United States
Environmental Protection
Agency

Enforcement and
Compliance Assurance
(2225-A)

EPA-300-R-97-001
March 1997

EPA

Identification of Pollution Prevention (P2) Technologies for Possible Inclusion in Enforcement Agreements Using Supplemental Environmental Projects (SEPs) and Injunctive Relief

Final Report

The research underlying this report was supported by the Office of Enforcement and Compliance Assurance, U.S. Environmental Protection Agency, through a cooperative agreement (Grant No. CR 819086-01-2) between MIT and EPA. The opinions and recommendations contained in this report do not necessarily represent the views and policies of EPA or MIT.

Identification of Pollution Prevention (P2) Technologies for Possible Inclusion in Enforcement Agreements Using Supplemental Environmental Projects (SEPs) and Injunctive Relief

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Abstract

Pollution Prevention (P2) is generally recognized as the preferred strategy to address environmental issues linked with industrial activity. Through a combination of various regulatory and incentive mechanisms, EPA can influence the adoption of P2. In this report, we describe a methodological approach for the identification of promising P2 technologies for possible inclusion in Supplemental Enforcement Projects in the context of Enforcement Settlements. The methodology offers a practical strategy for future application in the construction of pollution-oriented inter-sector prioritization schemes. We also demonstrate the search methodology in the identification of eight Standard Industrial Classification (SIC)-specific and four general-purpose P2 technologies.

More specifically, this report describes the screening criteria and proposed screening methodology in the identification of high-priority industrial sectors/industrial processes and product lines. These high-priority areas present a high potential for tangible environmental benefits if P2 technologies are implemented.

The relevant sources of information for this study came from the open literature, EPA publications on P2 and on enforcement, international compendia of P2 case studies, technical handbooks on P2, international on-line data bases, Internet-sites and interviews with EPA officials and researchers active in P2.

As a final task we discuss various innovative delivery mechanisms for the transfer of P2 technology. We believe that Internet-based systems possess great potential as platforms of cost-effective high quality P2 technology transfer.

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I. Introduction

A. Purpose of the Investigation

The purpose of this investigation was to identify new or unexploited P2 technologies that offer significant opportunities for environmental improvement in specific industrial sectors/processes/product lines that could be the focus of P2 SEP/injunctive relief initiatives.

The following tasks were to be undertaken:

(1) identify major or serious sources of pollution associated with specific industries, industrial processes and product lines where the dominant technology in widespread use has remained essentially unchanged over the recent past.

(2) identify promising P2 technologies in industrial processes and product lines that could offer significant improvements in environmental benefits, with special emphasis on multi-media improvements.

(3) identify those problem industries, industrial processes, and product lines--with special emphasis on small and medium size enterprises (SMEs)--which are in special need of technical information and assistance regarding P2 solutions and whose access to this information or assistance from trade associations, in-house expertise or R&D departments, or connections with universities and research institutions is limited.

(4) develop criteria related to both agency and firm concerns and characteristics for successful inclusion of specific technologies and technological approaches into SEPs and injunctive relief settlement agreements. These criteria include behavioral and economic factors.

(5) identify those technologies that show particular promise for more widespread adoption in or transfer to specific industrial processes or product lines through SEPs and injunctive relief settlement agreements.

(6) identify innovative delivery mechanisms for the transfer to needy firms of technical information and assistance related to P2 technologies. These might include expert systems, data-bases and written information.

B. General Approach

The major objective of the project, represented by Tasks 1-5, was to uncover major Pollution/Accident Prevention Opportunities (P2/AP) that have both:

- significant potential for multi-media pollution/accident prevention benefits in 5-10 industrial sectors/industrial processes/product lines, especially sectors dominated by small or medium size enterprises, and

- features that make favorable their inclusion in enforcement settlements, e.g., relatively proven technologies, limited implementation horizon, significant capital expenditure.

We sought to address *Gradual Releases* of pollutants with *Pollution Prevention* strategies, while *Sudden Releases* would be addressed by *Accident Prevention* strategies.

An additional goal of the project (Task 6) was to identify innovative delivery mechanisms for the dissemination of technological information related to P2 technologies to needy firms.

C. Identifying the Universe of P2/AP Opportunities

The first step in our effort was to identify the Industrial Sectors/Industrial Processes/ Product Lines that present both serious pollution problems <u>and</u> significant potential for improvement. This potential is defined by technological options that either exist in full operation in other areas (requiring diffusion or incremental innovation for their adoption) or exist only in bench scale/pilot plant scale thus requiring a largely innovative response).

The first historical integrated effort to map P2 (though not AP) opportunities across different industry types is found in an 1986 OTA report [1]. There OTA presents the opportunities for: 1) operations changes, 2) in-process recycling, 3) process changes, 4) input substitution and 5) end product changes, across different industry types.

The methodology we use builds on the OTA approach; however, we extend our research so as to cover:

- accident prevention opportunities
- industrial process and product lines in addition to industrial sectors.

In Table A1 of the Appendix we present, for comparison purposes, other methodological approaches to prioritization [2]. They focus predominantly on a substance-specific hazard/risk analysis, and only secondarily --if at all-- on technological opportunity criteria. We do not make use of these data.

The only scheme that is close to a technology/opportunity-focused approach is [3], where the purpose is: *"to identify a short list of industries or industrial segments or even generic technologies, that present: the most significant environmental problems or risks, and the most significant opportunities for waste reduction."*

However, this multi-attribute approach of the EPA Risk Reduction Engineering Laboratory (RREL), does not address accident prevention. With reference to the P2 area, the technologies we ultimately identified through our screening did include some found in RREL publications, although not all in the RREL list were suitable for the SEP enforcement implementation approach.

These methodological distinctions having been explained, we can now proceed with more detailed discussion of our approach, which begins by identifying both (1) pollution/accident problem areas and (2) stagnant technology.

1. Pollution/Accident Problem Areas

Strategies focusing on problem pollution identified:

- *Specific Industries*, based mainly on Standard Industrial Classification (SIC) classification. Of interest were pollution problems that a large number of firms within the SIC is facing. For example, all the Metal Finishing Industry (SIC 3471) is characterized by high concentration of metals in the waste streams; thus the existence of a technological strategy addressing this problem represents a widespread beneficial potential for this SIC.
- *Specific Industrial Processes*. These processes were encountered in many *different* industrial sectors, and in each of them the process used (the "practice") and the resulting environmental problems are essentially the same. For example, the electroplating process, which is the most problematic process concerning the Metal Finishing Industry (SIC 3471) is also encountered in various others industrial sectors. The automobile industry (SIC 347), in particular, is using extensively electroplating procedures in auto-parts manufacturing. Therefore, the locus of the electroplating process is much wider than can be assigned by a rigid SIC-oriented prioritization scheme.

At this point it is useful to distinguish Primary, Secondary and Ancillary processes.
In previous work for EPA [4] we have defined these terms as follows:

"a primary process is one that defines the product and yields its key functional property(s) (e.g., metal casting in the case of a steel bolt); a secondary process is one that is not primary to the function of the product but serves a supplemental function (e.g., the metal plating of the part which provides a non-corrosive or esthetically-pleasing finish), and ancillary processes are cleaning, degreasing, defluxing and similar operations which are often necessitated by the choice of primary and secondary processes (e.g., use of a chlorinated organic solvent to remove an oil-based metal cutting fluid)."

Applying these definitions to our example, electroplating in a job shop comprises the primary (core) technology in use, while it is a secondary technology in automobile manufacturing. Obviously, secondary processes are not unimportant, but industry may be more interested in undertaking innovation in core technology than in secondary or ancillary technologies. This is because core technology innovation may offer many different kinds of benefits in addition to reduced need for pollution control, such as reduced material and water costs and energy conservation.

Although our previous study [4] indicates that most SEPs in P2 that were included in settlement agreements involved diffusion in secondary/ancillary processes, one important conclusion was that enforcement could be used to prod the firm into considering innovation in the core (primary) technology.

- *Specific Product Lines*. In this case, in spite of the fact that the pollution profile of a particular industrial sector does not present major pollution concerns, a specific product line in that sector imposes high pollution loads may exist. A typical example of this is found within Pharmaceuticals (SIC 2834): Most of the world's production of $LiAlH_4$ is consumed in the production of cimetidine (an ulcer medicine of SmithKline Beecham), with obvious consequences for the waste stream. The existence of an alternative raw material (or intermediate) that would dictate a different synthetic pathway would contribute in the significant reduction (or the complete phase out) of the $LiAlH_4$ used in the specific product line [5].

2. Stagnant Technology

We attribute great importance to the technological stagnation concept because this can be a good indicator of the opportunities for P2/AP. Sectors/processes characterized by stagnation are an obvious choice for regulatory intervention encouraging technological progress. Although it may be the case that no innovation is possible in the area, in the vast majority of the cases the potential for progress is huge (at least in the form of simple technological diffusion) and the stagnation must be attributed to the lack of willingness (i.e., culture and attitude) and/or capacity (i.e., skill and knowledge) of the firms concerned.

Regulatory mechanisms, and enforcement settlements involving penalty mitigation in particular, represent the ultimate opportunity for progress P2/AP-wise for these "laggard" firms or technologies.

On the other hand, industrial sectors which are by nature dynamic and innovation-driven, where success is mainly based on extensive R&D expenditures, are not likely to need the direct interference and leverage from the Office of Enforcement and Compliance Assurance (OECA). In the case of these firms, EPA needs to provide clear goals and a clear time-horizon; the firms themselves are likely to be able to undertake the appropriate technological advances.

On that point, it reserves repeating that our research seeks to address <u>both</u> the gradual and the sudden releases of pollutants. The Sectors/Processes/Product lines that represent opportunities for P2 may be distinct from the Sectors/Processes/Product lines that exhibit AP potential. This is explained by the fact that firms may be innovation-driven to prevent pollution but not accidents. To elucidate this idea, we will use the Organic Chemicals Industry (SIC 286) and the Petroleum Refineries (SIC 291) as examples. These sectors are, economically speaking, very dynamic; they include many big firms with extensive in-house expertise and high R&D expenditures; and they base their success on frequent innovations either in their end products or their processes. Nevertheless, all this innovation is focused on the utility of their marketable products and they tend to neglect, or at least not to promote at comparable rates, innovation in inherent safety in their processes/product lines [6]. Because of this, the enforcement mechanism can leverage innovation in AP technologies even in areas that would not normally be considered in need of technical assistance or regulatory prodding.

We must also emphasize that the concept of stagnation is very difficult to quantify in a general manner (i.e., based on Statistical/Census data); this is because *economic* stagnation, although easily quantifiable, may not be indicative of *technological* stagnation.

<u>3. Next Steps</u>

Having identified a number of problem areas and stagnant technologies ripe for change, we then proceed to call out candidates according to criteria related to the SEP/enforcement requirements. This is discussed in the next section.

D. Criteria Related to Enforcement Concerns Regarding SEPs and Injunctive Relief.

We here focused on the subset of the high potential industrial sectors/processes/product lines identified previously with the following characteristics:

1. Technically implementable P2/AP technologies successfully addressing the specific problems of these sectors/processes/product lines *that already exist.*

2. P2/AP technologies that are also suitable for inclusion in enforcement settlements.

3. Those P2/AP technologies that can offer multi-media improvements, including worker-protection.

The term "technically implementable" in the first criterion means that any specific technology to be proposed/promoted is either in industrial use in some other sector/application (thus requiring diffusion or incremental innovation for widespread adoption) or at least is proven and accepted in *pilot plant scale* (requiring innovation). In any case, the scientific and engineering principles are well-defined and broadly understood. It is undeniable that *bench-scale* technologies are not yet suitable for inclusion in enforcement settlements as their risky implementation is insupportable both for the firm and the agency.

It is neither unexpected nor a negative consequence that the finally chosen technologies will be more diffusion than innovation oriented. On the contrary, it is compatible with the nature of the SEPs and the mindset/culture of the people that will be called to implement them [7]. Nevertheless, even if diffusion of proven technologies is the only mechanism of P2/AP to be effectively promoted, this is a huge improvement if put in the perspective of the very recent past [7].

Other attributes of a technology, in addition to the relatively low risk of technical failure, that makes it suitable for inclusion in SEPs and/or Injunctive Relief are the following:

- the implementation period of the SEP is of the order of one year (typical duration of agreements of that kind),

- the implementation of the technology should involve a sizable capital investment on the part of the firm, in order to qualify for a penalty mitigation agreement.

A third characteristic is that there be multi-media (MM) benefits resulting from the promoted technology. The term medium may refer to: (1) water, (2) air, (3) waste stream or (4) worker exposure (i.e., occupational health and safety).

The fact that we emphasize the MM-benefits does not mean that we overlook any single-medium technologies with very significant beneficial effects. Our emphasis on MM benefits is justified by two reasons:

- We want to avoid media-shifting technologies. That is, although technologies may seem to cope very efficiently and cost-effectively with a single-medium pollution/accident problem, they may actually shift the problem to another medium, e.g., reduce emissions by adopting a process that is hazardous for the health or safety of the workers [8].

- The MM benefits can include non-obvious economic advantages, making a P2/AP strategy more economically attractive than initially/superficially perceived.

If the firm is focusing on one-dimensional solutions, then Pollution Control (PC) may appear better/cheaper an alternative than P2; but if a multi-media strategy is adopted then P2 becomes much more attractive and frequently is more economic than PC.

This is expressed mathematically below, where C represents cost, and i any of the four media defined earlier in this section:

Even if: $C_{P2} \geq C_{PCi}$, i: any medium

it may be that: $\sum_{i} C_{P2} (\equiv C^{*}_{P2}) \leq \sum_{i} C_{PCi}$

By C^{*}_{P2} we define a single comprehensive technological change that addresses all the environmental concerns simultaneously.

E. Identifying the Weak and Needy Areas

Our third task was to identify those problem industries/industrial processes/product lines which are in special need of technical information and assistance regarding P2/AP solutions, especially where their access to this information or assistance from trade associations, in-house expertise or R&D departments, or connections with academia is limited.

With regard to P2 solutions we gave special emphasis to small and medium-size enterprises (SMEs). This is because in the universe of SMEs the subset that meets the above stated limitations is very extensive and, subsequently, the potential for regulatory leverage (through enforcement agreements) for P2-oriented technological progress is also extensive.

On the other hand, in the areas of: (i) acute events (sudden releases) (AP) and (ii) MM-oriented P2 solutions, the culture and the capacity of larger firms *may* be such that they are favorable targets for enforcement leverage. This lies in the fact that either the firm's or the overall sector's culture is oriented towards secondary prevention and/or single-medium approaches. It is generally difficult to come up with precise criteria that can serve as rules of thumb in the identification of the needy firms. In the case of AP where the cultural attributes are of major importance, the classification needs to be examined case-by-case.

The SME concept however is a bit more amenable. An adequate set of criteria that a company must meet to qualify for an SME, are related to: (1) access to capital, (2) number of employees, and (3) the geographical spread of its market.

The criteria that an Industrial Sector should meet to be characterized as of special SME interest are the following:

1. *Distribution of Establishments by Facility Size*, that presents more than 50% small and medium facilities, i.e., facilities with less than 100 employees.

2. Limited *access to capital*. This can be determined from the *Capital Expenditures to Labor Cost Ratio*, the *Profitability/Solvency/Financial Leverage Ratios* or the *Market Growth Rate*. (We were not able to find such data for all the 4-digit SIC sectors we analyzed.)

3. *Geographic Distribution of Establishments* characterized by high proportion of Rural vs. Urban establishments and/or high concentration of establishments in the five states with the higher industrial activity with regard to the specific sector. (We were not able to find such data for all the 4-digit SIC sectors we analyzed.)

* * *

The general approach for choosing candidate industrial sectors, industrial processes and product lines has been discussed in this section. In the next section, we describe our approach more specifically and we identify the industrial sectors, industrial processes and product lines suitable for use within the SEP framework.

II. Choice of Industrial Sectors, Industrial Processes and Product Lines: Identification of Promising Pollution Prevention Technologies for Inclusion in SEPs.

A. Description of the Screening Mechanism

In Figure 1 we present in flowsheet format, the screening approach used for identification of suitable technologies to be included as SEPs/injunctive relief in enforcement agreements. In Phase I we used sector-related criteria to identify the Industrial Sectors with high P2 potential; we also identified a set of generic problematic processes frequently met in many SICs. In Phase II we identified specific P2 technologies that can address the key environmental problems found in the SICs and in the generic processes identified in Phase I.

The screening procedure is as follows:

1. Phase I [Tasks 1 & 3]

a. Identification of *Industrial Sectors* with high P2 potential

Preliminary Analysis: We identified an extensive set of industrial sectors or sub-sectors, that are considered in the literature as the most closely linked with environmental problems [3]. As the number of the sectors that was investigated in prior work was generally chosen arbitrarily, we were not constrained by these choices. The SIC system was the most convenient base for the selection of sectors. However, the SIC system is an economy-oriented system with only secondary technological considerations; thus the initial universe of industrial sectors of interest will contained a "mixture" of 2-, 3- and 4-digit SIC codes.

We started by gathering data on the 29 SICs (Industrial Sectors) most commonly mentioned in the literature [1,3,9] as problematic. The data needed here are synoptic sector-profiles on hazard/risk, on industrial/market structure and on compliance performance (we were unsuccessful in acquiring this last type of data).

Filter I: We applied this filter (consisting of three subfilters) to 29 Sectors to find the 8-10 most suitable for further investigation. The subfilters were: environmental burden, technologic stagnation and percentage of (allegedly) needy firms. More specifically:

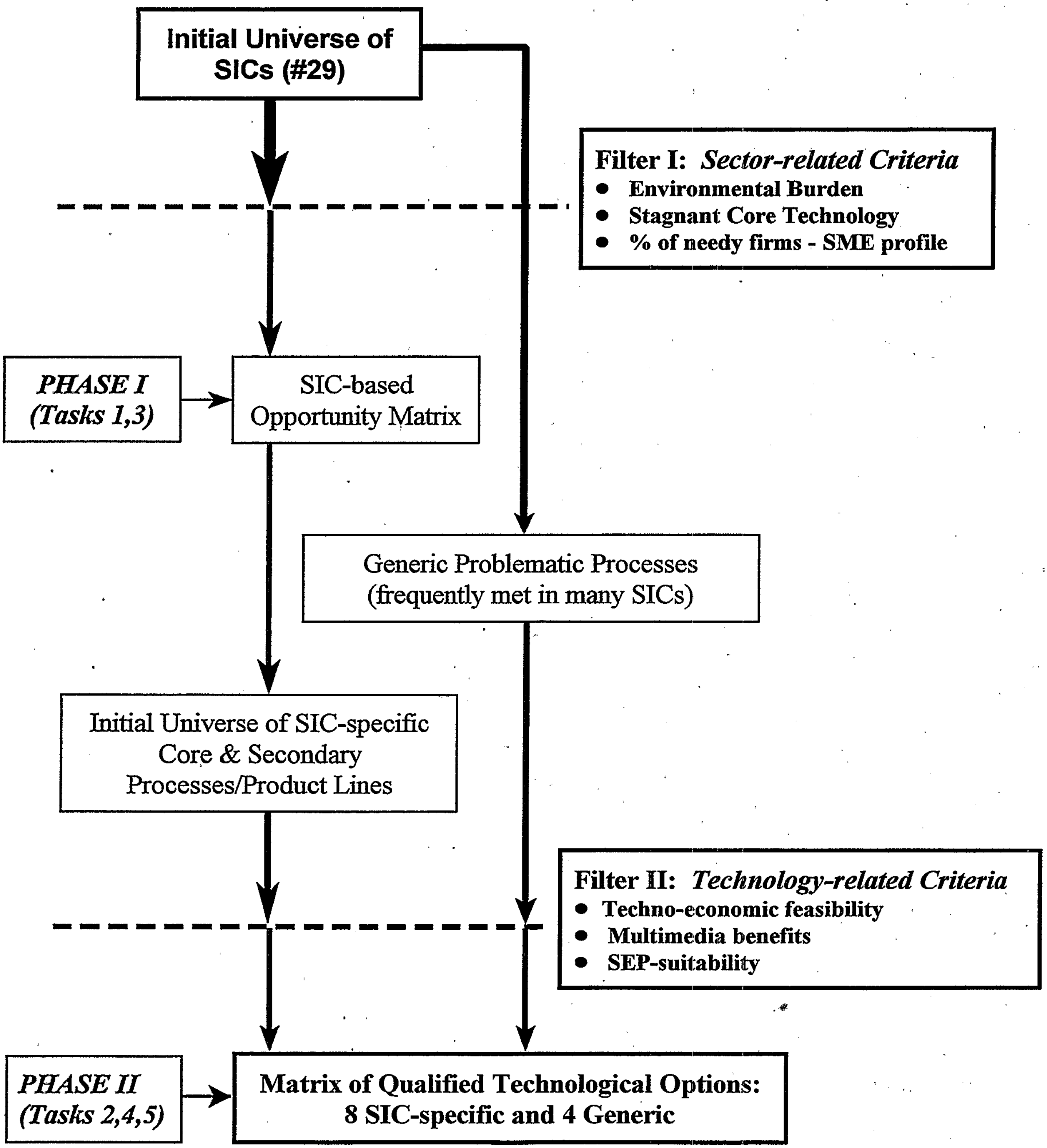
- **Subfilter Ia: Environmental burden of the industrial sector**

  Problematic sectors were identified based on:

  (1) The 1992 TRI Data [10]. The criteria related to TRI were:

  (a) The absolute amount of TRI releases and transfers.

FIGURE 1: The Screening Mechanism



(b) The ratio of (1) monetary Value of Shipments to (2) the total pollutant production, as measured by the total TRI releases and transfers (VSRT). Sectors with low VSRT ratios might be classified as "environmentally inefficient" and thus may become targets for diffusion of P2 technologies.

(c) The ratio of (1) Value Added by manufacture to (2) total TRI Releases and Transfers (VART). Low scores in that ratio imply environmental inefficiency and or that the sector is in a commodity business. The later attribute, is related to the level of needy firms in the sector (third subfilter); companies in commodity businesses may not have the financial resources and the technical expertise to achieve superior environmental performance.

(2) Secondary, qualitative criteria on environmental burden:

(a) Existence of pollutants classified as critical in EPA initiatives such as the 33/50 Program, the Common Sense Initiative and the Waste Minimization National Plan. [3,9,11,12].
(b) The appearance of a sector in at least one EPA publication [2,9,12,13,14], where it is characterized as a major polluter.
(c) The frequent appearance of a sector in NGO reports, where it is characterized as a major polluter [15-17].

(3) Enforcement Data from the EPA *Integrated Data for Enforcement Analysis* (IDEA) System. The following criteria are potentially important:

(a) Inspections per Facility per Year (IFY): high IFY ratios indicate an existing compliance problem.

(b) Inspections per Enforcement Action (IEA): low IEA ratios are a proof of major compliance problem.

The IFY and IEA data are currently available at a high level of aggregation in the 16 volumes of [18], unfortunately we were not able to get more detailed enforcement data and thus these criteria were not utilized.

- **Subfilter Ib: Technologic Stagnation**

We gathered information on the *core technologies* used in the 29 sectors. If these core technologies are *stagnant* over the last 10-15 years, then the probability for the existence of P2 opportunities increases significantly, and the sectors meet the "technological stagnation criterion."

The quantitative criterion for technologic stagnation is the Average New Capital Expenditures (ANCE). Low ANCE levels indicate high priority SICs. Low new investments in a sector mean either that there are no new technologies to invest on or that the economic performance of the sector is not optimal. Both explanations indicate stagnation and lack of dynamism; thus both a need and an opportunity for regulatory leverage exists.

For qualitative information about technological stagnation, we relied upon:

- Recent P2 technical Handbooks [19,20]
- SIC profiles prepared by EPA [18, all the 16 vols.]
- OTA publications [1,21]
- Interviews with experts [EPA Reg. 1, EPA HQs, EPA DfE, NEWMOA, TURI, MA OTA, Academia].

- **Subfilter Ic: Percentage of needy firms - SME profile**

We checked for the existence of moderate to high percentage of Small and Medium-size Enterprises (SMEs). The main source of Information is the Census of Manufacturers data, and the criterion used was the *Establishment Size Distribution*. That is, in the qualifying sectors more than 50% of the facilities should have personnel of less than 100 employees.

Other, qualitative criteria, generally used for that purpose include [5,9]:

- production characteristics (i.e., labor-intensive sectors are generally SME-dominated and posses limited access to capital), and
- market concentration (i.e., the less concentrated the market in a specific industrial sector, the more important is the role of SMEs in the sector).

<u>**b. Identification of *Processes and Product Lines* with high P2 potential:**</u>
<u>**(i) in the sectors already identified in Phase Ia, and (ii) in their own right**</u>

For the "qualified" industry/industrial sectors we were able to acquire detailed information on the technologies in use. We gathered data for all these three categories: core (primary), secondary and ancillary technologies. We also gathered data on the main product lines within these industrial sectors. The technologies/product lines of interest are the ones that impose environmental burdens. These burdens may be either under current EPA scrutiny/regulation or they may consist of an anticipated future economic concern due to stricter regulation [enforcement data from the EPA IDEA system and regulatory publications].

The problematic technologies/product lines may be either SIC-specific or generic. The *industry-specific* problems relate to core-technologies and product lines. The *generic* technologies are likely to be secondary or ancillary technologies encountered in more than 3-4 SICs. These generic technologies may have the highest potential for environmental benefits because they are easier to implement and can be considered in the context of many SICs. The ease of implementation lies in the fact that they are, in general, less sophisticated and they do not affect critical procedures/parts of the firm's life, i.e., they are not the "core" technologies.

Generally the technologies we identified were not different than the ones discussed in the Appendix [22], so we need no further description of them in this stage. After describing our screening procedure for Phase II, where we derived the final set of recommended technologies from the extended list we created in Phase Ib, we discuss the results of the application of the screening methodology in Section B and provide detailed technology profiles in Section C.

2. Phase II [Tasks 2, 4 & 5]

The initial universe of technological options, as we have already explained, consists of two parallel groups: the industry-specific and the generic options. We kept this division throughout this second stage of screening. In our flowchart (Figure 1), this is presented as two parallel flows of technologies passing through the same Filter II. This filter consists of three subfilters that are explained below.

- **Subfilter IIa: Techno-economic feasibility**

  We accepted only technologies that were already proven and implemented at least at the pilot level. We also wanted the technologies to have reasonable payback times (e.g., less than five years). The main sources of information have already been cited under Subfilter Ib. Other sources are:

  - Electronic Databases: UNEP ICPIC and Enviroene.
  - OTA fact sheets. We have reviewed over 40, with successful P2 cases mainly drawn from New England.
  - Publications related to the Design for the Environment initiative [23].
  - NEWMOA, TURI and NGO compendia of P2 successes, publications from CMA and from other Industrial Alliances [24-26].
  - P2 technologies that have won the Governor's Award for Toxics Use Reduction [12].

- **Subfilter IIb: Multi-media environmental benefits**

  The multi-media benefits may refer to: (i) water, (ii) air, (iii) waste-stream or (iv) worker exposure (occupational safety & health). A general discussion on the importance of multi-media benefits was provided in Section ID, while the sources of relevant information are the ones cited under subfilter IIa.

- **Subfilter IIc: SEP-suitability**

  We operationalized the criteria described in Chapter ID, as follows:

  (1) The promoted technology should be economical but not very profitable, i.e., the environmental project should not have a significantly positive NPV without the penalty mitigation (assuming that the discount rate used appropriately accounts for the project-specific risk). If the technological option has an extremely positive NPV, the firm should be eager to undertake it anyway.

  (2) The promoted technology should call for significant capital so that a penalty mitigation would be of value. Although the cut-off level is arbitrary, we, for example, chose a level of $25,000 to give a wide variety of different options; preference should be given to significant projects in utilizing scarce EPA compliance resources and attention.

(3) The horizon of implementation of the project should not be longer than 18 months. This is because the EPA attorneys and case attorneys are likely to deem inappropriate for the SEP process any project of longer duration. We note that information on project duration is not always available in the P2 literature; neither it is always meaningful since implementation periods may be very much firm-specific (i.e., depend on how much effort and resources a firm wants to devote in a project).

(4) As an extra criterion to ensure a certain level of comfort for EPA with the promoted technology, we use only technologies that are at least somewhat known to EPA. Obviously, this does not mean that the Office of Enforcement and Compliance Assurance should be already using/promoting these technologies but that the technologies should either have been

- mentioned/researched by the EPA ORD or RREL, or
- recognized with a Governor's award or
- found/mentioned in a reliable domestic or international database (e.g. Enviroene, UNEP ICPIC, etc.).

B. Application of our Screening Mechanism

The ultimate purpose was to come up with ~ 8 SIC-specific and 4 generic P2 technologies that can be used in SEPs.

Our first task was to select 8 SICs for detailed investigation; this was achieved using our literature sources (especially [3]) and quantitative criteria introduced and discussed in Chapter IIA.

The actual procedure used was the following: We started with the 29 4-digit SICs most frequently indicated in various reports and EPA initiatives ([1],[3],[9]). The complete data set we used in our screening is presented in Table IIB, which can be found in the next page. We ranked the sectors according to the first four criteria presented in Table IIA. Ideally, the two enforcement-related criteria (the fifth and sixth criteria) should be also used, but the relevant data were not available for this study.

Table IIA: Description of the Criteria in use

Criterion	Descriptor	Explanation	Source	Other Comments
R+T	Total TRI **R**eleases and **T**ransfers *(in M lb.)*	↑ (R+T) ⇒ ↑ priority on the SIC *(major environmental burden)*	1992 TRI Data	
VSRT	**V**alue of **S**hipments* over total TRI **R**eleases and **T**ransfers *(in $/lb.)*	↓ VSRT ⇒ ↑ priority on the SIC *(environmental inefficiency)*	1987 Census & 1992 TRI Data	
VART	**V**alue **A**dded by manufacture over total TRI **R**eleases and **T**ransfers *(in $/lb.)*	↓ VART ⇒ ↑ priority on the SIC *(a. environmental inefficiency and/or b. commodity business)*	1987 Census & 1992 TRI Data	
ANCE	**A**verage **N**ew **C**apital **E**xpenditures; *(NCE in $ per establishment)*	↓ ANCE ⇒ ↑ priority on the SIC *(sign of: stagnation, lack of dynamism, both a need and an opportunity for regulatory leverage)*	1987 Census of Manufacturers	
IFY	**I**nspections per **F**acility per **Y**ear	↑ IFY ⇒ ↑ priority on the SIC *(a. indication of existing problem b. opportunity for leverage)*	IDEA	Data not available for this study
IEA	**I**nspections per **E**nforcement **A**ction	↓ IEA ⇒ ↑ priority on the SIC *(a. proof of major compliance problem b. opportunity for the implementation of a SEP)*	IDEA	Data not available for this study

* In the case of Service industries we use the *value of receipts* instead of *the value of shipments*

Table IIB: The complete data set

SIC	Descriptor	Rank Lisic	Rank Other	SIC Range	NoE	%SME's	R	T	R+T	VS	VA	NCE	VSRT	VART	ANCE	IFY Ratio	IEA Ratio
3471	Electroplating	1	[1], [9]		3451	97.4	18	67	85	3,867	2,634	140	45	31	40,626		
2821	Plastics, resins and elastomers	2			480	74.8	214	328	542	26,246	10,873	1,247	48	20	2,598,333		
2869	Industrial Organic Chemicals N.E.C.	3			699	72.1	781	722	1,503	41,812	17,526	1,986	28	12	2,841,059		
285	Paint Industry	4	[1]	2851	1428	91.0	23	132	155	12,702	6,221	275	82	40	192,647		
371	Automotive manufacturing/ assembling	5	[1], [9]	0 - 7	4438	79.8	98	169	267	205,923	66,367	6,578	771	248	1,482,267	0.4	13.3
3674	Electronics/semiconductors	6	[9]		853	49+	6	20	25	19,795	13,429	1,921	780	529	2,251,817		
2911	Petroleum Refining	7	[9]		308	54.4	104	737	840	118,186	14,219	2,035	141	17	6,607,143	2.0	6.1
2879	Pesticides	8			277	91.3	101	119	220	62,997	3,832	234	286	17	845,126		
2752	Commercial printing, lithographic	9			24,984	97.3	14	5	19	32,832	18,232	1,539	970	82	61,579		
7216	Dry cleaning plants	10			21,257	99.8	NA	NA	NA	3,997	NA	NA	NA	NA	NA		
2819	Inorganic Chemicals N.E.C.	11			662	84.1	596	335	931	13,220	7,538	506	14	8	764,502		
2491	Wood preserving	12			540	62.5+	2	5	7	2,170	553	44	318	81	81,667		
753	Automotive repair shops	13			114,601	100.0	NA	NA	NA	26,664	NA	NA	NA	NA	NA		
2621	Paper mills	14			282	23.0	122	44	166	28,918	14,024	2,760	174	85	9,786,879		
2754	Commercial printing	15	[9]		332	87.0	38	10	47	3,060	1,534	176	65	32	528,614		
261	Pulp mills	16		2611	39	28.2	137	50	188	4,314	2,281	231	23	12	5,928,205		
226	Textile dyes and dyeing	17			648	78.2	4	4	9	7,042	2,321	173	799	263	266,358		
2893	Ink manufacture	18			504	97.2	35	7	42	2,392	985	38	57	23	75,198		
2834	Pharmaceutical preparations	19			732	75.3	44	109	153	32,094	23,884	1,471	209	156	2,009,699		
2891	Adhesives and sealants	20			714	93.4	9	14	23	4,678	1,996	112	201	86	156,443		
271	Newspaper publishing	21		1,3,4, 7-9	9091	91.8	0	0	0	31,850	24,311	1,523	78,229	59,712	167,495		
2865	Coal tar crudes, dyes and pigments	22			186	65.6	191	166	357	8,859	3,414	379	25	10	2,036,559		
372	Aircraft and parts	23			1622	76.4	32	34	66	77,304	40,803	2,536	1,176	621	1,563,564		
311	Leather tanning and finishing	24		3111	344	60+	8	14	23	2,219	747	28	99	33	80,523		
2753	Engraving and plate printing	25	[9]			NA	0	0	0	NA	NA	NA	NA	NA	NA		
331	Iron and steel		[9]	2,3,5,6, 7	1127	67.9	128	487	615	51,815	20,486	1,668	84	33	1,479,769		
334	Secondary smelting and refining of Non-Fe metals			3341	398	91.2	12	268	280	4,431	947	63	16	3	157,286		
335	Rolling, drawing and extruding Non-Fe metals			1,3,4,5, 6,7	1069	60.5	51	248	299	33,282	10,332	989	111	35	925,444		
336	Non-Fe castings (foundries)			0 - 9	1689	87.6	8	63	70	6,315	3,395	195	90	48	115,512		

Notation:	Source:
NoE = Number of Establishments (in K)	1987 Census of Manufacturers
%SME = % Establishments with <100 employees	1987 Census of Manufacturers
R = Releases (M ibs)	1992 TRI Data
T = Transfers (M lbs)	1992 TRI Data
IFY = Inspections per facility per year	IDEA
IEA = Inspections per Enforcement Action	IDEA
VS = Value of Shipments (M $)	1987 Census of Manufacturers
VA = Value added by manufacture (M $)	1987 Census of Manufacturers
NCE = New Capital Expenditure (M $)	1987 Census of Manufacturers
VSRT = VS/(R+T) in '87 $/'92 lbs	1987 Census & 1992 TRI Data
VART = VA/(R+T) in '87 $/'92 lbs	1987 Census & 1992 TRI Data
ANCE = NCE/(NoE) in $/establishment	1987 Census of Manufacturers

In the case of service industries we use the value of receipts instead of VS, VA.

For each criterion, we gave one point to each of the top-8 SICs. These results are presented in Table IIC.

Table IIC: top-8 SICs in every criterion				
Criterion/ Rank	**R+T**	**VSRT**	**VART**	**ANCE**
1	2869	2819	334	3471
2	2819	334	2819	2752
3	2911	261	2865	2893
4	331	2865	2869	311
5	2821	2869	261	2491
6	2865	3471	2911	336
7	335	2821	2879	2891
8	334	2893	2821	334

From the results of Table IIC we constructed the Table IID with the cumulative scores of the overall top- 8 SIC's.

Table IID: the 8 best SICs based on the applied criteria		
SIC#	Score	Rank
334	4	1
2869	3	2
2819	3	3
2821	3	4
2865	3	5
2911	2	6
261	2	7
3471	2	8

In the SICs of Table IID, we screened for SME-dominance; i.e., we discarded the sectors in which less than 50% of their establishments have less than 100 employees. That way, we eliminated SIC 261 -- Pulp mills, as a non-SME dominated sector. (As we can see in **Table IIB**, only 28% of the facilities in SIC 261 have less than 100 employees).

Our final target group consisted of the 7 remaining SICs of Table IID and the SIC code 285 (the Paint Industry). The latter, while not having very high scores in our prioritization mechanism, was deemed very important in [3] and in [27]. The final target group is presented in Table IIIE.

Table IIE: The Selected 4-digit SICs		
Sic #	**Descriptor**	**Explanation**
334	Secondary smelting and refining of Non-Fe metals	Table IID
2869	Industrial Organic Chemicals N.E.C.	Table IID and [3]
2819	Inorganic Chemicals N.E.C.	Table IID
2821	Plastics, resins and elastomers	Table IID and [3]
2865	Coal tar crudes, dyes and pigments	Table IID
2911	Petroleum Refining	Table IID
3471	Electroplating	Table IID and [3]
285	Paint Industry	[3] and [27]

The creation of Table IIE, completed **PHASE Ia** of the screening procedure. We concluded **PHASE I** (see Figure 1) by acquiring information on P2 technologies relevant to these sectors and on generic technologies frequently encountered in our literature survey. For targeting generic technologies, no quantitative method exists; thus we relied only on our literature survey and the relevant EPA report.

In **PHASE II** we used a set of the technology-focused criteria presented in Section II (1) (a) to analyze the technological options identified in **PHASE Ib**; we then identified the small set of 8 SIC-specific and 4 generic technologies that are our recommended technologies to be used by OECA in SEP or Injunctive relief cases.

In Table IIF we summarize the SIC-specific technological options which are promising candidates for P2 SEPs. In Table IIG we summarize the generic technological options which are promising candidates for P2 SEPs. In the following section IIC, we present detailed technological profiles of the 12 technologies.

TABLE IIF: SIC-Specific Technologies

SIC	Process/ Product line Description	Technological Options	Locus of change	Techno-economic Feasibility	P2 Benefits	Capital Expenditure	Time horizon	Data Source
334	Lead smelting	Use of an improved design mold eliminates the cutting process and results in less scrap to be smelted	Primary Process change	*Readily available * Payback <18 months	â air emissions â scrap, lead energy	$ 100,000	<12 months	UNEP ICPIC
2869	Batch organic chemicals manufacturing	Ultrasonic cleaning system replaced the use of solvents and caustic	Ancillary Process	* in use * fast payback	â water pollution â worker exposure	$ 36,000	Unclear { < 18 months}	UNEP ICPIC
2819	Hydrochloric acid production	Installation of an acid gas adsorption system	Secondary Process	* in use * fast payback	ââ wastewater â Hydrochloric acid, chlorate compounds	$ 250,000	4 months	INFOR M
2821	polypropylene production	Vinyl Acetate (VA) recovery system	Adjunct to the Core Process	Payback <2.5 yrs	â 30% of the hazardous (ignitable) VA stream	$ 1,300,000	13 months	EPA RREL
2865	Manufacturing of plasticizers	Recycling of distillation overhead waste and installation of on line analyzers to reduce by-products	Primary Process - equipment modifi-cation	* Fully implemented * Payback ~ 8 yrs (no liability reduction savings considered)	â 13% in hazardous waste (mixed organic chemicals)	$ 500,000	Unclear	UNEP ICPIC
2911	Petroleum refining	Installation of an oily water treatment unit to remove insoluble emulsified oil from the desalter wash water	In-process recycling in a primary process	*In use *Payback ~ 3 yrs	Complete removal of emulsified oil â in sludge generation	$ 60,000	N/A	API
3471	Surface finishing of fabricated metal products	Installation of an aqueous cleaning system eliminates the use of TCA	Ancillary process	* Fully commercialized * Payback =1.4 yrs	Elimination of TCA emissions	$ 80,000	N/A	UNEP ICPIC
285	manufacturing of colorants	Installation of additional mill chambers and pumps to reduce the frequency of cleaning and the amount of purge generated.	Ancillary process modifi-cations	*In use *Payback < 1yr	43% reduction in the amount of resinous and water waste generated	$ 25,000	< 1 yr	ENVIRO ENE

TABLE IIG: Generic P2 Technologies

SIC Range	Process/ Product line Description	Technological Options	Locus of change	Techno-economic Feasibility	P2 Benefits	Capital Expenditure	Time horizon	Data Source
34-35-36-37	Vapor degreasing	Use of an aqueous wash system instead of TCA	Secondary Process	Payback 2.5-3 yrs	Eliminates the heavily toxic TCA in air emissions and in the waste stream	$ 464,000	Unclear {probably < 18 months}	RREL paper
34-35-391	Metal plating	wastewater purification and metal recovery	Primary or Secondary Process	Payback 3 yrs	ââ metal hydroxide sludge, usage of chemicals â water usage	$120,000	< 18 months	PP News
28-35-36-37	Paint removal	Use of a cryogenic process for paint removal from steel structures, substitutes the use of acids or pyrolithic oven	Secondary Process	* Payback < 1.5 yrs * patented technology	No acids, no liquid wastes, improved worker safety conditions, decreased solid wastes	$ 235,000	Unclear {probably < 18 months}	UNEP ICPIC
285-34-35-36-37	Painting of metal parts	Substitution of solvent based paint with powdered paints	Secondary Process	Payback < 1 yr	Minimized emissions and worker exposure to organic solvent (TCA and mineral solvent vapors).	$383,000	Unclear {probably < 18 months}	UNEP ICPIC

C. Detailed Description of the Identified Technologies

In the description of technologies discussed below, features of the existing processes/product lines/technologies, as well as options for change that we have identified as worthy of promotion, are found in bolded text.

A. SIC-Specific Options

Technological Option #1: SIC 334

Pollution Prevention technology in the secondary lead processing in a Manufacturer of Starting, Lighting, and Ignition (SLI) Batteries

The facility operates one, two, or three 8-hour shifts and employs 220 people. In 1993, they sold 231,000 batteries.

Facility operations can be divided into six main steps: **(1) conversion of scrap lead into cast panels**, (2) conversion of virgin lead into lead oxide powder and paste, (3) pasting and curing of panels, (4) container formation of batteries, (5) tank formation of batteries, and (6) laboratory analysis and process controls. The battery making process begins on two parallel tracks: the facility recovers lead from used batteries that are collected and brought to the facility, scrap lead is recycled and then cast into grids, and virgin lead is mechanically converted into a powdery lead oxide, which is used to make a paste. These separate feeds merge at the grid pasting machine where the paste is pressed into the grids. Pasted plates are cured and then take one of two paths to become battery elements: tank formation or container formation. These processes convert the paste into active material that will electrically charge and discharge throughout the useful life of the battery. In tank formation, this process takes place in large tanks whereas in container formation, the cured plates are assembled and formed in the battery case itself.

To make the lead oxide paste, lead oxide powder is mixed with de-ionized water, sulfuric acid, and organic expanders. One recipe makes a positive plate, while a slightly different recipe makes a negative plate. The pasted plates then move on a conveyor belt through a drying oven. After pasting and drying, the plates move into a curing chamber for about 48 hours to convert the remaining lead into lead oxide.

Existing Pollution Problems

(1) waste acid from the used batteries that are cracked to recover lead is disposed of on-site, (2) uncovered lead slag and dust piles, (3) excessive energy used in smelting ovens, curing rooms, and the tank formation process, and (4) excessive wastewater generation in the grid pasting and washing processes. **In addition, over 2,500 kilograms of lead oxide paste is spilled and fed into the smelting process each day, using virgin lead where scrap lead would suffice**. Finally, several technological problems **(e.g., the outdated lead oxide mill and lack of a moisture analysis oven) increase raw materials use and adversely affect battery quality**.

Pollution Prevention Opportunities

Overall, this assessment identified nineteen pollution prevention opportunities that could address the problems identified and produce significant economic benefits for the facility. If implemented, these opportunities could save over $1,531,206 (US) in the first 12 months for an investment of $522,500 (US).

The pollution prevention strategy is premised on the belief that addressing sources of waste and pollutants also improves the company's economic position by reducing operating costs and improving product quality. In this case, product quality is increased by (1) increasing the lead oxide particle size by buying a liquid atomization mill, (2) increasing the moisture content of the paste recipes, (3) increasing the curing temperature, humidity, and air circulation, (4) analyzing the moisture content of the pasted plates on-site, at the oven, (5) monitoring the smelting oven temperature and adjusting to the optimal level, (6) curing larger batches of pasted plates, and (7) utilizing cadmium sticks in the laboratory to measure cell voltage.

The following is a list of the opportunities for pollution prevention recommended for the facility and presents the environmental and product quality benefits, implementation cost, savings, and payback time for each. Because the quantities of pollution generated by the facility and possible pollution prevention levels depend on production levels, all values should be considered in that context.

Conversion of Scrap lead into Cast Panels--Smelting--Options included:

- **Buy temperature monitoring instrument to adjust oven which reduces toxic emissions and slag and reduces energy costs. Costs $1000, provides a financial benefit of $1000 per year. Thus it has a pay back period of one year.**

Casting Panels--Option included:

- **Purchase improved design mold which reduces waste, lowers energy use and eliminates steps in the process. The cost is $100,000 (US). Financial benefit and payback period is incorporated in plate cutting.**

Conversion of Virgin lead into lead oxide powder and paste-- Options included:

- **Purchase a liquid lead atomization mill - improves efficiency and reduces emissions of lead oxide powder. The cost is $200,000 (US) which provides quality improvements.**

Pasting and curing Panels: Cutting-- The options identified included:

- **Eliminate the cutting process which reduces scrap and saves lead and energy. The cost is $100,000 with a financial benefit of $70,956 per year and a payback period of less than 18 months.**

Tank formation of plates: Eliminate the process --saves water and natural gas, reduces worker exposure to acid and lead dust, reduces volume of waste water and improves battery quality. The cost is $100,000 with a financial benefit of $693,000 per year and therefore a payback period of less than three months.

Implementation Status

The facility has already implemented many of the low/no cost changes. In addition, the facility has begun to implement several capital intensive changes. For example, it has placed an order for boost charging equipment ($ 100,000) and requested price quotes for a liquid lead atomization mill ($240,000). Source: The UNEP ICPIC database.

Technological Option #2: SIC 2869

Ultrasonic reactor cleaner reduces waste generation and cuts energy costs, in an industrial organic chemicals manufacturer.

A Chemdet Sonic Cleaning system is now used at 3 M to clean batch reactors, replacing the old process of filling the reactor with caustic or solvent and boiling the solution for one or two days. Cleaning chemicals are pumped under pressure through a twin-nozzled rotating spray head to break down the waste. Then, caustic or solvent is sprayed under 600 lb. pressure to complete the dissolution and flush the vessel clean.

Material/Energy Balance and Substitution
FEEDSTOCKS: Solvent, caustic
WASTES: Spent solvent, caustic, containing adhesives, resins, polymers
MEDIUM: Liquid

Economics
CAPITAL COST: **$36,000**
OPERATION/MAINTENANCE: Reduction in labor costs not reported
SAVINGS: $575,000 in first year, from labor, materials and machine costs

P2 Benefits
FEEDSTOCK REDUCTION: Reduced requirements for solvent and caustic not reported
WASTE PRODUCTION: 1,000 tons/yr. of water pollutants were eliminated
IMPACT/PROBLEMS: Installation of the Chemdet system for cleaning the reactors has eliminated the need to fill the 4,000 8,000 gallon reactors with solvent and caustic, which greatly reduces the amount of spent solvent generated.

Source: The UNEP ICPIC database.

Technological Option #3: SIC 2819

Closing of evaporation ponds and introduction of an acid gas adsorption system in the production of hydrochloric acid

In 1987 Dow Chemical introduced a process change in the Pittsburg, California plant. The process change involved the installation of an acid gas adsorption system, that eliminated the need to send brine to evaporation ponds. This process change which called for a capital expenditure of **$250,000** reduces caustic waste by 12,000,000 lb./yr. and hydrochloric acid waste by 160,000 lb./yr. for a payback period of less than 2 months. {Note: Many SMEs that use such a process will incur longer payback times because the volumes of wastes they handle, and thus the level of cost reductions they will enjoy, are much smaller.}

Previously, the wastestream of hydrochloric acid gas, formed by the reaction between chlorine and organic compounds, was scrubbed with caustic, forming brine: a portion of this brine was sent to evaporation ponds while the rest was used to produce chlorine gas through electrolysis. Now, the hydrochloric acid is first scrubbed with water and then caustic. This stepwise method salvages a portion of the hydrochloric acid waste stream so that it can be reused as a raw material elsewhere in the plant or sold as a product. It also avoids the formation of sodium chlorate compounds that precluded the in-process recycling of the spent caustic stream. Further, less caustic is needed to convert remaining hydrochloric acid to brine, and all brine is used as raw material to produce chlorine gas.

Source: " Environmental Dividends: Cutting More Chemical Wastes," INFORM 1992.

Technological Option #4: SIC 2821

Recovery and reuse of vinyl acetate in the production of polypropylene

The full description of the technology is given in the following attachment.

Source/Citation: Mr. Henry Ward, Union Carbide Health, Safety and Environmental Affairs, 39 Old Ridgebury Rd., Danbury, CT 06817 (through an EPA RREL compendium of P2 case studies).

UNION CARBIDE PLASTICS AND CHEMICALS CO., INC.
SEADRIFT/TEXAS CITY, TEXAS

Recovery and Reuse of Raw Materials in Chemical Products/ Elimination of Toxic Metals in Cooling Water Treatment Via Product Substitution

Seadrift Plant

The Union Carbide Seadrift Plant is located along the southeast Texas coast approximately 130 miles from Houston, Texas. The plant, one of Carbide's largest, employs close to 1,300 people. The plant produces ethylene, glycols, amines, solvents, polyethylene, and polypropylene.

Seadrift's largest waste stream is a residue that contains high concentrations of vinyl acetate (VA) along with heavier components such as poly oils. It is characteristically ignitable, making it hazardous under RCRA. At its peak, this waste stream averaged over 5 million pounds per year.

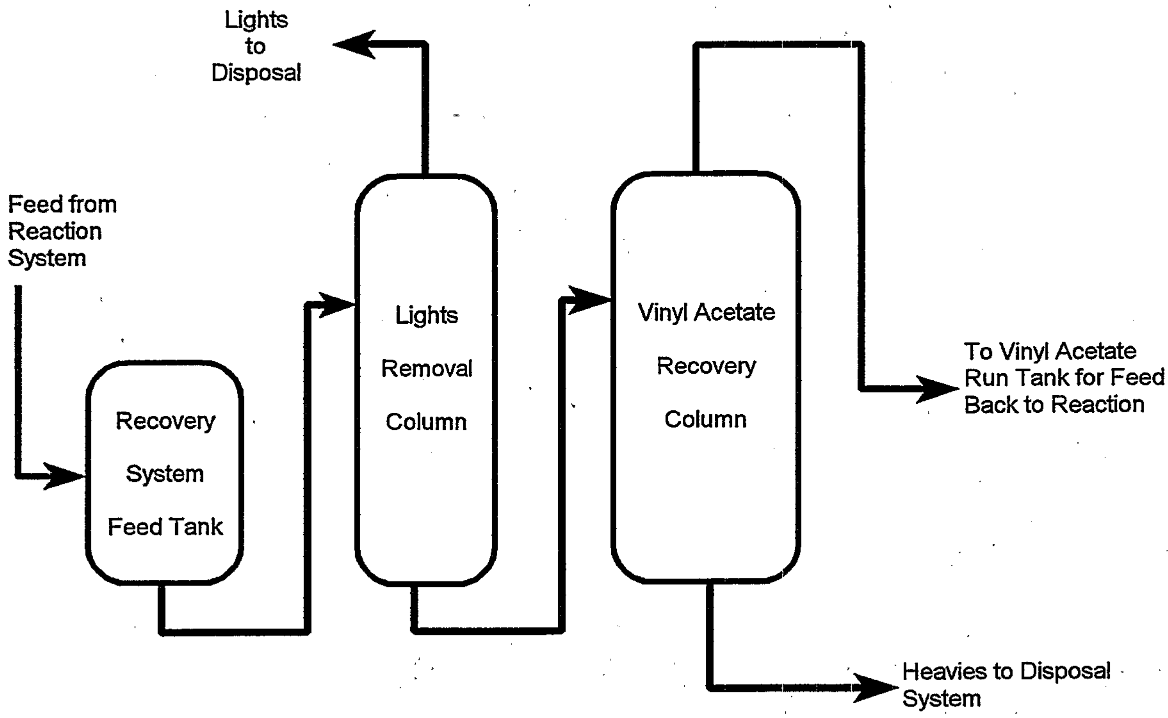
In late 1987 the plant installed a VA recovery system on their High Pressure 2 Polyethylene Unit. This recovery system began full-time operation in 1988. The project installation cost of this recovery system was approximately $1.3 million and took 12 months to complete. After the first full year of operation, documented raw material efficiency improved 10%. This resulted in a savings of $570,000. The volume of the hazardous waste stream was decreased by 1.4 million pounds during this reporting period. No additional manpower was added to operate the recovery system. Operational costs for the new equipment, such as utilities and maintenance, have been minimal. Over the three year period of its operation the recovery system has resulted in reported savings of approximately $2 million.

The vinyl acetate system is closed-loop recycle (see flow diagram on next page). The residue is taken from the reaction system purge column and various entrainment separators to the Recovery System ("Lights" Column Feed Tank), which operates at fairly low pressures and temperatures below 100 C. In the feed tank some of the dissolved lights (ethylene and propylene) are sent to a vent gas suction system. An inhibitor is also added at this point to prevent the VA from polymerizing.

The residue stream is then fed to the Lights Column where the bulk of the dissolved ethylene and propylene are taken out. This column contains a number of trays with an integral upward-draft condenser. The column operates under 20 psi and below 100 C.

The lights from the Lights Column go to the Flash Tank for disposal via thermal treatment and the heavies (vinyl acetate and poly oils) go to the Vinyl Acetate (VA) Recovery Column. The VA Recovery Column contains 21 trays below 20 psi and below 150 C. The column takes refined VA as an "overhead" make at a reflux ratio of approximately 2. The recovered vinyl acetate is therefore able to be used as a raw material in the original process.

Improvements were made to the recovery system during 1989 which resulted in another 10% increase in efficiency. The calandria was revised to provide better fluid dynamics and heat transfer. Modifications to recycle piping improved recovery during start-up, shutdown, and reactor upsets. Closer attention to product scheduling and operating parameters (such as base temperature) have also allowed for improvements with no additional capital investment. The control panel display has been modified to show operators the cost savings in a graphic way to encourage optimization.



1) Feed and Make Rates Vary With Reactor Product

2) Operating Conditions Vary With Reactor Product

3) Major Equipment Only is Illustrated

SEADRIFT PLANT

Simplified Flow Diagram
Vinyl Acetate Recovery System

Source: Union Carbide, Seadrift Plant

Technological Option #5: SIC 2865

New solvent recovery process in the manufacturing of plasticizers results in reduced quantity of waste generated

Manufacturing processes were modified to reduce the quantity of hazardous waste generated by 13%. Process modifications include: additional recycling of distillation overhead waste, installation of on line analyzers to reduce the production of by products, better control of chemical reactions to improve yield.

Case Study Summary

The manufacture of plasticizers, such as phthalic anhydride or phthalic esters, generate the following listed wastes: K015 (still bottoms from the distillation of benzyl chloride), K023 (distillation light ends from the production of phthalic anhydride from naphthalene), and K024 (distillation bottoms from the production of phthalic anhydride from naphthalene). Approximately 5 million lb./yr. of these wastes were generated at this plant. Some wastes were incinerated; some were landfilled on site and off site.

Scale of Operation: This facility has more than 100 employees, and more than 1000 tons of waste were manifested between 1981-1985.

Stage of Development: Fully implemented

Level of Commercialization: This information is not available.
Results of Application: 13% reduction in the quantity of hazardous waste generated

Investment cost: $500,000 (1987)

Cleaner Production Benefits
Economic Benefits: $78,000 annual savings in treatment/disposal costs.
Liability reduction: Reduced liabilities by reducing the quantity of hazardous waste generated.
Regulatory compliance: Regulatory compliance is easier with **a 13% reduction in the quantity of listed hazardous waste generated at this plant.**

Waste and/or Emission Description
Physical state: Liquid, solid
Composition: Mixed organic chemicals
Description: K015, K023, K024

Cross Industry Application: Organics manufacturing

Source: "A Study of Hazardous Waste Reduction and Recycling in Four Industrial Groups in New Jersey," Environmental Resources Management, Inc, April 1987 {through UNEP ICPIC}.

Technological Option #6: SIC 2911

Installation of an oily water treatment unit to remove insoluble emulsified oil from the desalter wash in a petroleum refining process

The full of description of the technology is given in the following attachment.

Source: "Waste Minimization in the Petroleum Industry - A compendium of practices," API Publication 849 30200 *(Used with permission).*

Refining Waste Minimization Practices
Case Study 4-4: Deoiling of Desalter Effluent

Introduction

A West Coast refiner has a desalter producing 13,675 tons per year (TPY) of oily water containing approximately 6.3 weight percent oil and 0.1 weight percent solids which would ordinarily be discharged to the refinery wastewater system. If allowed in the wastewater system, the oily water forms sludges and emulsions that would have to be removed and disposed.

Description of Waste Minimization Practice

As part of original construction, the refiner installed an oily water treatment unit downstream of the desalter. The purpose of the unit is to remove insoluble oil from desalter wash water containing emulsified oil. The figure on the next page is a simplified flow diagram of a typical system.

The oily water stream from the desalter is contacted with 1647 tpy of naphtha and a surfactant chemical. The water-oil-solvent stream is mixed in an in-line, low-shear mixer and proceeds to the main separator vessel, where an electrostatic field is established to maintain a sharp hydrocarbon/water interface and to assist in the separation process. The separation occurs because of density differences between the two phases.

The distillate solvent oil extracted from the water exits the top of the main separator and is sent to crude oil storage. Oil-free water (12,800 tpy) is discharged from the bottom of the vessel and proceeds to the refinery disposal system.

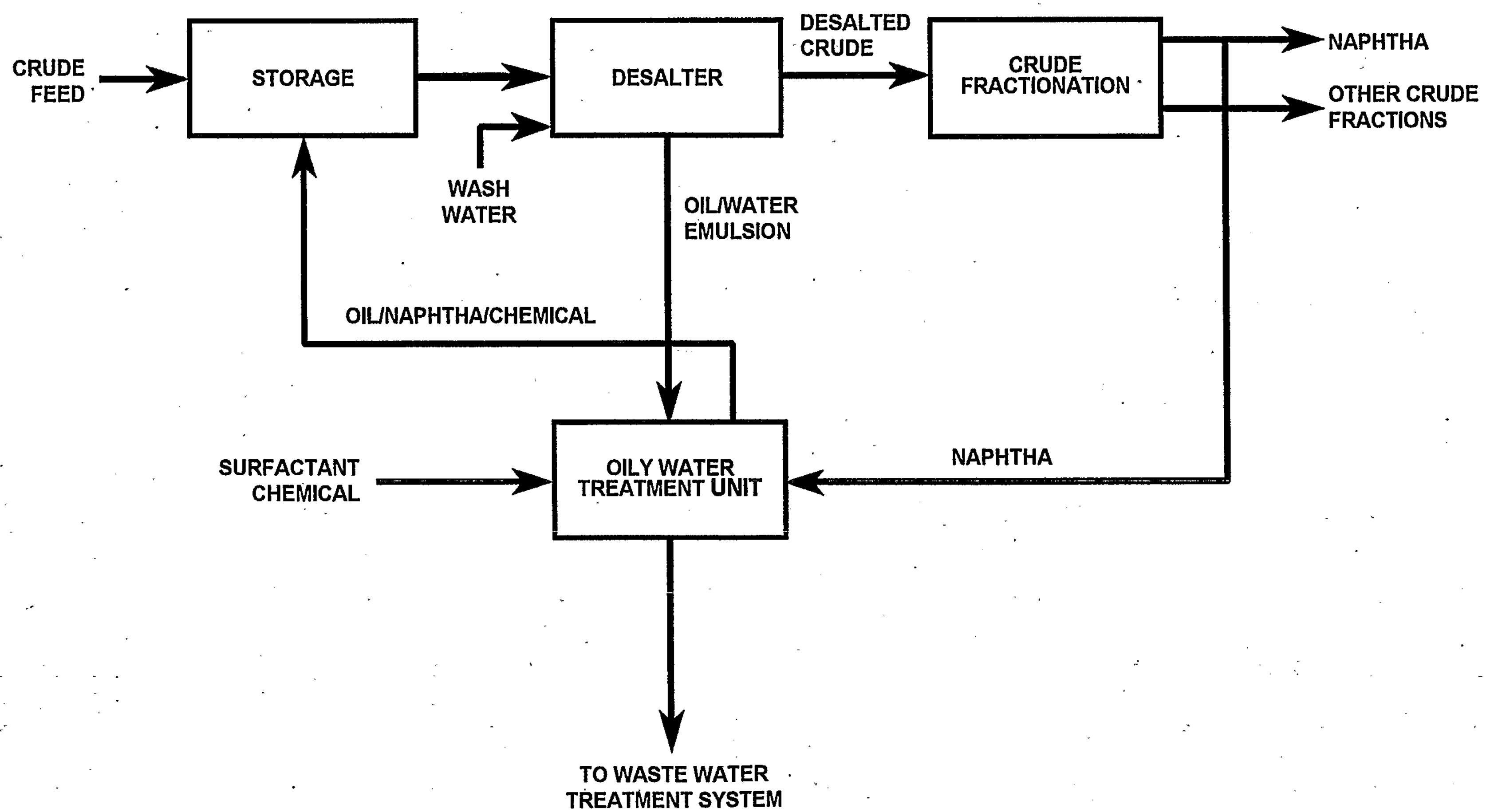
Effectiveness

The oily water treatment unit removes approximately 862 tpy of oil. Treated wastewater typically contains 100 to 500 ppm oil and grease and 25 to 200 ppm solids. Assuming an API separator sludge composition of 70% water, 20% oil, and 10% solids, sludge generation is reduced by at least 122.4 tpy. At a nominal $200/ton disposal cost, annual disposal cost savings would be $24,500/year. The user reported initial difficulties with the mixer supplied with the treatment unit, and installed an in-line mixer to replace the original equipment. Aside from this modification, the unit has operated for nine years with very little maintenance. The long-range effectiveness of this system appears to be good.

Costs

The capital cost of the oily water treatment unit is approximately $60,000. Naphtha use amounts to 525,600 gallons per year and naphtha is recovered. Approximately 730 gallons per year of surfactant chemicals are used (1979 average cost for surfactant chemical was $10.93/gallon). Electrical power consumption for this unit is not known.

Deoiling of Desalter Effluent



Technological Option #7: SIC 3471

1,1,1 Trichloroethane(TCA) is eliminated from the production process by aqueous based cleaning at a fastening parts manufacturing facility

Cleaner Production Class: improved operating practices, substitute less toxic raw material
Industry Class: surface finishing, cleaning, and coating

SIC Code: 3400, fabricated metal products, 3471, electroplating, surface finishing

P2 Technology Category: The P2 technology involved initially reducing TCA use and finally eliminating its use by installing aqueous cleaning systems.

Case Study Summary

Process and Waste Information: This facility manufactures nails, staples, and the tools to drive these fasteners. The fastening tools are made of aluminum, magnesium and carbon steel. To produce these fastening parts, grinding, milling, drilling, lathe working, heat treatment and metal finishing operations are employed. Prior to many of these operations, parts are cleaned in a cold application using TCA. TCA was being discharged in the wastewater at levels twice as high as the allowable limit. Absorbents used around the machine tools also showed levels of TCA that prevented disposal in the regular trash. The company decided to attempt to eliminate the use of TCA from the manufacturing of fastening tools.

A task force identified potential causes of excessive TCA cleaning wastes: too much availability of cleaners, unnecessary dumping of TCA, lack of operator awareness, and unnecessary parts cleaning. Initially, the firm reduced the number of cleaning stations from 37 to 27. Costs associated with dumping of cleaners were made the responsibility of each department. Operators were surveyed to identify TCA use and determine opinions for alternatives.

P2 Opportunities:
The selected pollution prevention measure was to use a heated tank with liquid agitation, contingent on the necessary chip removal and oil removal systems. In the machine maintenance areas, two mineral spirit cleaners were installed and the company is in the process of installing **aqueous-based cleaning systems**. At the time of this writing, they had installed 13 aqueous washing systems and two (2) mineral spirits cleaning systems. They expect to have a total of 15 aqueous systems, centralized within departments, to replace 37 former TCA locations.

Other process implementation, in addition to the processes for reducing TCA, included treating soapy water by oil separation and in house pH neutralization. Also, a precision grinder was replaced by an older piece of grinding equipment which does not require virgin material. A "procedure" (not further described) was also recommended that would prevent the spoilage of coolants.

Scale of Operation: Approximately 6500 gallons per year of TCA were used. No other measure of the scale of operations was provided.

Stage of Development: The P2 technology is in the implementation stages, all equipment is not yet fully installed.

Level of Commercialization: The technology is fully commercialized.

Material/Energy Balances and Substitutions:

Material Category	Quantity Before	Quantity After
Waste Generation:		
1,1,1 trichloroethane	400 ppb in waste	not detectable in water discharge
Feedstock Use:		
1,1,1 trichloroethane	6500 gallons	0
Water Use:	N/A	N/A
Energy Use:	N/A	N/A

Economics

Investment Costs: The anticipated capital expenditures during 1990-1991 on this project are **$80,000**. This includes costs for aqueous cleaning systems, waste water collection equipment, and equipment installation.

Operational & Maintenance Costs: $15,000 in utility costs are required for heating and pumping aqueous fluids. There is an extra electrical cost associated with heating and pumping aqueous cleaning fluids equal to $15,000 per year. TCA cold cleaning had no utility cost.

Payback Time: With an approximate annual savings of $56,500 and $80,000 in capital costs, the pay back period is approximately **1.4 years**.

Cleaner Production Benefits

A net savings of $7,000 is expected from reduced disposal costs, since the disposal costs in 1988 were $9,000 and they expect that the cost for disposal of separated oils will be $2,000. In addition, the annual cost saving associated with the disposal of absorbents no longer contaminated with TCA is $34,000.

A net savings from replacing virgin TCA and aqueous cleaners will be $7,000. This was calculated from the difference in the 1988 cost of virgin TCA ($27,000) and the 1991 costs for aqueous cleaning solution ($20,000).

Other processes implemented, in addition to the processes for reducing TCA, included treating soapy water by oil separation and in house pH neutralization. The annual savings from segregation and in house treatment are $20,000. The savings from changing to an older grinder lead to an annual savings of $1,200 from reuse of the coolant. The annual savings from preventing spoilage of coolants are $1,300.

Overall, the potential savings from eliminating TCA is approximately $56,500 per year.

There are also regulatory advantages that cannot be directly quantified. Permit concerns associated with TCA discharge were greatly diminished by successfully negotiating with the regulatory agencies to tie the metal finish discharge into the nearby town sewer system. The company will no longer have to report under SARA for TCA which will save considerable time. Finally TCA air discharges will be eliminated. This may be especially important since TCA has come under intense scrutiny and regulation because of its ozone depletion and air toxics potential.

Citation: American Electroplaters and Surface Finishers Society, Inc., and the Environmental Protection Agency; "12th AESF/EPA Conference on Environmental Control for the Surface Finishing Industry," January, 1991; pp. 165-181.

Technological Option #8: SIC 285

Plasticolors, Inc., has developed and implemented a waste minimization program which reduced waste generation by 43% during its first plan year

Clean Technology Category

Process raw materials modification and **process modifications** were undertaken by Plasticolors, Incorporated, to implement their goal of waste minimization.

Case Study Summary

Plasticolors, Inc., manufactures dispersions, additives and colorants. In early 1990, the company began a waste minimization program to reduce the amount of waste generated and to reuse materials when possible without affecting product quality. The amount **of resinous and water waste** generated during the twelve months prior to their waste minimization program (WASTEMIN) was 556,100 pounds. **During their first plan year** it was 315,478 pounds, a **reduction of 43%.** Overall production during this time decreased by 17%. In addition, 12,227 pounds of solid waste (office/computer paper and cardboard) was sent out for recycling rather than to a landfill where it had previously been sent.

All areas of Plasticolors' operation have been involved in the WASTEMIN project. All employees have received various degrees of training and education regarding the proper segregation, collection, reuse and/or disposal of residual materials and their associated costs. Segregation and separation of flammable materials from combustible materials, and pourable from thick liquids prior to disposal, has been a common practice for many years. However, Plasticolors' Waste Minimization Team has also begun segregating material for reuse in the manufacture of new or existing products.

Initially, Plasticolors' waste reduction program **consisted of collecting and reusing resins. These resins were used to purge out sandmill chambers and related equipment between product runs**. This material was identified, collected and stored for use in the next batch of material to be made. Production scheduling was also incorporated into this process so that the colors being processed were in the proper sequence. **Two additional mill chambers and pumps were purchased to reduce the frequency of cleaning and, consequently, the amount of purge generated. Plasticolors' largest reduction in generated waste has come from the production area.** The lab has also been involved in the WASTEMIN project. The lab revised their procedures, collects smaller quality control samples and retains samples.

The pollution prevention techniques concerning minimization and/or reuse of resinous and water waste were conceived, developed and implemented by the Waste Minimization Team. This team was made up of employees from all areas of the company, from line employees to office managers. The team utilized the talents, abilities and input of all the employees. The seven member team was charged with accomplishing a first year 25% waste reduction. These reduction techniques have been used since their implementation. The technology and processes incorporated by Plasticolors were not commercially available.

Economics

Investment costs
Two sandmill chambers, pumps and associate equipment **$24,556**

Operating and Maintenance costs	
Waste Minimization team	
(comprised of seven members meeting weekly)	350 hours - $5,968
Employee Training	
(Procedural and awareness)	140 hours - $2,387

The **payback period was less than one year**. The total investment during **the plan period of October 1, 1990, to September 30,** 1991 was $32,911. Using the previous twelve months as a baseline, the net savings were $83,480 of which $55,656 was divided among all employees as a waste minimization bonus. This amounted to each employee receiving a check for approximately $500.

Cleaner Production Benefits

The **reduction in waste** and its associated costs had a positive financial impact on Plasticolors. Additional resources are now available for use in other growth oriented areas of their business. The reduction has also had a positive impact on Plasticolors' team concept of doing business and it reinforced efforts to involve operators and technicians in the problem solving process. Plasticolors has strengthened its relationship with the local community in which it is located.

Source: Case found in Enviroene: {http://es.inel.gov/techinfo/case/comm/ plastico.html}.

B. Generic Technological Options

Generic Technological Option #1: Vapor Degreasing
{SIC-range = (34, 35, 36, 37)}

Use of an aqueous wash system eliminates completely the use of 1,1,1 TCA in degreasing

The full of description of the technology is given in the following attachment.

Source: Case was provided by the RREL and the Center of Clean Products of the University of Tennessee

DEMONSTRATIONS OF ALTERNATIVES FOR VAPOR DEGREASERS

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INTRODUCTION

The "Cleaner Technology Demonstrations for the 33/50 Chemicals" is a cooperative agreement project between the Center for Clean Products and Clean Technologies and the U.S. EPA. Though originally designed to support the 33/50 Program, the results of this RREL-funded research will have a broad range of applications within industry and offer pollution prevention benefits beyond the 33/50 goals. The overall objective of this project is to evaluate substitutes of the 33/50 chemicals in order to encourage reductions in their use and release within specified priority use clusters. Priority use clusters, identified in the "Product Side of Pollution Prevention: Evaluating Safe Substitutes for the 33/50 Chemicals" report, are products and/or processes that consume a significant fraction of the 33/50 chemicals (1). The first evaluation, presented here, focused on the metal and parts degreasing priority use cluster and specifically substitutes for solvent degreasing processes that eliminate the use of the chlorinated degreasing solvent dichloromethane, tetrachloroethylene, 1,1,1-trichloroethane, and trichloroethylene.

In this study the Center for Clean Products worked directly with an industry partner to demonstrate substitute feasibility and to gain actual industrial information. Calsonic Manufacturing Corporation (CMC) is aggressively pursuing less polluting alternatives to solvent degreasing and agreed to participate as the Center's industrial partner to demonstrate solvent degreasing substitutes. CMC manufacturers automotive parts included heaters, blowers, cooling units, motor fans, radiators, auxiliary oil coolers, and exhaust systems. Over the past four years, CMC had evaluated and implemented a number of environmental improvements to completely eliminate 1,1,1-trichloroethane (TCA) from their degreasing processes. This research focused on two of these improvements: an aqueous wash system which replaced five vapor degreasers of the radiator manufacturing line, and a no-clean processing alternative (i.e., application of an evaporative lubricant which does not require cleaning for subsequent processing) which eliminated two vapor degreasers of the condenser manufacturing line.

METHODOLOGY

The technical, environmental, economic, and national impact evaluations performed for the aqueous wash system and no-clean alternatives employed at the CMC facility had the following specific objectives:

1. technical evaluation
   - o evaluated the substitutes' effects on process and product performance as compared to the solvent degreasing processes
2. environmental evaluation
   - o evaluated the releases and off-site transfers of the 33/50 chemicals in the production process compared to the substitutes' chemical releases and transfers
3. economic evaluation
   - o evaluated the costs, traditional and nontraditional, of the substitutes as compared to the 33/50 chemicals
4. national evaluation
   - o evaluated and compared the overall life-cycle national environmental impacts of replacing the 33/50 chemicals with the substitutes

Data required to perform the technical, environmental, and economic evaluations were collected from CMC through data request tables, site visits, and interviews with CMC employees. Data request tables, completed by CMC employees and during site visits, allowed for the collection of process information including capital costs, operating and maintenance costs, utilities consumption, and production data. Questions concerning generation rates and disposal costs of waste (hazardous and non-hazardous) and wastewater accompanied the data request tables, as well as questions concerning permitting requirements. Tables and questions were directed at operations both before and after the process changes.

Site visits and interviews allowed Center staff to become familiar with the day-to-day operations of each CMC manufacturing line of interest. This information was used to extend the traditional economic evaluation by using activity-based cost accounting. Activity-based cost accounting specifically identifying the frequencies, durations, costs, and possible chemical emissions for every activity required to operate and maintain the solvent degreasers and alternative systems. Direct manufacturing activities, as well as indirect support activities (e.g., paper work, waste management, supervision) were identified and included in the evaluation.

These evaluations of CMC, supplemented by on-line databases and literature sources, were used to estimate the national environmental impacts that could occur if entire industrial sectors replaced solvent degreasing systems with the alternatives.

RESULTS

For this study, process and product performance were used as the two parameters to evaluate the technical feasibility of the alternative cleaning systems. As part of a continuous manufacturing line, the cleaning process (or no-clean alternative) has the potential to influence both of these parameters. Process performance was defined as the rate of production. Product performance was based on the part reject-rate per unit of production, which was determined from the leak test records of every unit manufactured. The production and part reject-rates when the solvent degreasing processes were on-line were used as the baseline for comparisons with the alternative processes.

Production rates and part reject-rates were both established through historical records and employee interviews. Evaluation of this data revealed that the production rate of either process line (radiator or condenser) was not affected by the change to the alternative system. Neither was the part reject-rate of the condenser line, both before and after the process change to the no-clean alternative. The part reject-rate for the radiator line, however, did significantly decrease after the aqueous wash system was installed. By implementing the aqueous wash system, and through the efforts of a Radiator Task Force established by CMC, the leak detection rate of the radiator line was decreased nearly 77 percent.

Though the alternative processes eliminated TCA releases and transfers from the radiator and condenser process lines, other chemical releases and transfers resulted from their implementation. Therefore, it was necessary to evaluate multiple media (land, air, and water), as well as hazardous and nonhazardous wastestreams, to capture the full impact of the changes to the alternative processes.

Air releases and off-site transfers, reported to the 1992 Toxic Release Inventory (TRI), were the predominant releases and transfers of TCA from CMC's manufacturing facility. Table 1, below, summarizes these releases and transfers, and shows how they decreased over the past four years. TRI only requires facilities to report total releases and transfers of a chemical, not process-by-process releases or transfers. Therefore, specifically identifying the contribution to the overall reductions from either the radiator or condenser process lines was not possible. However, chemical use records for these process lines, and employee interviews establish the following estimates:

1. the radiator process line, consuming 250,400 lb. of TCA for solvent degreasing in 1990, released 115,000 lb./yr. in 1990, 86,800 lb./yr. in 1991, and 0 lb./yr. in 1992; and
2. the condenser process line, consuming 88,500 lb. of TCA for solvent degreasing in 1992, released 75,500 lb./yr. in 1992, and 0 lb./yr. in 1994.

The implementation of these alternatives eliminated this consumption of TCA and the releases and transfers associated with its use.

The implementation of the aqueous wash system for the radiator line, however, generated an 8,400 gallon/day water wastestream. Treated at an on-site pretreatment facility, this wastewater represents a significant waste management change. A nonhazardous, oily wastestream, skimmed from the surface of the aqueous wash reservoirs, was also a newly generated wastestream of the aqueous wash system. The no-clean alternative, by applying an evaporative lubricant to eliminate the need for parts cleaning, generated a new source of volatile organic compound (VOC) emissions to air. Based on lubricant consumption records, and assuming 100 percent evaporation, approximately 4,000 pounds/year (1.7 pounds/day) of volatile organics are emitted to the air from this alternative process.

TABLE 1. CMC TRI-REPORTED RELEASES AND TRANSFERS OF TCA

Year	TCA Air Emissions (lb./yr.)	Percent Change	TCA Off-Site Transfers (lb./yr.)	Percent Change
1990	425,756	—	233,530	—
1991	194,622	-54.3	338,525	45.0
1992	176,239	-9.4	206,345	-39.0
1993	89,446	-49.8	194,975	-5.5
1994*	66,800	-25.3	109,000	-44.1

* Values estimated from eleven months of TCA purchase records and trends of previous years

The traditional economic evaluation, results of which are presented in Table 2, indicated return on investments in as little as 0.3 years (CMC-determined RI for the condenser line). The activity-based costs accounting economic evaluation had not been complete at the time of this abstract publication. However, initial review of the activities recorded during site visits to CMC identified significant differences in the required activities between the solvent degreasing processes and those of the alternative systems. These differences centered around two operations: one being the activities required to manage toxic chemicals and toxic waste; the other was the costs associated with the treatment of the aqueous system's wastewater. These results will be available by the time of the presentation, and copies of the methodology and results will be available.

TABLE 2 - COMPARISON OF SPECIFIC TRADITIONAL COSTS

Costs	Radiator		Condenser	
	Degreasers	Aqueous System	Degreasers	Evap.Lube.
Capital investment	not avail.	$463,585	not avail.	$44,000
Chemical Costs	$182,490	$21,400	$67,040	$4,720
Waste Disposal	$20,000	$12,430	$13,735	$0

Chemical releases and transfers occur through out their life cycles: from their production, use, and disposal. Significant changes in these emissions can occur if entire industrial sectors were to implement alternatives to solvent degreasing similar to those of CMC. Therefore, a life-cycle, multi-media approach to the national environmental impact evaluation was used to capture the overall environmental impacts of the alternatives.

Production facility releases and transfers of the chlorinated degreasing chemicals, in TRI reporting year 1992, totaled 1,286,823 lb. An estimated 34 percent of the chlorinated solvents produced in the U.S. were used in solvent degreasing applications in 1992 (2). Using a life-cycle approach, some fraction of the production emissions may be attributed to solvent degreasing: 34 percent to the production releases, establishing the potential upper boundary, equaled 440,000 lb. The EPA estimates that 24,500 solvent degreasers were operational in 1992 within the US (3). These solvent degreasers consumed approximately 440 million pounds of chlorinated solvents. Based on this information, the EPA also established a 1992 air emission baseline from these 24,500 solvent degreasers at 283.5 million pounds (4). Eliminating the use of chlorinated chemicals in solvent degreasing processes would greatly reduce or eliminate these emissions, both associated production releases and transfers, as well as the use and disposal releases and transfers. Phase-out regulations for TCA will reduce the use and releases/transfers of TCA regardless of the degree of which these alternatives are implemented.

The alternatives to solvent degreasing also have life cycle environmental releases and transfers. Aqueous detergents may include in their formulations surfactants, saponifiers, chelators, corrosion inhibitors, and stabilizers. Specific examples from each of these additive classes were analyzed. Disposal of the water wastestreams may have significant effects on publicly owned treatment works (POTW). The POTW infrastructure of the nation was evaluated, and the potential impact the aqueous wash systems have on the infrastructure was established. A similar life-cycle approach was used to evaluate the mineral-spirits-based evaporative lubricants.

CONCLUSIONS

A significant number of studies are being conducted, or have been completed, which evaluate the effectiveness of cleaning alternatives. These studies primarily focus on one of the four evaluations performed in this study; little integration of all potential issues is attempted. This cooperative agreement with EPA expands the existing knowledge of alternatives to solvent degreasing by integrating technical, environmental, and economic issues, as well as addressing the life-cycle attributes of the alternatives on a national scale.

The technical feasibility of CMC's process changes has proven to be positive. Significant reductions in toxic chemical releases and transfers were a result of the process changes, while other wastestreams were generated which required different management schemes. The traditional economic evaluation of this study did not reveal any unique conclusions. However, the activity-based cost accounting method did identify the costs associated with managing toxic chemicals and wastes, costs normally absorbed by the company as overhead. Finally, the national impact evaluation identified the importance of a life-cycle approach to evaluate pollution prevention projects. Though the alternatives evaluated in this research eliminate chlorinated chemical emissions, there are new wastestreams and constituents that must be addressed.

REFERENCES

1. Product Side of Pollution Prevention: Evaluating Safe Substitutes of the 33/50 Chemicals, EPA/600/R-94/178, U.S. Environmental Protection Agency, Office of Research and Development, September 1994.

2. Product Side of Pollution Prevention: Evaluating Safe Substitutes of the 33/50 Chemicals, EPA/600/R-94/178, U.S. Environmental Protection Agency, Office of Research and Development, September 1994.

3. National Emission Standards for Hazardous Air Pollutants: Halogenated Solvent Cleaning - Background Information Document, EPA-453/R-93-054, U.S. Environmental Protection Agency.

Generic Technological Option #2: Zero-discharge metal plating systems {SIC-range = (34, 35, 391)}

In process wastewater purification and metal recovery in the metal plating process at a jewelry manufacturing SME

The full of description of the technology is given in the following attachment.

Source: The technology was presented in the Spring 1993 issue of the Pollution Prevention News.

Moving Towards Zero

Our approach to solving pollution prevention problems in this country is showing a gradual shift from end-of-pipe controls to front-end reduction of strategies. The next logical step? Closing the loop entirely. As innovations at the Robbins Awards Co. of Attleboro, Massachusetts show, getting rid of pollution is not some environmental pipe dream; the company's closed-loop production system proves that reduced use and zero discharge of toxics are technically feasible objectives that can translate into significant savings.

Robbins is a medium-sized company that designs and manufactures custom jewelry and awards. Production of these goods involves a metal plating process famous for high levels of pollution; the process is chemical intensive, requires high volumes of water, and produces huge quantities of wastewater residuals.

Robbins zero discharge system, installed in 1988, involves two subsystems: wastewater purification and metal recovery. These two units have reduced the company's water usage by 48 percent, chemical usage by 82 percent, and production of metal hydroxide sludge by 99.8 percent, from 4,000 gallons per year in 1986 to seven gallons in 1988. Installation of the system cost the company $120,000, plus $100,000 for a new wing to house the units. Overall savings average $71,000 per year; the investment was repaid in full after three years.

A combination of factors spurred Robbins to explore the zero discharge option. A 1985 study of the Ten Mile River identified Robbins as one of the river's major polluters. As a result, the State's Office of Technical Assistance (OTA) held a series of pollution reduction workshops. OTA's message convinced Robbins' environmental manager, Paul Clark, to substantially reduce the company's water usage, from 12 to 15,000 gallons per day to only 2,500 gpd.

Then in January 1987, EPA and state officials announced strict new pollution restrictions based on the 1985 report. In addition, MassPIRG filed a lawsuit stating that Robbins had violated its wastewater discharge permit limits repeatedly from 1981 to 1987, translating into 2,500 violations, withpotential fines of up to $30 million. (MassPIRG put the suit on hold while Robbins made the transition to closed-loop production, and dropped the case after the company demonstrated that it had achieved zero discharge in 1988.)

As Clark explored the feasibility of a closed-loop system, pollution control suppliers told him, "it can't be done." The state OTA agreed to visit the company, and came up with specific ideas on how a closed-loop system might work. Now it was up to Clark to convince top management that the closed-loop system was the most cost-effective way to bring the company into compliance with the strict new discharge requirements. The numbers were clear, but the system had never before been tried. Seniors managers agreed to Clark's proposal with some hesitation, but have since become forceful advocates of toxics use reduction. "Companies have to become effective in dealing with environmental issues," says Robbins' Executive Vice-President John Bradley. "The ones that don't are going to be paying huge fines and penalties - they won't be in business by the year 2000.

Other companies are showing growing interest in the Robbins approach. Crucial ingredients to Robbins' success include technical support from the state, a citizens' group threatening legal sanctions, strict federal requirements, and an innovative, persistent advocate for change within the company. According to Bradley, the major hurdle to overcome is fear of risk. "Upper management has to be flexible," he says. "They can't shut anything out just because it hasen't been done before."

For more information, contact John Camera, Facilities Manager, Robbins Co., 400 O'Neil Blvd., Attleboro, MA 02703: Tel: 508-222-2900.

This article is reprinted from *The What Works Bulletin*, a bi-monthly publication highlighting outstanding environmental action. *What Works* is published by The Environmental Exchange, a national nonprofit organization accelerating environmental action by sharing information about what's working to protect the environment. To exchange information about successful environmental initiatives, contact The Environmental Exchange, 1930 18th Street N.W., #24, Washington, DC 20009; Tel: 202-387-2182.

Generic Technological Option #3: Paint Removal
SIC-range = (28, 35, 36, 37)

A cryogenic process for paint removal from steel structures, using liquid nitrogen instead of acids or pyrolithic oven

Cleaner Production Principle: Material substitution

Description of P2 Application:

The process for paint removal is based on liquid nitrogen's ability to quicken cooling. The differing rates at which the material of the structure and paint coat contract results in cracks in the paint. By means of mechanical action the paint coat is then removed. The resulting solid waste can be used for the production of plastic objects. The objects to be treated are placed in a tank containing liquid nitrogen (-196 °C); the removal process can be realized in a continuous and completely automated plant. Conventional processes utilize acid dripping or pyrolitic ovens and produce pollutants. Liquid nitrogen, chemically inert, is already in the atmosphere and can be obtained at low cost. This type of process **does not produce liquid waste.** The **solid waste that is produced can be recovered and utilized** to produce plastic objects. Existing plant capacity is 2500 Kg/h of objects to be treated. The technology has been fully implemented and in operation since 1990. It is covered by a **patent.**

Economics: Referring to 2.500 Kg/h of treated objects the investment cost is $220,000 to $250,000. Payback time is 1/1.5 year.

Advantages: In addition to the benefits outlined above, nitrogen is a comparatively low cost raw material and the objects processed by this technology have a life span five times longer compared to those produced by other processes. Although this process has a high productivity until 3.000 Kg/h, this is not a constraint for an SME.

Source: The UNEP ICPIC database.

Generic Technological Option #4: Solvent Substitution in Paints {SIC-range = (285, 34, 35, 36, 37)}

Substitution of solvent based paint with powdered paints minimizes organic solvent emissions

Cleaner Production Class: **substitute less toxic raw material**

Industry Class: surface finishing, cleaning, and coating

Clean Technology Category: This clean technology scheme involves the **utilization of powdered paints instead of solvent based liquid paints**.

PROCESS AND WASTE INFORMATION: A fixture manufacturing facility in Landskrona, Sweden utilized a mineral oil based cutting oil for metalworking. Manufactured components were then degreased using trichloroethylene solvent. **Solvent based paints were utilized in the final finishing of parts.**
The use of powdered paints results in reduced organic solvent vapor emissions and reduced operating costs.

SCALE OF OPERATION:	400,000 pieces/yr.
STAGE OF DEVELOPMENT:	Clean technology is fully implemented.
LEVEL OF COMMERCIALIZATION:	Clean technology is fully commercialized.

MATERIAL BALANCES:

Material Category	Quantity Before	Quantity After
Waste Generation:		
Trichloroethylene vapor:	N/A	5 tons/yr. less than before
Mineral Solvent vapor:	N/A	30 tons/yr. less than before
Wastewater:	N/A	N/A
Feedstock Use:	N/A	N/A
Water Use:	N/A	N/A
Energy Use:	N/A	N/A

COSTS: Investment for system for powdered painting was **$383,000**. No other investment costs provided. Operating costs for powder painting is $415,800/yr less than for solvent based painting.
Thus, the Payback for painting system changeover investment was less than 1 year.

P2 BENEFITS: New processes **minimizes organic solvent emissions**, costs associated with solvent purchase and waste disposal greatly reduced. Further, **workplace exposure to solvents is prevented**. In addition, new system facilitates continuing compliance with air pollution standards.

SOURCE: Siljebratt, Lars et al; Förebyggande miljöskyddssstrategi och miljöanpassad teknik i Landskrona, etapp 2. ISSN 0281 5753 {From the UNEP ICPIC database}.

III. Innovative Delivery Mechanisms for P2 Technology Transfer [Task 6] *

The sixth task of the project is to identify innovative delivery mechanisms for the transfer of technical information and assistance related to P2 technologies to needy firms. These might include expert systems, data-bases and written information.

In this section we (1) describe currently existing outreach and technology-transfer mechanisms ("platforms"), (2) identify and assess ongoing developments in the area, and (3) develop recommendations for innovative mechanisms for P2 technology transfer to needy firms.

We describe the existing electronic and non-electronic sources with particular focus on "platforms" that seem promising for our specific task. The currently existing EPA infrastructure is of particular interest in the following discussion. We have chosen not to focus on the present weaknesses of EPA in institutionalizing P2 in information management, since significant EPA initiatives are ongoing. Reference [28] gives an insightful description of EPA's organizational problems, while reference [29] addresses the shortcomings of a very significant EPA outreach mechanism, the Toxics Release Inventory; the discussion relevant to Task 6 in [29] focuses on the Database Maintenance/Standardization and the Data distribution. At this point, a mere description and understanding of the current outlook is all we seek.

A. Non-electronic Information Sources

1. EPA Pollution Prevention Information Clearinghouse (PPIC)

The objectives of this clearinghouse are, to:
- establish government and industry P2 programs
- identify technical process options to reduce pollution

Contact: (202) 260-1023

2. US EPA Small Business Ombudsman Clearinghouse

The services provided are: "small business P2 grants, general assistance to small business seeking to comply with EPA regulations." This clearinghouse has significant experience with SMEs. This already-established channel of communication may be useful for technology transfer purposes.
Contact: (800) 368-5888

3. Center for Hazardous Materials Research (CHMR) at the University of Pittsburgh Applied Research Center

The Center collects information on hazardous waste minimization, P2; distributes related publications and provides training. Contact: (412) 826-5320

* This chapter is based on information gathered as of June 15, 1995. Months later, the Internet-related sources of Environmental information had mushroomed. However, we believe that the essence of this discussion remains accurate.

4. State Agency Initiatives

These programs, that are discussed in more detail in Chapter II, include:
NEWMOA; MA OTA; Connecticut Technical Assistance Program (ConnTap); MinTAP; New Hampshire P2 program [which promotes the WasteCap Interactive computer model-WICM, a software program to help business with recycling]; RI Office of Environmental Coordination; Vermont Dept. of Environmental Conservation; Maine DEP & Waste Management Agency.

5. The Technology Transfer Center at TURI

This is a "model" clearinghouse and research library specialized on toxics use reduction and P2. The center offers a variety of tools to access practical information in P2:

(a) a research library searchable through the INMAGIC library software

(b) external databases:

- North East States PP Database
- Technical information from the Great Lakes Region states clearinghouses
- Vendinfo, a vendor database from Great Lakes Region states clearinghouses
- The Rhode Island database of Vendors
- The US EPA Solvent Alternatives Guide (SAGE)

(c) several databases on CD ROM, including "TOMES" (a database describing chemical toxicity and handling from Micromedix) and the "1987-1992 TRI data."

B. Electronic Information Sources - "Traditional"

1. Government-related

a. EPA Pollution Prevention Electronic Information Exchange System (PIES)

The features of this system pertinent to our study are:

- Industry-specific information packets. These include successful case studies and process-specific factsheets.
- Information on relevant Conferences and workshops.

b. Strategic Waste Minimization Initiative (SWAMI):

Software developed by EPA for P2 and materials tracking in industrial facilities.

2. Non government-related initiatives

a. TECHINFO
Bibliographic Database available on diskette from the Solid & Hazardous Waste Education Center, Wisconsin. (608) 262-6250

b. RILBY
Bibliographic Database available on diskette from the Waste Reduction Resource Center, North Carolina. (800) 476-8686

C. New Trends in Electronic Information Sources: The Internet Era

1. Government sources

a. EPA on the INTERNET

EPA has recently started a Web-site that has useful links to various data sources pertinent to our goals:

- TRI Data: Toxic Release Inventory documents. The data manipulation is not yet easy. One is better off by ordering the CD. When the TRI database acquires a user-friendly GUI (graphical user interface), the number of its users and the quality of the data analysis are expected to significantly improve.

- EPA-TOX: All the non-TRI documents of the OPPT.

b. National Technical Information Service (NTIS)

This service is a self-supporting Federal agency under the Technology Administration - US DOC. They are mainly known for the Fedworld© system. One of the fields of their specialization is Technology Transfer (namely, patent licensing and technology descriptions). Also, they are very successful as providers for Training Audiovisual Services. Currently, there exists an ongoing partnership between NTIS and EPA OERR for the dissemination of Superfund-related information. [These services are not free of charge]
Contact person: Pat McNutt, Marketing Director (703) 487-4812

c. Toxicology Data Network (TOXNET)

This is a computerized system of files oriented to toxicology and related areas. TOXNET is available via INTERNET in the address "TOXNET.NLM.NIH.GOV", and among others it offers the complete TRI data.

d. The Alaska Technology Transfer Assistance Center

This effort may become the model for static, i.e., non-interactive, technology transfer to SMEs. Essentially it offers all the bibliographic information needed to assess a technology. It also gives the pertinent information for licensing patented technologies. At a later stage this effort could be enriched so as to offer customized information for the specific needs of the interested SMEs, either through an expert system, or through a built-in dynamic simulator to calculate the actual environmental and economic results of the adaptation of a P2 technology to the specific needs of the interested SME.
{Internet-Address: http://www.polarnet.com}

2. Non-business sources (NGO's etc)

An ever-increasing number of user-groups is launching environment-oriented lists. For our purposes the only interesting case is ECONET. A service (not for free) provided by "The Institute of Global Communications," it provides access to international bulletin boards & electronic conferences, and databases such as the Environmental Gatemakers Association directory and the Sierra Club National News report.

3. Business Homepages

Many companies are launching homepages in the Internet either for public relation reasons (see Monsanto) or to provide better customer service (e.g., GE Plastics). We mention the existence of these homepages as a clear indication that the Internet will be a critical field for business-related communication activity very shortly. The Monsanto site is very interesting because it contains a complete example for "the development of an integrated in-situ Remediation Technology." This is the best example we found in the area of a static (i.e., non-interactive) model for technology transfer.

The GE Plastics site is important because it is the first case of a big chemical concern conducting business through the Internet. If this trend expands, then Internet will cease to be a *terra incognita* for the SMEs since they will have to conduct business (e.g., as subcontractors) through this medium. This is a critical issue, because one of our main concerns is that due to "cultural barriers" many SMEs will not have access to an innovative and powerful Internet-based platform. A general discussion of the current technological trends in the area of telecommunications and their impact in scientific sectors like Chemistry and Process/Environmental Engineering are presented in [30].

D. Presentation and critique of identified promising platforms

1. Enviro$ense *{http://www.epa.gov/envirosense}*

Enviro$ense is an interagency Internet-based system funded by EPA and the Strategic Environmental Research & Development Program. The Internet site is maintained and operated by the Idaho National Engineering Laboratory. The description of Enviro$ense in the web-page is the following:

"Enviro$ense, funded by the Environmental Protection Agency and the Strategic Environmental Research and Development Program, allows those implementing pollution prevention programs or developing research and development projects to benefit from the experience, progress, and knowledge of their peers. Enviro$ense includes a pollution prevention forum for all levels of government, researchers, industry, and public interest groups.

Enviro$ense has been developed to host an expert architecture known as the Solvent Umbrella. The Solvent Umbrella will allow users to access solvent alternative information through a single, easy-to-use command structure.

The features of Enviroene that are relevant to pollution prevention (symbolized as P2 throughout the database) are:

(1) the Technical/R&D Information section where many cases of innovative pollution prevention technologies can be found. This section includes the following subsections:
a) P2 Case Studies
b) P2 Fact Sheets
c) Economic (Capital Finance) Information
d) P2 Industry or Process-Specific
e) P2 Research, Development, and Demonstration
f) P2 Supplementary Environmental Projects (SEP) Database
g) Waste Exchange
h) Search Pollution Prevention Publications Bibliography

(2) the Solvent Substitution Data Systems section, where users have access to solvent alternative information through a single, easy-to-use command structure

The data found in Enviroene are highly specialized, international and go into great depth. EPA is apparently on the right track, building capacity/expertise for sophisticated technology transfer mechanisms. We believe that promising P2 technology profiles like the ones we identified in this report, should be included in that initiative under a section called "P2 technologies suitable for SEPs"

2. An Industrial Assessment Database for Energy Efficiency and P2 [31]
{http://OIPEA-WWW.rutgers.edu}

With funding provided by the Office of Industrial Technology of US DOE and EPA PPRB, the Energy Analysis and Diagnostic Center/industrial Assessment Center (EADC/IAC) Program was established in 1976. EADC/IAC is a service provided to small to medium sized manufacturing firms, and among other services provides SMEs with assessment recommendations for P2. These recommendations give detailed engineering design information as well as anticipated savings, implementation costs and payback calculations. Although the program has a 20 year history, it now enters its most dynamic and "interactive" phase with the development of a daily updated relational data base called "EADC/IAC Program Database." This database is administered by the Office of Industrial Productivity and Energy Assessment (OIPEA) at Rutgers University; and it consists of two separate datasets:

(1) the Assessment database, which contains information pertaining to each individual assessment

(2) the Recommendation database, with information pertinent to the specific recommendation

At this point, the effort is to incorporate to both (1) and (2) waste reduction /P2 data. This is done in an "expert system" mode and the data used refer to the following stream types:

- Energy
- Waste reduction
- Resource Cost
- Production

We were unsuccessful in our effort to get in hold of a manual and a version of the program, thus we cannot provide a valid assessment of this system. However, in the 21st RREL symposium the project managers described their endeavor as follows: "The database reflects the latest in industrial assessment techniques, energy and waste costs for small to medium size industrial plants."

3. Computer-supported Information System for measuring P2 progress [32]

This a research project undertaken by EPA RREL and the objective is "to build an information system (IS) for P2 which comprises a simulation model of an industrial production and waste generation system (IPWGS)." An IPWGS model is used to predict waste generation, carry out cost analysis of already existing waste management practices and after applying appropriate P2 strategies and technologies measure P2 progress. The selected Data Base Management System is ACCESS while the dynamic simulation software in ITHINK.

This project may prove critical in the endeavor for constructing an interactive/dynamic transfer mechanism. Moreover, if this mechanism can be accessed and used through Internet we will have a very powerful and versatile tool for the promotion of P2 in SMEs.

Our only concern is that although such a system is potentially much more powerful than a static Homepage (e.g., Monsanto); the current experience shows that interactive simulators (e.g., ASPEN, CAMEO) are not very user-friendly. Thus, we may end up with frustrated /intimidated SME managers. Hopefully this latter problem will be effectively addressed through the choice of the rather "main-stream" programs ACCESS and ITHINK. These Windows-based software programs are widely used already both in business and in academia (particularly ACCESS) and in addition to their user-friendliness they do not require very sophisticated and expensive hardware (such as Unix-based workstations) as the typical Engineering Simulators; on the contrary they can be used in simple PCs. Again, we would need access to the actual software developed in order to offer a valid assessment of its potential as a technology-transfer tool.

E. Recommendation

As we have already indicated in part IV-D, we believe that the Internet possesses the highest potential to become the main platform of dissemination of environmental information. This is because the Internet is much more convenient and user-friendly that the modem-accessed bulletin boards that do not posses a GUI environment, it offers the ability to link to guide the interested "client" to other sources of information, it is feasible to combine multimedia (e.g., informational videos or interactive flowcharts) and powerful data search facilities (for efficient database queries) and it seems that the users are increasing with such high rates that very soon, the connection to the Web will be such a cheap and easily implementable activity that even the most unsophisticated SMEs will be able to afford.

In this light, we propose that EPA OECA post all the promising P2 technology profiles, such as the ones that our research identified, in a web-page in the Enviroene site.

Our only concern is that the quality of the publicly-available information may not be good enough, to leverage the new medium. As we discuss in other work [8], many of the P2 cases found in PIES, Enviroene and in the UNEP database, do not have an easily absorbable format and do not contain vital information on issues such as the worker health and safety aspects of the promoted technologies. For example

- The case studies found in the above-mentioned databases completely lack information regarding the interactions of human beings with the production processes, materials, or products. Process engineers generally do not consider workers or jobs as part of the production process. From a worker health perspective, this is a serious problem that must be solved if risk shifting from the environment to people is to be limited.

- No information is given regarding the physical or economic context for the processes. It is very difficult to know what the processes in the PIES system or in the UNEP -ICPIC database actually looked like with respect to the physical space in which they were located, the degree of automation, the quality and maintenance status of the equipment, engineering controls, or administrative practices used to run the processes including shift work. From an industrial hygiene perspective, it is well-known that the actual conduct of the processes described in these case studies can vary considerably depending on the economic context and physical surroundings of the workplace. For example, chemical manufacturing is performed using practices that range from manual reactor vessel charging, mixing, packaging, and maintenance to process steps that are almost completely enclosed and automatic. The same process under these different conditions could have very different implications for worker health.

- Limited information is given regarding the physical form of the substances at certain stages in the process so that should a worker be exposed, the physiologic route of entry cannot be adequately anticipated. The physical form of substances can occasionally be determined by knowing process specifications such as temperature and pressure but these process specifications are not given consistently. Information is lacking about the manner in which materials are added to a process, maintained, stored and disposed.

IV. Conclusions

The conclusions drawn from this project relate to four issues:

A. Value and limitations of the Proposed "Prioritization Methodology"

- The methodology developed in the project achieves an appropriate balance between ease of use and accuracy. Our proposed criteria cover all the important aspects of a comprehensive P2 strategy. We use toxics data from TRI, economic data from Census reports and (ideally) we would incorporate the EPA OECA expertise by using IDEA data. We then translate these data into meaningful measures that describe the environmental performance of the industrial sectors: environmental burden, environmental efficiency, economic stagnation, compliance performance, SEP suitability. The main value of this report, aside from identifying 12 technologies that can be promoted through SEPs, is that it gives the Agency a useful framework to further efforts to prioritize and optimally allocate its scarce human resources.

- The absence of sufficiently detailed enforcement data affected the quality of the prioritization results. We urge OECA to improve the access to its IDEA database and to better utilize that database in its strategic targeting process.

B. Quality of Available Data on P2

- The available data on P2 technologies are not standardized: some sources describe technologies while others are in a case-study format. Both types of description are usually not complete. The lack of economic information on the technologies is very common, and -more importantly - very few cases give clear information on the trade-offs or relation between environmental benefits and occupational health and safety benefits.

C. The Identified Needy Sectors

- The sectors we identified were no surprise, however, we believe that the use of enforcement-related criteria will give even more accurate targeting. It is worthwhile noting that there exists a small number of generic technologies widely used in many SICs where P2 options are available that can significantly enhance the environmental profile of many companies. These technologies include alternatives to vapor degreasing and paint removal. OECA should focus its efforts for SEPs in such technologies, since they have a large impact in many SICs and they concern secondary/ancillary processes for which companies are not particularly sensitive/defensive about changing.

- It is clear that the TRI data enable us to do very significant analytical work. The more accurate the TRI data are and the more SICs they cover, the better quality of targeting OECA will achieve.

D. Opportunities for Innovative Transfer Mechanisms

- The Internet is the medium of choice.
- The content, the format and the level of detail of P2 case studies need improvement.
- Innovative software tools can help the state OTAs to leverage their impact in advising needy SMEs or they may even enable SMEs to choose the best available P2 practices on line.

V. Future research

Based on the experience acquired in this project we believe that the choice of P2 SEPs would be greatly enhanced by undertaking further research in the following two areas:

(1) Identify, through a comprehensive targeting system like the one proposed in this report, a small amount of 4-digit SIC sectors where P2 SEPs can have the biggest impact; acquire very detailed operational and technical data through field-based P2 data-gathering for the main technologies used in the sectors and come up with detailed technology profiles. These profiles will then contain much more information than the information one can find in a database. The data-gathering should include information from test runs and full environmental and economic analysis of the results.

(2) Undertake an effort to improve the quality (depth and breadth) of data presented in the P2 databases: very detailed economic documentation, information on multimedia benefits, specific focus on worker health and safety benefits or trade-offs, implementation horizon, level of commercialization of the technology, etc. That way, when a SEP is being considered, the parties will have a very clear understanding of the pros and cons of each technology option (technological, economic, behavioral, etc).

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