exposure. Unfortunately, this has not yet developed into an integrated approach between occupational and environmental health; thus, resulting in unsystematic attempts to achieve the united goal of exposure prevention (to the worker and the community).

The EPA's promotion of pollution prevention has required only voluntary participation from manufacturing facilities. However, on a more local level, occupational and environmental professionals in Massachusetts created the Toxics Use Reduction Act of 1989 (TURA) as a way of requiring manufacturing facilities to consider "reducing, avoiding, or eliminating" their use of toxic or hazardous substances (or byproducts) without "shifting risks between workers, consumers, or parts of the environment."[1] According to the law, manufacturing facilities striving to improve environmental performance by implementing pollution prevention plans have the choice of adopting the following strategies: input substitution, process and product changes, improvements in operation and maintenance, materials recycling and resource conservation. Since pollution prevention strategies look at eliminating the root causes of pollution generation, rather than controlling releases to the environment, the impact on worker exposure and workplace conditions is fundamentally different from previous efforts at reducing the impact on the environment through control strategies which did not improve - and in many cases worsened - exposures inside the plant.

This paper evaluates the effect of pollution prevention (P2) in the form of toxics use reduction (TUR) on worker safety and health at three printed wire board facilities covered under TURA. Through in-depth case study analysis, it attempts to identify specific TUR activities, which have had an impact on worker health. While the TUR options chosen by the three facilities mainly included input substitution or process change, thus resulting in less toxic substances replacing more toxic substances, an obvious or potential outcome of these TUR activities was reduced worker exposure. This report evaluates the relationship between occupational and environmental health within the corporate structure and identifies the factors driving companies to reduce toxics both inside and outside of their plants.

II. METHODOLOGY

The TUR interventions at each of the facilities were primarily directed at environmental concerns. The occupational health impact of each TUR option was determined based on both post-intervention and pre-intervention evaluations of the occupational health and safety (OHS) conditions in each plant. An informal OHS survey and three complementary survey instruments were used to gather data at the plants. The three complementary survey instruments are: the OSHA Program Evaluation Profile (PEP),

1 Massachusetts General Laws 310 CMR – 1086.

(OSHA 1997), the Pollution Prevention Option Analysis System (P2OASys, a software tool developed by the Toxics Use Reduction Institute and the University of Massachusetts at Lowell in 1997), and an open-ended interview with key informants at the plants, designed to explore the root causes of the occupational health changes attributable to the TUR interventions.

The PEP instrument provides numerical scores (ranging from 1 to 5) that represent the degree of development of the occupational health function in each plant. For each plant the overall (PEP) score are calculated (scale 1-5). The same scores for the six key elements, described in Table 2 are also calculated. The overall score is then tested as predictors of net gains in OHS elements of the P2 evaluation survey, P2OASys.

The P2OASys instrument provides, in addition to environmental impact data, a number of items related to workplace health and safety conditions. Six elements directly measuring worker health are identified as OHS Emphasis elements. The pre-intervention score for each of these OHS Elements is then subtracted from the corresponding post-intervention score to generate a measure of impact of the intervention. A positive value is then interpreted as an improvement, and a negative value as worsened, OHS workplace conditions.

While the intent of this study is not to perform statistical analysis of the numerical data, we are able to gain knowledge of the positive or negative effects of the TUR activities on worker safety and health. The results of the surveys (PEP and P2OASys) allow a determination of whether net gains in OHS took place after the P2 intervention. By evaluating the relationship between toxics use reduction and occupational health, we learn how environmental programs lead to improvements in worker health and how we can ensure that both occupational and environmental concerns are considered in tandem.

OHS activities should be included in P2/TUR intervention programs, not only to make them more effective, but also to reduce or eliminate potential risk shifting between the two. The data collected from the plant visits permitted the researcher to develop recommendations for considering OHS concerns when choosing TUR options. Based on the OSHA PEP results, recommendations are made on the minimal needs of a firm in their occupational health function necessary to sustain positive effects of environmental interventions such as TUR. The recommendations describe the theoretical and operational steps necessary to initiate a P2/TUR intervention, including meaningful participation of a worker health assessment team functioning jointly with environmental health professionals.

III. INTRODUCTION

A. Study Population

Data was collected from three printed wire board facilities in Massachusetts. These plants are subject to the provisions of TURA, and were selected for the study from a list of several manufacturing facilities throughout the state. The companies chosen are not necessarily representative of the industry, however each agreed to participate because of their experience with TURI and the Toxics Use Reduction Planner Program. Facilities range in size and structure. Each of the company's TUR activities was intended to have a positive impact on the company's environmental performance. In most cases, the strategy

which was selected for reducing environmental impacts was input substitution or process change which resulted in the replacement of less toxic substances for more toxic substances. An obvious or potential outcome of these TUR activities could have been reduced worker exposure - although this was not the primary goal of their TUR program. While not every TUR intervention described in this study meets the requirements of a "listed" chemical or process under TURA, each one has been chosen to represent significant efforts in pollution prevention, which have lead to the reduction of toxics used and byproducts generated.

B. Survey Instruments

OSHA PEP

The OSHA Program Evaluation Profile, or PEP (OSHA 1997), was originally designed by OSHA as an audit tool to assist compliance officers during general industry inspections, to assess workplaces and their health and safety programs through a scoring system of six major categories and 15 subcategories. It was developed by representatives of OSHA's National Office and field staff in a cooperative effort with the National Council of Field Labor Locals (NCFLL) and is based on the Safety and Health Program Management Guidelines (Federal Register, January 26, 1989).[2] It is considered to be an effective tool to measure good faith and to evaluate companies' safety and health programs.[3] The PEP evaluation form is also used by the OSHA consultation branch and is often left with the employer for their own use in evaluating the effectiveness of their safety and health programs.[4]

The program elements in the PEP correspond generally to the major elements of the 1989 Guidelines. The six elements to be scored in the PEP are:

1. Management Leadership and Employment Participation
2. Work place Analysis
3. Accident and Record Analysis
4. Hazard Control and Prevention
5. Emergency Response
6. Safety and Health Training

Each element is provided with five verbal descriptors of workplace characteristics representing five levels. The descriptors are intended as brief illustrations of a workplace at a particular level. The following chart summarizes the levels:

2 OSHA Notice CPL 2, Directorate of Compliance Programs, "Program Evaluation Profile (PEP) example", August 1, 1996.
3 Dr. Ruth Rutenberg, "Evaluation of the Program Evaluation Profile (PEP), Prepared for The Occupational Safety and Health Administration, Ruth Rutenberg & Associates, Inc., December 1997.
4 Based on information obtained during a phone conversation with the New Hampshire Consultation Branch of OSHA.

Score	Level of Safety and Health Program
5	Outstanding Program
4	Superior Program
3	Implemented Program
2	Developmental Program
1	No Program

For each element, the most appropriate characteristic that best describes the facility is chosen. The descriptors are chosen for " best fit" and may not necessarily match the workplace exactly or in literal detail. The score for the Management Leadership and Employee Participation elements is the lowest number of the following three scores: management leadership, employee participation, or the average score for all four factors. The factors of management leadership and employee participation are given greater weight because they are considered the foundation of a safety and health program. For each of the other elements, the score is averaged based on the responses of all factors within each element. In keeping with the OSHA guidelines, in averaging factor scores, responses were rounded to the nearest whole number, rounded up from 1/2 or greater and rounded down from less than 1/2. If the element or factor does not apply to the worksite being surveyed, a notation of N/A (not applicable) is given. This becomes a score of 0 and does not affect the final score.

An overall score for the worksite is recorded as the average of the six individual scores for the six elements rounded to the nearest whole number. The overall score on the PEP constitutes the level at which the facility's safety and health program is scored. This level is an informal assessment of the program and does not represent a compliance judgment; that is, it does not determine whether an employer is in compliance with OSHA standards.

P2OASys

The second survey instrument used was the Pollution Prevention Option Analysis System (P2OASys) designed to perform both contemporary P2/TUR and retrospective P2/TUR impact evaluation. In order to be able to measure the P2/TUR intervention impact, this risk characteristics instrument derives a semi-quantitative evaluation of the changes after the TUR intervention.

This instrument has 11 key elements or hazard categories with subsections for each element:

1. Acute human effects (10 elements)
2. Chronic Human Effects (8 elements)
3. Physical Hazards (5 elements)
4. Aquatic Hazards (5 elements)
5. Bioaccumulation (5 elements)
6. Atmospheric Hazard (4 elements)
7. Disposal Hazard (4 elements)
8. Chemical Hazard (13 elements)

9. Energy and Resource Use (3 elements)
10. Product Hazard (3 elements)
11. Exposure Potential (1 element)

These elements are measured as quantitative units (PEL's, LD_{50}, etc.) or qualitative units (evaluated as high, medium or low). They are integrated to give a numerical score from zero to 10. Six elements directly measuring worker health are identified in P2OASys. They are: acute human effects, chronic effects, physical hazards, chemical hazards, product hazards and exposure potential. Depending on the certainty of the data, a percentage certainty factor can be used to weight results of a final score. Scores of OHS Elements can be calculated separately.

The retrospective and contemporary P2OASys survey was conducted at each facility to assess both occupational and environmental health parameters of the current technology or process (before the TUR intervention) compared with the alternative technology or process that was implemented (after the TUR intervention).

Open-Ended Interviews

The final survey instrument is the open-ended interview conducted with each of the key informants at each facility. This interview is designed to investigate the underlying reasons behind the positive and/or negative impacts on occupational health of the TUR intervention. This interview identifies the firms' perspective on the effects of the TUR intervention on occupational health, the limitations and potentials of the P2 intervention for this purpose, additional opportunities for improvement of the work environment, operational methods to achieve integration of P2/TUR and occupational health in one intervention, identification of personnel that could help conduct the integrated intervention, and how to evaluate the performance of the integrated approach.

Table 1 depicts the three survey instruments with the key elements of each.

Table 1: Outcomes of Pollution Prevention Interventions with Three Survey Instruments

Survey Type	Key Elements	Before P2/TUR Intervention	After P2/TUR Intervention
OSHA PEP	Management Leadership and Employee Participation		X
Evaluation	Workplace Analysis		X
	Accident Analysis		X
Semi-Quantitative	Hazard Prevention and Control		X
	Emergency Response		X
Scores: 1 to 5	Health and Safety Training		X

Table 1: Outcomes of Pollution Prevention Interventions with Three Survey Instruments

Survey Type	Key Elements	Before P2/TUR Intervention	After P2/TUR Intervention
P2 OASys	Acute Human Effects *	X	X
	Chronic Health Effects*	X	X
Pollution Prevention	Physical Hazards *	X	X
Options Analysis	Aquatic Hazards	X	X
System	Bioaccumulation	X	X
	Atmospheric Hazard	X	X
	Disposal Hazard	X	X
Scores:	Chemical Hazard *	X	X
Low, Medium, High	Energy/Resource Use	X	X
(L, M, H)	Product Hazard *	X	X
	Exposure Potential *	X	X
Open-Ended Survey	Positive effects of P2/TUR intervention on worker safety and health		X
	Barriers or limitations of P2/TUR interventions to positively impact worker safety and health		X
Key Informants	Opportunities for improvement of worker safety and health		X
	Methods to achieve integration		X
	OHS/EHS Team of Personnel to promote integration		X
	Performance Measures		X
	How to create successful OHS/EHS intervention program		X

(* OHS Emphasis)

IV. CASE STUDIES

The following section describes each PWB facility. The original proposal for this study was to evaluate four companies, however, due to unforeseen circumstances, one company had to resign from the study. As this is a case study research project, it is still possible to achieve adequate analysis using the data collected from the three remaining companies. It is not the intent of this study to perform statistical analysis with a large study population. The findings of an in-depth evaluation of three PWB manufacturing firms' TUR activities and their effect on occupational health will help us to anticipate further research needs in this area, and allow us to expand our study to whole industry groups, as well as small and large businesses alike.

The descriptions below are based on discussions with each key informant, as well as the researcher's observations during several visits and tours of each company. During these visits, evaluations were made according to both physical and chemical hazards in general and particularly those associated with each TUR project chosen. While these walk-throughs were not as comprehensive as an OSHA safety inspection, the researcher was able to observe firsthand the workings of the facilities and the occupational safety and health status of some of the operations. Additional, more comprehensive description of

employee responses to the OSHA PEP questionnaire and their perceptions of the OHS status of each facility are provided in the next section.

This study evaluates two TUR interventions for each facility. Typical TUR activities for printed wire board manufacturing include the following:

- Reduce dragout
- Reduce and substitute chemicals
- Reduce copper buildup on plating racks
- Reduce chemical losses from evaporation
- Conserve water
- Reduce sludge generated
- Materials recovery

All three case facilities have consistently implemented these general TUR options.

A. Company #1

This company was purchased in 1998 by a larger international PWB manufacturing firm. There are approximately 550 non-union employees in a 200,000 square foot facility. They manufacture multi-layer circuit boards (approximately 9,000 panels per week). Sales are over $2M annually. This facility is located in a zoned industrial area with residences situated approximately 600 feet away. Housekeeping at this facility is considered excellent. Chemical fumes are detectable in the plant, but ventilation generally appears to be in good working order. Most equipment is state of the art, and is either enclosed or contained.

Despite the recent purchase of this facility by a larger PWB company, the environmental and safety personnel have remained the same, with the EHS manager placed organizationally directly under the Vice President of the company. The EHS manager (key informant) attempts to maintain the same atmosphere of the former owner by remaining proactive with regard to environmental pollution reductions. He considers the company a "pioneer", on the cutting edge, not only in printed wire board manufacturing, but also in toxics use reduction. Prior to 1998, they participated in two of EPA's Design for the Environment Printed Wire Board Projects - alternatives to electroless copper for through-hole metalization and alternatives to tin/lead for surface finishes (alternatives to hot air solder leveling). This facility was also ISO 14000 certified prior to June 1998. They have frequently utilized the assistance and services of TURI and OTA (Office of Technical Assistance). The EHS manager is not sure how "innovative and safety driven" management will continue to be under the new ownership. It is his feeling that the current owners may be more "down to business" with the "profit/shareholder/customer satisfaction" mindset. Therefore, since it is still transitioning from old leadership to new at the time of this study, this individual facility is discussed as a single case in this study (as opposed to evaluating the corporation as a whole).

There is a separate "risk manager" who handles occupational safety issues (OSHA compliance) such as workers' compensation, Hazard Communication, training, air monitoring, medical surveillance, etc. This person is part of the TUR team. All safety programs are in place and are modified as needed. A "Training Needs Identification Program" requires new employee orientation presentations. There is a Hazardous Waste Training Plan and an Environmental, Health, and Safety (EHS) Internal and External Communications Procedure (to communicate EHS and OHS news to all employees). Weekly occupational and environmental audits are performed by the EHS and OHS managers and/or supervisors of each production area, with any violations handled through the EHS Corrective Action Request Procedure. On occasion, the Vice President has been seen performing these safety audits. A checklist is filled out according to criteria, discrepancy, and corrective action, and remains a working document until the corrective action has been completed. Each department supervisor and some of the operators in that area perform self-audits as well. There are regular safety meetings where employees can discuss safety and health concerns.

Upper and middle management demonstrate leadership in OHS/EHS issues, and employee participation is considered to be important at this facility. Training is handled by each department supervisor and appears to be adequate and kept up-to-date. Employees appear to be skilled at their jobs and aware of the hazards they face. Injury and illness records are kept in order. Hazard analyses are performed regularly for each job, and are included in the standard operating procedures. Appropriate controls (engineering, and administrative controls) are in place for significant hazards. Quick response time to emergencies with investigation following each incident is general policy, with an emphasis on a preventive approach to both occupational and environmental health issues is made. In compliance with OSHA regulations, this facility has effectively implemented a safety and health program.

There is an in-house Emergency Response Team with trained members including engineers and operators. A formal approval process for new chemicals being considered for purchase and use is utilized. Company #1 does not have a formal safety incentive program. The Process Engineering Group is the primary implementation force for TUR at this facility, carrying out all technical and economic evaluation, and ultimate implementation. The exception is for those projects based in the wastewater treatment plant or other facility support areas, for which implementation is coordinated directly by the Environmental Services Group. Regular meetings are held (every two weeks) to discuss TUR progress, among other topics. The TUR team consists of managers and engineers, with informal solicitation for worker input.

Pounds of toxics used peaked in 1993, (considered an "inefficient" year), however pounds of toxic chemicals required per layer-adjusted panel produced in 1996 decreased from 2.06 lb/panel to 1.43 lb/panel in 1998, a 30.6% reduction (data for 1999 was not available at the time of this study). Company #1 has started seeing the effects of their TUR efforts.

TUR Interventions

The TUR interventions chosen for this study for Company #1 are the elimination of chlorinated solvents (1,1,1 trichloroethane) and the elimination of glycol ethers in outer layer resist processing and outer layer developing. 1,1,1 trichloroethane (TCA) was used to remove tape residue from circuit boards subsequent to gold plating. TCA was replaced with a terpene-based material with a more pleasant orange odor. The process machinery and work area needed little to no modification, as this was a "drop in" replacement.

Significant reductions of glycol ether use were achieved by converting to fully aqueous dry film in the outer layer resist coat/expose/develop/strip process. Specifically, fully aqueous dry films can be developed with potassium carbonate versus glycol ethers and stripped with a sodium hydroxide/monoethanol amine/coline mixture rather than glycol ethers.

Other TUR efforts at this facility include the replacement of tin/lead etch resist with tin only, resulting in a reduction of 33,000 pounds of lead over a three-year period. Company #1 also brought in new pretreatment recycling equipment (i.e., reverse osmosis), which decreased overall water demand by 30%. They replaced FREON 113, (which was used in the IPD area as a circuit board cleaner), with an aqueous cleaning unit. This was not a "drop in" replacement project. The new aqueous cleaner takes up more space, cost over $250,000 to purchase and install, and requires more time to process boards. However, because of the implementation of this TUR technique, a listed toxic chemical was eliminated, labeling rules required by the Clean Air Act were not necessary, and air emissions of volatile organic chemicals were reduced company wide.[5]

Future TUR efforts being contemplated by Company #1 include non-formaldehyde alternate hole metalization processes, eliminating lead in hot air leveling, and investigating VOC-free fluxes for hot air leveling.

B. Company #2

This facility is one of three technical centers of a national PWB manufacturing company with ten facilities located throughout the U.S. One of the other facilities in New England was scheduled to be ISO 14000 certified in May 2000, with plans for all sites to be certified by year 2002.

Company #2 is located in an industrial park. This non-union facility operates 5 shifts per week (first, second and third shifts on the weekdays), and is open 24 hours a day, with manufacturing shifts available six days a week, and the Environmental Health & Safety department available 7 days/week. It is considered a prototype shop, not a "volume" shop, producing approximately 1,500 multi-layer cores/day and shipping about 250/day. Being a lower volume shop and the prototype facility, their emissions do not go down every year, but they are involved in testing TUR projects for the other facilities. They specialize in military approved applications, and therefore must follow the military

5 Toxics Use Reduction Plan, 1998 (Company #1)

specifications for the product. Company #2 has a goal of 5% reductions in toxics used and generated annually.

The key informant for this facility was the EHS Manager. A separate safety specialist reports to the EHS Manager. This person handles occupational safety issues such as workers' compensation, Hazard Communication, OSHA training, chemical maintenance, and is also part of the TUR team. Other members of the TUR team include engineers, general management, technicians, and waste treatment operators. Company #2 performs air monitoring twice a year and as needed if a new process is introduced or an old process is changed. They also perform a comprehensive EHS audit twice a year. A list of 38 elements (or indicators),is used in this audit to help inspectors confirm compliance and "beyond compliance" status at the facility. There is an in-house Emergency Response Team. All safety programs are in place and updated as needed. As stated in the Employee Safety and Health Policy, the employees are regarded as the company's "most valuable asset" and the prevention of industrial injuries and illnesses is the ultimate goal. Company #2 does not currently have a formal safety incentive program; however there has been one in the past.

In accordance with the "Chemical Approval Process" for all new chemicals and products that would be purchased for their manufacturing processes, a team of process engineers, the safety specialist and the EHS manager work together to assess the hazards of each chemical being considered by obtaining information and data from the suppliers of each product (e.g., using MSDS's, Technical Data Sheets, etc.). This team also looks at chemicals' toxicity, cost, and frequency of discharge as part of this evaluation. This team can reject a new chemical/product for any "violations" of these criteria. Company #2 currently has a corporate policy not to introduce new chemical hazards into the workplace.

The EHS Manager demonstrates leadership in health and safety issues, however, from discussions with employees, there appears to be a feeling that upper management is not as supportive, especially when production is concerned. Employee participation is sought on some issues; however, employees are not generally part of the decision-making process when it comes to OHS/EHS concerns. Training appears to be adequate and kept up-to-date, although the workers interviewed felt it was "canned" and not very helpful. Employees appear to be skilled at their jobs and aware of the hazards they face. Injury and illness records are kept in order. Hazard analysis is performed regularly for each job (by the EHS and OHS managers) and included in the standard operating procedures; however not all employees are aware of changes in the SOPs. Appropriate controls (engineering, or practice, and administrative controls, and PPE) appear to be in place for significant hazards; however the employees find there to be numerous problems, and failures in equipment or systems. Chronic ventilation problems in certain areas were noted by employees, with dissatisfaction expressed relative to the response to their concerns by upper management. In general, quick response time to emergencies is the company policy; however, practice tends to be more reactive than preventive. Employees feel comfortable bringing safety and health problems up to their supervisors and to the

EHS Manager. In compliance with OSHA regulations, this facility has implemented a safety and health program.

TUR Interventions

The TUR interventions chosen for this study for Company #2 are the installation of a new acid recycling and recovery technology for the solder strip line and the use of a plasma etchback system (replacing sulfuric acid system).

Other TUR efforts include the elimination of TCA, tighter equipment control and higher free ammonia etching in inner and outer layer ammoniacal etch, resulting in reduction in ammonia use and elimination of anhydrous ammonia. Company #2 has also introduced a 90 percent ion exchange system for waste treatment, reducing the dependency on waste treatment chemicals. Future TUR efforts being considered by Company #2 include direct metalization (eliminating copper deposition) and carbon graphite immersion (etch and rinses).

C. Company #3

The last facility studied is a smaller facility that has been in business for over 30 years. There are approximately 130 non-union employees, about 70% of which have been there since the 1970's, and 30% of which are new, "transients" who often represent a larger employee turnover. The facility is approximately 63,000 square feet and is located in a large residential area. Three shifts operate daily. Annual sales are $12+ Million. Company #3's product is single/double-sided, multi-layered, rigid printed circuit boards ("Masters", or panels, containing 1 to 1,200 individual printed circuit boards). They manufacture both prototype and production volumes.

The EHS Manager (key informant) has the primary responsibility of environmental compliance, with additional duties in occupational health. This person's background is environmental engineering. Individual safety and health programs appear to be in place, however, there is no formal safety and health policy/program. Formal training in occupational safety awareness is sporadic, but is provided when each job warrants it (i.e., change in chemistry or process, etc). An outside consultant provides assistance on some occupational issues. Monthly safety meetings are held, but are not attended by all employees, mostly only newly hired employees. Informal inspections are performed by the EHS Manager throughout the plant, as well as an informal chemical evaluation when the company is considering using or producing new products. It is company policy to consider occupational health before anything else when looking at TUR options. Air monitoring is performed periodically (usually through the insurance carrier's audit process, two to three times annually). Hearing tests are given to employees annually. The Emergency Response Team consists of shift supervisors, maintenance personnel and operators.

The TUR planning team includes managers, engineers, technicians and operators, with solicitation for worker input. According to the EHS Manager, there has been continuous environmental improvement through improved maintenance throughout the facility, and

more efficient use of chemicals (e.g., less frequent process bath changes). Company #3 tries to conserve wherever possible in the facility, and to make things easier for the workers (i.e., installing new hoists over the baths to eliminate heavy lifting). One manager indicated that he believes the employees are the company's most important resource. The company considers liability (injuries) important, and seems to adopt a preventive approach to ensuring occupational and environmental health. Similar to the other study facilities, however, this company believes that they should not compromise quality in their processes, as they still have to meet customer needs.

The EHS Manager demonstrates leadership in health and safety issues, with upper management support. Employee participation is sought on some issues; and their input is considered relative to OHS/EHS matters. Employees appear to be skilled at their jobs and aware of the hazards they face. Hazard analyses are performed for each job and are included in the standard operating procedures. These hazards are communicated to the employees verbally and in written form. Appropriate controls (e.g., engineering, practice, and administrative controls, and PPE) appear to be in place for significant hazards. Quick response time to emergencies is the company policy, however, for large emergencies, outside assistance is solicited. Company #3's approach to both occupational and environmental health and safety is preventive.

TUR Interventions

This facility has been involved in many TUR activities throughout their operations. In their flow-through wastewater recycling process, Company #3 changed its reactant from ferrous sulfate (a TURA reportable chemical) to a non-toxic polyferric alternative. This not only eliminated the use of ferrous sulfate (1994 saw usage at 34,050 pounds), but the new chemistry also reduced the amount of chemical needed to $1/16^{th}$ of the ferrous sulfate usage. This chemistry modification also eliminated the need for additional reducing agents in the wastewater pretreatment system. The second TUR intervention was driven primarily by OHS considerations. Specifically, in their dry film development process, Company #3 changed to a less labor-intensive "feed-and-bleed" system, and replaced sodium carbonate with potassium carbonate.

Other TUR activities conducted at Company #3 include the elimination of TCA, replacement of tin for tin/lead etch resist, and the installation of a new ammoniacal etch machine, which resulted in the reduction of 6,000 pounds of ammonia in one year.

Future TUR projects being considered by Company #3 include replacing their electroless copper process with carbon graphite, etch regeneration, and switching from one ounce copper to ½ ounce copper, resulting in a 50% reduction in copper and etch.

V. RESULTS

A. OSHA PEP

As mentioned in Section II, the PEP is an educational document for workers and employers, as well as a source of information for OSHA's use and inspection process. It provides information on the effectiveness of an employer's health and safety program.

The PEP has been evaluated for OSHA[6] and endorsed as the instrument of choice to classify the general status of occupational health in a firm. Primarily used by OSHA enforcement agents, it collects data on required health and safety statistics, and focuses on six critical areas that are evaluated and scored:

- Management Leadership and Employment Participation
- Work place Analysis
- Accident and Record Analysis
- Hazard Control and Prevention
- Emergency Response
- Safety and Health Training

The areas evaluated are scored from one to five depending on the answers from the employees who take the survey. To ensure consistent interpretation and reliability between this study, and OSHA agents, the researcher has followed the detailed instructions accompanying the PEP document. The six-part survey was given to four to six managers or supervisors at each facility. These employees filled the survey out and returned them to the researcher in sealed envelopes. They were considered "managers" when preparing the OSHA PEP scoring tables. The employees, considered "workers" in the PEP tables, included operators, supervisors, and technicians. Rather than choosing the workers randomly, the key informant of each facility chose these employees because, for some employees, the English language is not their first language. The key informants chose employees who were affected by or who had worked in the area or process where the studied TUR interventions took place. The researcher personally interviewed the workers with questions based on the PEP survey (including all six elements) in order to achieve a more in-depth evaluation of the workers' perception of the health and safety status of their company. Their responses were translated into the PEP survey and scoring system of the PEP. The experience of the researcher as an occupational safety and health consultant was drawn upon to translate and apply this data.

For the purposes of this study, the researcher also personally interviewed several employees of each firm who were somewhat familiar with the TUR interventions adopted in their work area. Responses were then translated into the OSHA PEP, and scored accordingly. By interviewing the employees, the researcher hoped to obtain more descriptive and detailed information of the status of each company's health and safety program, based on the employees' perceptions. The employees were assured that their responses would not be disclosed to management in any other format than the scored PEP

6 Dr. Ruth Rutenberg, "Evaluation of the Program Evaluation Profile (PEP), Prepared for The Occupational Safety and Health Administration, Ruth Rutenberg & Associates, Inc., December 1997.

form. The employees were chosen by the key informant at each facility, based on their work relationship with the TUR interventions, and/or for their ability to provide insightful responses regarding the operations and production processes of the plant. The PEP questionnaire was designed based on the PEP evaluation tool and included parts of supplemental employee questionnaires also used by the OSHA consultation branch.

Table 2 depicts the final scores for both managers and workers of each facility in all six elements. Overall averages were determined for each element for managers and workers based on a normal scale (i.e., not rounded).

Table 2: Final Averaged PEP Scores

Level of Safety & Health Program	Averaged Scores
Company #1	
Managers	4
Workers	3.8
Average of managers and workers	***3.9***
Company #2	
Managers	3.6
Workers	3.2
Average of managers and workers	***3.4***
Company #3	
Managers	3.3
Workers	3
Average of managers and workers	***3.2***

Discussion

There is much detail in the results of the OSHA PEP survey and questionnaire that are not detailed in this report. General findings, however, have been determined and are presented below.

Analysis of Overall Scores

While the total averaged scores from Table 2 indicate that workers and managers are quite close in their perceptions of the health and safety status of their facilities, upon closer examination of the individual responses from the worker questionnaire, it is clear that some areas of the health and safety programs are lacking. We can make general comparisons between the scores of workers and managers; however, there may be bias on the part of the managers' scores, particularly since they scored the survey themselves. Management, in all three companies, was very aware of the companies' policies around safety and health, and felt strongly that they had an effective program. These personnel were either directly involved with making these policies (EHS and OHS managers), or were engineers or administrative personnel, and not part of the hands-on floor operations. The workers, on the other hand, were very involved with production and floor operations, and could provide detailed information on their knowledge of health and safety programs according to their jobs and their immediate work environment. Thus, there will be some obvious differences between managers and workers' responses, simply because of the position they hold in the company.

In our evaluation of the PEP scores, we find that all three facilities' average total score was between 3 and 3.9 (including both managers and employees). According to the OSHA guidelines for the PEP survey, this indicates that each facility has implemented an OHS program. Average manager scores were consistently higher than worker scores. Company #1 scores for both managers and workers were very close in all elements surveyed, thus resulting in the smallest difference between manager and worker scores (0.2).

It is more difficult to see a trend in the responses of the workers because of the varied work experiences of each respondent. We do see, however, that the workers more routinely scored lower than the managers in most elements. Again, this is most likely due to the fact that it is the workers who are more affected by the requirements of the company safety and health program, and experience its limitations first hand.

Detailed Analysis by Company

The average scores of each company (combined managers and workers), when compared to the other companies' scores, indicate that Company #1 scored the highest with an overall score of 3.9. Company #2 scored the second highest with 3.6, and Company #3 scored the lowest with 3.2. As described in Section IV above, Companies 1 and 2 are the largest of the three facilities. There is an EHS and an OHS manager for each, with the EHS manager taking the lead on TUR activities. Company #3 is a smaller company with fewer personnel and resources to accommodate both OHS and EHS concerns.

Company #1: The above scores indicate that both managers and workers agree that the health and safety program at their facility is superior according to the OSHA PEP evaluation system.

The workers interviewed have each been with Company #1 for over 12 years. Their jobs range from group leader of wet processes, technician in the plating area, waste treatment operator, and supervisor of the analytical lab. They are all somewhat familiar with OSHA standards and are comfortable bringing problems to their supervisors at any time. They all felt that management supported health and safety and met the needs of the employees. They also believed that the safety committee programs are effective in including worker concerns with management decision-making. Some thought the training sessions could be more interesting, however most found them to be helpful. They all generally agree that toxics use reduction efforts have led to a safer work environment for employees.

Company #2: There is a larger difference in scores between the managers and workers at Company #2. More workers responded individually in the 2 and 1 range, indicating that they felt some aspects of the health and safety program are still developmental. As stated earlier, this variation could be due to the experience and perception of the workers, as production operators, and their "hands-on" dealings with health and safety issues in their area.

Employees interviewed held positions as process group leader, waste treatment operator, and chemical lab technicians. Most have been with the company for 1 to 5 years, with one individual having been there for 13 years. There is a general consensus that management attends to safety concerns, but that they do so more in a "reactive" rather

than proactive approach. Highly hazardous safety concerns are addressed quickly; however, some safety issues remain a problem. Three workers stated there is a chronic problem with the ventilation system in their area, and that it has still not been completely fixed. Most of the workers are not involved in the safety committee meetings, and those who are feel it is not very effective in changing things at the plant. According to these workers, their participation in decision-making around occupational and environmental issues is not encouraged. Workers do feel the company has a good emergency response program.

Most of the employees believed that while upper management verbally stresses that safety is important, they did not follow through with actions of support when needed, especially when production was involved. These workers felt that production was the most important issue to upper management and that it comes before any other concerns. Two of the workers said they thought the OHS and EHS managers do a good job around occupational and environmental safety; however, they are not given adequate authority to override production decisions.

Company #3: While more of the managers' individual responses scored in the superior range, more of the workers' responses scored in the developmental range. When averaged, the scores for both managers and workers fell into the implemented range.

Workers interviewed were primarily operators in the dry film and imaging production areas, and in quality assurance. They have been with the company between 8 and 21 years. These employees are not very familiar with particular OSHA standards; however, they are aware of general hazard communication and personal protective equipment requirements. They tend not to be aware of a formal written health and safety program. The general feeling is that management supports health and safety in the plant, and that the opinions of the employees are considered when making decisions around occupational and environmental issues. All employees felt comfortable bringing up safety concerns with management. There seems to be an awareness of toxics use reduction, and that management wants to eliminate toxic chemicals in the plant as much as possible.

One employee felt that safety concerns were not addressed until they were a real problem. This employee believed that upper management sometimes dismissed safety concerns when they thought they weren't critical. Based on the experience of this individual, upper management did not have the "safety mindset" to consider safety first. This person also felt that requirements around personal protective equipment were not always met, and that the supervisors sometimes did not comply with these requirements.

B. P2OASys – Overall Scores

The second survey instrument, the Pollution Prevention Option Analysis System (P2OASys) was used to perform both contemporary P2/TUR and retrospective P2/TUR impact evaluation. This tool allows us to measure the P2/TUR intervention impact, by deriving a semi-quantitative evaluation of the changes after the TUR intervention. In this way we are able to see a before and after "picture" of the TUR intervention.

Table 3 summarizes the results of each TUR intervention with a numerical score for the current technology (before TUR) compared to the alternative (after TUR). While the table appears to indicate changes in chemistry only, details of the TUR intervention show

there were some process changes as well that lead to lower ergonomic hazards, lower worker exposure potentials, and to reductions in energy use.

In each case below, the alternative, or the TUR option adopted, resulted in a lower score than the current technology, indicating that based on all elements measured by the P2OASys, the alternatives chosen were indeed less hazardous.

Table 3 ***Final P2OASys Scores***

Pre / Post TUR	Company #1 PEP Ave 3.9		Company #2 PEP Ave 3.4		Company #3 PEP Ave 3.2	
Before TUR	Glycol Ether	52	Sulfuric Permanganate	86	Ferrous Sulfate	61
After TUR	Potassium Carbonate	38	Plasma Desmear	33	Polyferric Sulfate	30
Difference	**- 14**		**- 53**		**- 31**	
Before TUR	1,1,1 Trichloroethane	63	Old solder strip system	40	Sodium Carbonate	50
After TUR	Terpene	48	New solder strip system	14	Potassium Carbonate	28
Difference	**- 15**		**- 34**		**- 38**	

Company #1 replaced glycol ethers with potassium carbonate in the dry film and outer layer development processes, resulting in a lower score for chronic human effects and physical hazards. These two differences in scores are weighted automatically and result in a lower score for the potassium carbonate. The importance of considering chronic human effects and physical hazards when looking at TUR alternatives is represented by the final score, giving glycol ethers a 52 and potassium carbonate a 38.

For the second TUR intervention of switching from TCA to a terpene-based cleaner/degreaser, the terpene alternative scored lower in acute and chronic human effects, physical hazards, and disposal and chemical hazards. With a final score of 63 for the TCA, and a 48 for the terpene, it is evident that the TUR alternative was a good choice.

Company #2 replaced the old sulfuric acid/permanganate desmear with the plasma desmear, a complete process change. This resulted in a lower score for all elements of the P2OASys. The second TUR project of installing a new solder strip system that recycles the used nitric acid, also resulted in a lower score, particularly within the elements of physical hazard, disposal hazard, energy use, and exposure potential.

Company #3 switched from using ferrous sulfate to polyferric sulfate in their waste treatment operations, which resulted in a lower score for both acute and chronic human effects, for physical and chemical hazards, and for exposure potential to workers. In the dry film development process, this company went to a “feed and bleed” system and replaced sodium carbonate with potassium carbonate. This resulted in a lower P2OASys score in acute human effects, physical hazards, disposal hazard, and exposure potential.

In all three cases, the TUR alternative chosen resulted in lower hazard scores than the current technologies.

B. P2 OASys – OHS Elements

As already mentioned in our description of the P2OASys, there are six elements that measure for changes in occupational health and safety when considering TUR options. The tables below illustrate the scores for these six elements with a final score for each "before and after" TUR intervention.

Table 4. Hazard Score, OHS Elements: Company #1

Hazard Score Table	Pre TUR	Post TUR	Pre TUR	Post TUR
	Glycol Ether	Potassium Carbonate	1,1,1 Trichloroethane	Terpene
Category	**Score**	**Score**	**Score**	**Score**
Acute human effects	6	6	9.5	8
Chronic human effects	10	2	8	4
Physical hazards	8	2	9.5	4
Chemical hazard	8	8	10	9
Product hazard	2	2	2	2
Exposure potential	6	6	6	6
Final	**40**	**26**	**63**	**48**

Table 5. Hazard Score, OHS Elements: Company #2

Hazard Score Table	Pre TUR	Post TUR	Pre TUR	Post TUR
	Sulfuric-Permanganate	Plasma Desmear	Old Solder Strip	New Solder Strip
Category	**Score**	**Score**	**Score**	**Score**
Acute human effects	10	6.5	0	0
Chronic human effects	8	0	0	0
Physical hazards	10	2	10	6
Chemical hazard	10	7	0	0
Product hazard	10	0	0	0
Exposure potential	10	6	10	6
Final	**58**	**21.5**	**20**	**12**

Table 6. Hazard Score, OHS Elements: Company #3

Hazard Score Table	Pre TUR	Post TUR	Pre TUR	Post TUR
	Ferrous Sulfate	Polyferric	Sodium Carbonate	Potassium Carbonate
Category	Score	Score	Score	Score
Acute human effects	10	8	10	6
Chronic human effects	6	4	0	0
Physical hazards	8	6	10	4
Chemical hazard	9	6	10	10
Product hazard	10	0	0	0
Exposure potential	10	6	10	2
Final	**53**	**30**	**40**	**22**

In all three companies, the scores for the OHS elements of the P2OASys were lower after the TUR intervention. While not all OHS elements could be filled in for each process (current technology vs. alternative) due to lack of systematic technical and chemical databases for each process and/or chemical change, our results do show in each case, that the TUR intervention lead to a less hazardous OHS situation. This indicates that the TUR intervention did have a positive impact on occupational health and safety. However, the overall effect cannot be determined, since the assumed value of zero for those elements that could not be completed due to lack of information let to an overstatement of TUR gains.

C. Open-Ended Questionnaire

The following points highlight the responses of the key informants of each facility regarding the causes of the occupational health changes attributable to the TUR interventions. By interviewing these individuals, we are able to understand the firms' perspective on the effects of the TUR intervention on occupational health, as well as discover the limitations and potential of the P2 intervention for this purpose. We are also able to gain insight regarding additional opportunities for improvement of the work environment, operational methods to achieve integration of P2/TUR and occupational health in one intervention, identification of personnel that could help conduct the integrated intervention, and how to evaluate the performance of the integrated approach.

Company #1

- Positives: TUR (reduction or elimination of chemicals) leads to less exposure to employees.

- The TUR option must include aspects of worker safety and health; there should be a check system for all chemical, process or equipment changes in plant to evaluate both EHS and OHS risks; all employees involved in the change should be included.

- An integrated approach can be measured by toxic chemical use, IH monitoring, injury and illness reports, and employee feedback.

- A successful integrated approach must include consistent participation of all employees, from process engineers to operators on the floor. There must be top management support.

Company #2

- EHS and OHS are equally important; and therefore there is neither a positive nor a negative impact of one over the other.

- Costs associated with each P2/TUR option (both EHS and OHS) are important, where anticipation of potential problems must be considered (environmental and occupational health impacts).

- A successful integrated approach must incorporate a system where the P2/TUR option is evaluated by all employees affected by the change, including project managers, process and product engineers, department supervisors, operators, quality control, purchasing, the controller, the business unit manager, and even suppliers of the equipment.

- A company needs to be aggressive with SOP's that spell out internal requirements for evaluating P2/TUR options.

Company #3

- It is company policy that worker safety comes before TUR, that's why it's important to consider them both together and not separately. Some TUR options actually lead to increased risk to the employees and should not be considered.

- Generally TUR positively impacts worker safety and health, but cost is always a large part of the decision.

- An integrated approach can be measured by tracking toxics reduction, but more importantly, by talking to the operators and getting feedback on how the process is working.

- A successful integrated approach must be preventive, in that both EHS and OHS risks are considered up front, and all stakeholders are involved in the process (both management and employees).

- An integrated approach must include EHS and OHS equally (i.e., not driven by one over the other.) It must be preventive, not just reactive. TUR alone is not enough. It is driven by the pollutant and only in large amounts. Companies must act in good faith to reduce both EHS and OHS risks but don't get credit for doing continuous improvements. A program needs to address the role a small business takes to go "beyond compliance" in both EHS and OHS areas.

VI. DISCUSSION / OBSERVATIONS

The instruments used in our case study evaluation give us a context within which to evaluate, at the corporate level, the effect of environmental intervention programs on occupational safety and health. In our analysis above, the methodology used provides a systematic, reasonable quantification of the change in occupational health attributable to P2/TUR. As a result of our analysis, we realize that it is important to consider and incorporate both environmental and occupational concerns from the beginning when implementing intervention strategies.

The results of the OSHA PEP scores indicate the level of sophistication and the effectiveness of the OHS program at each facility. While the focus of this study was not to strictly evaluate the health and safety records of each of the companies, the researcher's OHS evaluation of each facility, including discussions with the key informants, as well as the managers' responses to the PEP survey, provide insight into the details of the OHS program as it has been designed and implemented by management. The responses of the workers allow for additional analysis of the effectiveness of the company's OHS program. The workers, or operators on the plant floor, are more affected by the daily safety requirements of their jobs and therefore provide a more detailed description of how the OHS program applies to them. We are able to observe first hand, the opinions of the people affected by the TUR change and the effect of that change on their work environment.

It is useful to begin our evaluation with an assessment of the facility's OHS program. By doing this, we are able to determine how sophisticated the company is regarding occupational health issues. By then bringing in the P2OASys survey, we are able to begin our analysis of the relationship between occupational and environmental health. We can evaluate how the sophistication of a company's OHS program relates to the success of an environmental intervention program. In other words, is the success of an environmental intervention program contingent upon a superior OHS program? In what way does the OSHA PEP predict positive impacts of P2 interventions on worker safety and health? Would the difference in P2OASys scores be less dramatic in companies with lower PEP scores? Do high PEP scores and increased improvement in P2OASys scores indicate greater integration of OHS and EHS? To what extent does worker health and safety motivate TUR and what are the benefits to workers from TUR? What roles do individual personalities, corporate organization, and worker participation play in motivating companies to consider both occupational and environmental health issues when adopting TUR options?

While the answers to some of these questions are broader than the scope of this research project, we are able to make some conclusions based on the tools used and the information gathered regarding the relationship between environmental and occupational health at the corporate level.

- The higher the overall OSHA PEP score, the more sophisticated the company is around safety and health issues in general.

- Lower PEP scores and large differences between managers' scores and the workers' scores indicate that the company OHS program is inefficient in more than one area.
- The companies whose managers and workers both scored high in the PEP survey (scoring 4 or greater) are usually more "proactive" around occupational and environmental issues and already adopt a preventive approach toward both concerns.
- Companies with higher PEP scores tend to have personnel with stronger backgrounds in safety and health (OHS) and toxics use reduction (EHS).
- Companies with lower PEP scores may lack the resources and skills needed to provide an effective OHS program.
- Smaller companies may not have the resources to carry out the integration of OHS and EHS concerns.
- Large differences in P2OASys scores (before and after the TUR intervention) indicate a more successful reduction in hazard and exposure potential after the TUR option has been adopted.
- The P2OASys demonstrates that chemical substitution and process change result in parallel reductions of both occupational and environmental hazards.
- P2/TUR interventions are not usually driven by OHS needs.
- In the cases discussed in this study, P2/TUR has had a positive impact on OHS, however the focus of TUR lies on the general environment, not the work environment, and the overall effect on TUR could not be definitively determined.
- Industry in general looks at TUR as a way of complying with hazardous waste regulations and to reduce costs associated with waste disposal.
- Having to think about toxics use reduction does seem to encourage companies to consider both environmental and occupational health concerns simultaneously.
- Conscious integration of EHS and OHS is due to the foresight and preventive approach and philosophy of the company and its employees.

VII. RECOMMENDATIONS

A. General Recommendations

By looking at three manufacturing facilities for which compliance with the Toxics Use Reduction Act in Massachusetts is vital for improved environmental performance, we are able to explore the model of primary prevention and how it relates to both environmental and occupational health. As we see, P2/TUR appears to positively affect occupational health, whether intentionally or inadvertently. TUR has the ability to shift environmental and occupational health strategies from control to prevention, where exposure prevention precedes exposure control. Pollution prevention and TUR embrace primary prevention and link environmental and occupational health together. While we have attempted to demonstrate the important link between environmental and occupational health through the findings of our study, we come to the conclusion that the shift from control to prevention must emerge as one integrated, holistic strategy to promote primary

prevention as part of a comprehensive public health model, including environmental and occupational health.

Although this case study analysis is limited to three study cases, it has allowed us to create and utilize a sequential model including tools that support the process of OHS/EHS integration. The OSHA PEP manager survey and employee questionnaire provide us with a benchmark of each company's occupational health and safety status. With this information and with the use of the other tools, we can begin to evaluate the relationship between a company's OHS condition and their environmental performance.

Ideally, this study should be expanded to evaluate a larger study population of companies, so that more statistical analysis can be performed. In a larger study over a longer period of time, it would be beneficial to look at a company's OHS status both before and after the P2/TUR intervention, giving us more data to measure the impact over time of the environmental intervention on occupational safety and health. Injury and illness rates over a specific period of time should be evaluated as an additional indicator of the relative health of the companies. Future research could also focus on the difference between P2OASys "before and after" scores. Comparisons of the PEP scores and the P2OASys differences would also test the predictability power of the PEP scores. Finally, comparisons could also be made between the PEP scores and the OHS elements of the P2OASys, to determine if improvement in these areas indicate a higher integration of OHS with EHS.

When considering TUR options, the priority is mainly placed on the general environment over the work environment, thereby highlighting even further the disparity between workplace-focused and environment-driven approaches to TUR. Based on the results of our study, recommendations can be made on the minimal needs of a firm in their occupational health function necessary to sustain positive effects of environmental interventions such as TUR, and in their environmental health function necessary to consider occupational health risks as well. These recommendations describe the theoretical and operational steps necessary to initiate a P2/TUR intervention program including meaningful participation of the entire workforce and essential consideration of occupational health concerns.

The facilities evaluated in this study have begun the process of incorporating OHS elements into their P2/TUR programs. Some have done it through informal methods and some have made a more formal attempt to consider OHS concerns when adopting TUR options through written programs and standard operating procedures. By understanding what has motivated our study companies to consider OHS when evaluating TUR options, we are able to offer recommendations, based on their efforts, successes, and shortfalls, for achieving superior environmental performance along with reduction in occupational safety and health hazards.

B. Recommendations for Corporations

On the corporate level, the following recommendations are offered:

Organizational

- Corporations need to combine or merge OHS and EHS departments and allow an equal voice to each when considering TUR options for the company. However, in this context, creating a new centralized department and assigning OHS/EHS functions to this department alone, may have the effect of setting up another layer of organizational bureaucracy. We do not want to generate more "turf wars" in this setting or send the message that OHS and EHS issues are the job of the people in that office, meaning that other personnel should focus only on their own primary production and other responsibilities. Instead, the goal is to create an internal office where personnel skilled in all levels of the organization (not just OHS/EHS) are able to promote and assist operational and production staff in making the day-to-day decisions that must naturally consider all aspects of the business as a whole, including the elimination of potential occupational and environmental hazards. In this way, one department will not be making "trade offs" with another, thereby sacrificing safety and good health for production or cost savings.

- As stated above, OHS/EHS personnel should be part of the upper management corporate structure and should have equal status with production management personnel.

- Costs and benefits to both environmental and occupational interventions must be considered mutually, considering long-term real as well as potential savings of adopting TUR options.

Program Implementation

- Formal programs should be developed that integrate internal and external OHS and EHS requirements for compliance with both OSHA and EPA regulations.

- Companies need to raise awareness about P2/TUR by requiring internal safety training to consist of cross training in EHS and OHS subjects, particularly on how chemical and/or process changes can affect both environmental and occupational health outcomes at the facility. In general, if an employee is empowered with the knowledge they need to make educated decisions about the chemicals they are using, and how these chemicals affect the production process, then they can make a huge contribution to the company's ability to find alternatives that in the long run will save the company money, and reduce risk all around.

TUR Team Structure

- TUR teams should include active participation from both OHS and EHS personnel.

- Top management should show support and commitment for environmental and occupational health by becoming involved in the TUR process and participating in decision making on the same level as all other participants. The goal should be to build an internal safety consciousness that begins with visible support from the top.

- TUR teams should include active participation of operators and shop floor workers, and must incorporate their perspectives into decision-making and TUR program development. This will support a more inclusive and participatory approach to safety and health where the concerns of all stakeholders are taken into consideration, and will ensure that each participant will "buy into" the efforts of the company to act responsibly in environmental and occupational health issues.

- TUR teams should look outside the realm of regulatory compliance and simultaneously consider reducing or eliminating use of toxic materials that adversely impact environmental and/or occupational health at the facility. This will ensure an integrated approach by evaluating these impacts equally for health effects, and not just for compliance purposes.

C. Recommendations for TUR Planning Activities

While this study focuses on opportunities for manufacturing facilities to achieve success in their "beyond compliance" efforts in both occupational and environmental health, general recommendations for future TUR planning activities can also be made.

- OHS needs to be formally integrated into programs like TUR and P2, so that companies will be required to automatically look at both OHS and EHS together. While TURA requires that covered facilities do not "shift risk" to other stakeholders, such as workers, there is no formalization or "recommended methods" of achieving this in any other segments of the law.

- Cross training in both OHS and EHS within and between occupational and environmental agencies is necessary in order to increase awareness about the need to address: (a) risk transfer to workers when evaluating and documenting pollution prevention interventions; and (b) environmental impacts when evaluating end-of-pipe industrial hygiene interventions.

- State P2 assistance programs should offer more comprehensive services, including evaluations of work environment exposure impact of P2 interventions.

- Additional tools need to be developed (similar to the P2OASys) that will help companies to evaluate the impact of TUR interventions on both occupational and environmental health at and outside their facilities.

VIII. SUMMARY

The purpose of this study was to evaluate the occupational health impact of pollution prevention interventions designed to prevent environmental hazards. While traditionally there have been divergent paths of practice for occupational and environmental health concerns, the two are closely connected. It is important, however, to consider the implications of risk transfer between the general and work environment. In order to avoid this risk shifting, OHS perspectives and goals must be more clearly incorporated into TUR legislation and training, making sure to always consider the effects of TUR and P2 on occupational safety and health. In turn, TUR and P2 must also be incorporated into OHS programs designed to promote hazard prevention as opposed to hazard control. While some environmental programs have included attention to OHS, such as Massachusetts' TURA, and EPA's Design for the Environment, OHS intervention programs seldom include simultaneous consideration of environmental hazards. There is a need to join the objectives of prevention-driven strategies such as toxics use reduction with similar work environment strategies to prevent occupational injury and illness.

This study7 has been an attempt to begin discussion around the effects of environmental intervention programs on occupational safety and health. We realize now that while P2/TUR reduces exposure to toxic substances in the general environment, it also offers unique opportunities to reaffirm primary prevention principles in occupational health.

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7 For additional information, contact the authors to obtain a copy of the full masters' program thesis, which discusses the methods and results more fully.