SOURCE REDUCTION AND THE WASTE MANAGEMENT HIERARCHY

By

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I. INTRODUCTION

In recent years, a significant controversy has developed around the concept of the waste management hierarchy. The idea of the hierarchy emerged out of the realization that land disposal of untreated hazardous waste had been a mistake. The toxic substances deposited in and on the land had migrated through the soil, into the ground and surface water and were being emitted into the atmosphere. Such releases pose a potentially serious threat to human health and the environment. The hierarchy--an ordering of waste management options according to their presumed ability to protect the environment--was the natural outcome.

By the mid 1980s, there was a consensus that alternatives to land disposal should be identified and pursued. Despite the acknowledged dangers of continued land disposal, the price for such disposal remained artificially low. It did not yet reflect the full liability costs that would ultimately be borne for cleaning up contaminated sites. In recognition that land disposal would remain the lowest cost management alternative without regulatory intervention, Congress took action in 1984. It passed the Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act (RCRA) which effectively called for EPA to phase out the land disposal of virtually all untreated hazardous substances by the

year 1992 at the latest. This prompted increased interest in alternative management methods, and the concept of waste minimization--minimizing the amount of waste that is ultimately generated--came into its own. Other terms--waste reduction and source reduction--emphasized limiting the waste generated at the source.

The debate on the definitions of these terms and their proper role in the waste management hierarchy is now in full swing. This paper describes, analyzes and puts in context that debate. It draws on case studies to illustrate that, in the final analysis, the issues at stake are ideological. The results suggest that generic positions lead to equivocation rather than action; better hazardous materials management will come about not through further debate but rather through implementing improved measures on a case-by-case basis. In some instances, these measures will prove appropriate for certain plants and operations and not for others. In other instances, measures may apply across a particular industry.

In Section II, I describe the waste management hierarchy and the terms and definitions employed by the different actors in the hazardous waste arena.

In the context of the hierarchy, in Section III I present the positions of the various interest groups and explain the criteria by which they evaluate "proper" hazardous waste management.

In Section IV, I develop three case studies of hazardous materials that illustrate that a rigid approach to "proper" waste management under the rubric of the hierarchy will not be effective. Instead, the hierarchy should serve as only a rough guide and our view of it must change according to the characteristics of a particular waste management problem.

In Section V, I summarize the results of the analysis and suggest a constructive future course.

II. CHARACTERISTICS OF THE HIERARCHY

Although there are numerous variations, there is a consensus that the simplest form of the waste management hierarchy is as follows:

- Source Reduction
- Recycling
- Treatment
- Land Disposal

The hierarchy is an ordering of hazardous substances management options according to their possible environmental consequences. In principle, the options at the top offer more protection to the environment than those at the bottom. The basic idea of the hierarchy is endorsed by virtually all interested groups. Source reduction--reducing the hazardous waste at the source and in the plant--is the most desirable option. In a particular case, when source reduction options have been exhausted, then recycling of the remaining waste should be the next option considered. When recycling opportunities have been exhausted, then treatment is of next priority. Only after treatment options have been exhausted is secure land disposal to be considered.

The history of the hierarchy is interesting and helps to explain the different interpretations of various terms. As I illustrate in the next section, it is not the ordering of options that is disputed but rather the criteria by which options are judged to be "exhausted." As background for this discussion, I review approaches taken by a number of different organizations and positions on waste management.

OFFICE OF APPROPRIATE TECHNOLOGY (OAT)

The California Office of Appropriate Technology (OAT), in 1981, was one of the first actors to define an "optimal hierarchy of management and disposal methods" (OAT, 1981). The methods together with their definitions in order of preference were:

- Waste Reduction - changes in industrial processes to generate fewer hazardous byproducts.
- Waste Recycling - includes resource recovery and other techniques that conserve raw materials.
- Physical, Chemical, and Biological Treatment - processes that render material innocuous, reduce toxicity, or reduce volume.
- High Temperature Incineration.
- Solidification/Stabilization of Residuals Before Landfill.

environment." The definition specifically includes recycling when it occurs internally to a process but excludes recycling and treatment of wastes after they have been generated (OTA, 1983).

INFORM

In 1985, INFORM published a record of the efforts at 29 plants to reduce waste (INFORM, 1985). Their organization defines a term "waste reduction at the source" to exclude recycling or treatment. It means that "the source of the waste is altered in some way so as to reduce the amount generated or eliminate it altogether."

ENVIRONMENTAL DEFENSE FUND (EDF)

The EDF report defines source reduction to cover "any technique by which the amount of hazardous substance that is imposed on society's waste-handling capacities is reduced" (EDF, 1986). This definition includes off-site recycling but does not include dewatering, incineration, or other forms of treatment.

SUMMARY OF TERMS

In general then, most sources agree that there are four distinct elements of the hierarchy: source or waste reduction; recycling; treatment; and land disposal. Two major sources

The major difference between the OAT hierarchy and the one listed above is that incineration is separated explicitly from other treatment options.

ENVIRONMENTAL PROTECTION AGENCY (EPA)

The EPA, in a recent report to Congress, used the term waste minimization to encompass source reduction, recycling and treatment (EPA, 1986). Source reduction was defined as the reduction or elimination of waste generation at the source, usually within a process. Recycling, according to EPA, can be either on- or off-site. It is the use or reuse of a waste as a substitute for a commercial product or feedstock, or the reclamation of useful material. Treatment includes various technologies like incineration and biological degradation.

The EPA report states that waste minimization is defined broadly under HSWA as any action taken to reduce the volume or toxicity of wastes. Although this implies that treatment is included, more recently EPA has considered redefining waste minimization to exclude treatment. This issue should be resolved in the near future.

OFFICE OF TECHNOLOGY ASSESSMENT (OTA)

The OTA report defines waste reduction as "in-plant practices that reduce, avoid or eliminate the generation of hazardous waste so as to reduce risks to health and

define source or waste reduction to exclude on- or off-site recycling that is not an intimate part of the process in question (INFORM, 1985; OTA, 1983). A third source, EDF, defines source reduction to include off-site recycling (EDF, 1986). A fourth source, EPA, defines the term "waste minimization" to include the first three elements of the hierarchy to some extent (EPA, 1986). As I discuss in the next section, it is not the definitions as such that spawn the controversy, but rather where the emphasis is placed in the waste management hierarchy and the differing views on implementation.

III. THE CONTROVERSY

In this section, for convenience, I define two polarized groups. The first group, the "source elimination proponents" (SEPs) generally includes the environmental activist groups and their supporters. The second group, the "bottom line proponents" (BLPs), generally includes private industry, some governmental organizations and some consulting firms. There are many other actors whose views lie in a continuum that spans the space between the two extreme positions.

THE EXTREME POSITIONS

Source reduction--the first element in the waste management hierarchy--has come to be a political concept. The goal of the most extreme SEPs is to eliminate toxic chemicals from our society. They see source reduction as a vehicle for accomplishing this end. Recycling and treatment are not acceptable to this group because such activities implicitly allow for the generation of hazardous substances in that they involve processing hazardous materials or their residues. Indeed, the opposition of SEPs to siting alternative treatment facilities--particularly incinerators--is intimately tied to the belief that source reduction not only has priority in the hierarchy but actually must be the only choice.

The BLPs have put most of their energy and resources in the past into end-of-pipe treatment in response to the regulations promulgated over the last fifteen years. These regulations were designed to prevent or reduce the release of materials to various environmental media, and land disposal was cheap. The natural outcome of this situation was an end-of-pipe mentality. Various types of treatment plants and incinerators were built to satisfy the regulatory statutes. These were used to treat waste generated on-site by many firms and to treat waste sent from a variety of off-site locations.

ANALYSIS OF POSITIONS

Virtually everyone agrees that source reduction should occupy the preeminent position at the top of the hierarchy. That is, there is a consensus that, within a given situation, source reduction opportunities should be exercised to the extent possible. Once this has occurred, recycling, the next element in the hierarchy, should be implemented to the extent possible, and so on down the hierarchy. The disagreement between the two groups arises from differing interpretations of the phrase "to the extent possible."

To SEPs "to the extent possible" means until no hazardous material is generated. BLPs, in contrast, interpret "to the extent possible" to mean exhausting cost-effective

opportunities for source reduction. The SEPs take their extreme position deliberately; they believe that if anything less than the "optimal" set of source reduction options is implemented, then these less effective options will become institutionalized and industry will stop searching for additional source reduction opportunities. Indeed, their fears may be well-founded; present evidence suggest that end-of-pipe treatment has become institutionalized. Industry began to look further into source reduction only when Congress required EPA to phase out land disposal, and liability for cleaning up sites became a real threat. This increased the cost of using the end-of-pipe technologies, and in comparison, some source reduction options began to appear cost-effective.

Not surprisingly, the BLPs, who are generally more familiar with industrial processes than SEPs, do not believe the SEP's goal of eliminating toxic substances from society is realistic. They are willing, for the most part, to devote impressive resources to identifying source reduction opportunities. Those that are cost-effective will almost certainly be implemented because they will save the firm money. However, industry is shortsighted in its conditions for cost-effectiveness and generally requires a very short time frame for a return on investment--commonly no more than three years. Furthermore, their heavy stake in end-of-pipe treatment suggests a long time horizon before certain source reduction options will satisfy the cost-effectiveness criterion.

The SEPs advocate regulation of generators. They believe that industry will not adopt source reduction measures that are not cost-effective without a government regulation that forces them to do so. The BLPs, in contrast, oppose regulation because they do not believe that government intervention provides the most innovative solutions to problems. In fact, as I discuss later, some regulations have been effective in forcing a new societal view of an issue. In other cases, private sector solutions may provide the "best" outcome.

IV. CASE STUDIES

The two positions described in Section III represent the extremes and neither position can achieve the desirable societal outcome. Those who embrace the polar positions are arguing in the political arena for an ideological point of view. It is all very well to pursue these higher goals, but such higher goals do not solve the day-to-day waste management problems of the nation. In the case studies that follow, I demonstrate the complexities of managing waste and adopting source reduction measures. These cases emphasize that the extreme positions, instead of solving the hazardous waste issues of today, lead to societal paralysis. The setting for each of the case studies is California, so the regulations and waste management system of the state govern the available options.

SUBSTITUTION VS. NEW EQUIPMENT

A large aerospace firm produces and machines various metal parts for aircraft. This firm presently uses stabilized 1,1,1-trichloroethane (TCA), a chlorinated solvent, for cleaning and degreasing these parts. The metal parts are dipped into an open top vapor degreaser to clean the contaminants which include metals, soils and oils. The vapor degreaser is very old and it does not function properly.

Because the freeboard--the height of the degreaser above the vapor zone--is very low in this old machine and because the machine does not have condensing coils, a significant amount of water vapor enters the degreaser from the air above the vapor zone. The water causes two problems. First, unstabilized TCA forms hydrochloric acid in the presence of water so the TCA must be stabilized. This stabilizer, however, is depleted more quickly when water is present. Thus, the contaminated TCA must be replaced with freshly stabilized solvent more frequently. Second, the waste TCA contains significant quantities of water. The water and TCA must be separated before the TCA can be recycled and reused.

The plant environmental engineer (EE) is looking for opportunities to cost-effectively minimize the firm's waste because of the land disposal bans, the increased risk of liability for sending waste off-site, and the increased cost for off-site treatment. The EE has received permission from his management to replace the current solvent line with an aqueous cleaning system. Because of other company priorities and because planning is required to integrate the new system into the plant operation, the conversion will not occur for about a year.

Now, the EE is aware of a number of options. He could purchase a new vapor degreaser for the TCA to eliminate its contamination by the water vapor. In a new degreaser, water contamination would not occur, and the new machines do not emit as much solvent because of increased freeboard and condensing

coils. A new degreaser would therefore reduce worker exposure to the TCA because it would be better contained. It would also allow the firm to avoid the cost of separating the TCA/water mixture and treating the water. If the EE decided to purchase a new degreaser, the firm would have to make a capital investment that would delay the purchase of the new aqueous cleaning system. This would increase the length of time the firm continued to use a hazardous chemical.[1]

Disposal of the waste presents problems for the TCA/water mixture and the pure aqueous case. In the case of the mixture, the waste would include liquid TCA contaminated with metals and organic material and water contaminated with the same constituents, assuming the water and TCA are separated. In many localities, the water would require further treatment before it could be released to the sewer. A sludge of metals and organics would be generated and it would probably be disposed of in a land disposal site.

The spent liquid TCA from the TCA/water mixture could be recycled using distillation on- or off-site. The purified TCA could be reused in the cleaning process. A still bottom containing metals, organics and small concentrations of TCA would be generated. This sludge would probably be blended with flammable solvents, taken to the cement kiln in Lebec,

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[1]Some water/detergent formulations contain active ingredients--like monoethanolamine, for instance--that are toxic and therefore pose a health threat.

California, and burned as supplemental fuel. The organic material and the TCA would be incinerated; the chlorine formed in the combustion process would be incorporated into the cement and neutralized. The metals would be captured in the baghouse and used in an asphalt process.

In the case of the pure aqueous waste, there would be a sludge generated in the water treatment process that could be disposed of in a landfill if metal concentrations were low enough. If not, further treatment of the sludge to remove the metals would be required before landfilling could occur.

In this situation, what would the SEPs' and BLPs' views be? The SEPs, since their goal is to eliminate toxic chemicals from society, would say the firm should not purchase the new degreaser, but should replace the TCA with the aqueous system as quickly as possible. They are willing to take short-term losses--higher worker exposure and high TCA losses--to realize long-term gains--substitution of a nonhazardous for a hazardous material. Indeed, the SEPs would emphasize that this case argues for a regulation. Such a regulation would require the firm to purchase a new vapor degreaser and then to adopt the aqueous system no matter what the cost. The BLPs would recommend choosing the path that was most cost-effective over the short-term, a path that would depend on the firm, the differential treatment costs, and the circumstances. No regulation is necessary, according to the BLP, because it would force a noneconomic decision.

What is the "best" course for the firm to take? The company will convert to the aqueous system eventually. In the meantime, should the EE try to minimize the present, high worker exposure by purchasing new equipment and delaying the conversion for several months? If he purchases new equipment, he will indeed lower worker exposure but will increase the transportation accident risk as the contaminated material is sent to the recycler and the cement kiln. Use of water--presumably the nonhazardous alternative--does not prevent hazardous waste from being generated. In fact, the same level of metals will be landfilled in both cases. The noneconomic trade off thus becomes worker vs. transportation risks. Since these are not easily quantified, the choice of which risk is more acceptable is in the last analysis a judgement call.

SMALL QUANTITY GENERATORS (SQGs)

There are an estimated 630,000 small and very small quantity generators in the nation who produce less than 1,000 kilograms of waste each month (Abt Associates, 1985). Many of these SQGs are small businesses run by families or by a small number of employees.

John is a furniture maker who runs a one-man operation in Southern California. He is an SQG who generates four types of waste in the course of his business. He produces paint wastes, paint stripping wastes, spent chlorinated solvent, and

spent lacquer thinner. He combines all these wastes in one drum and has a waste hauler pick it up periodically. The waste hauler charges a very high price to remove the waste because it is low volume and he has to send it out of state for destructive incineration. John has repeatedly tried to interest recyclers in his waste. They are willing to pick up the waste but, like the waste hauler, will charge an extremely high fee to do so. The small quantities available for recycling are not worth the pickup effort so the recycler simply treats the waste the same way as the hauler. He sends it out of state for destructive incineration.

In principle, at least two of John's wastes could be recycled. The paint wastes are not likely to be usable and the paint stripper waste is a methylene chloride/phenol combination that recyclers generally will not try to reclaim. On the other hand, the lacquer thinner and the chlorinated solvent can be readily recycled for reuse.

Peter is setting up a transfer station that will concentrate on combining and recycling material from SQGs. He intends to establish a so-called milk run where he will pick up waste from a number of SQGs in the same business. He can then combine wastes of the same type and recycle them in a large batch operation periodically. He has identified and contacted all the furniture makers in the county and he will begin the route service soon. John will be one of his customers.

How does the SEP view this operation Peter is trying to establish? The SEP would be opposed to Peter's milk run

because it would lower the cost of waste disposal to the generator which would, in turn, release the pressure to identify nonhazardous
substitutes. In theory, the reasoning is that if SQGs are faced with exorbitant disposal fees, they will put pressure on the suppliers of the lacquer thinner and solvents to find acceptable nontoxic alternatives. If disposal costs were lowered through a route service, suppliers could continue marketing toxic chemicals. If the status quo were maintained, some SQGs who faced huge disposal costs would be forced to close their business; that would simply put more pressure on the suppliers. The BLPs would likely encourage the route service because it would lower disposal costs.

What are the issues here? Many SQGs are families who work very hard to make a living. Disposal costs have increased drastically in recent years and are eating into their small profits. John needs to solve his waste problem and the route service Peter is offering looks attractive. Indeed, John's disposal costs will be reduced because Peter is receiving useful material that can be recycled. If we oppose the route service, SQGs' disposal costs will continue to increase. Would this encourage faster development of presently unknown safe substitutes? SQGs are rarely members of trade organizations either because an appropriate one does not exist or because the fees are too high. Consequently, they may not always be effective in lobbying suppliers.

This case presents two options. First, we could implement the route service and delay adoption of safe substitutes. Second, we could allow costs to continue to increase hoping the SQGs will put pressure on the suppliers. Again, as in the first case study, the choice of options is a value judgement. They reflect different views of likely future events. The SEPs believe that if the pressure on generators is relaxed--whether it be through regulation or increased costs--they will never adopt source reduction measures willingly. They also have faith that eventually the suppliers will identify substitutes that do not pose a threat to human health or the environment. The BLPs believe that the option that costs the least is the obvious choice.

MILITARY SPECIFICATIONS

A manufacturer in Los Angeles produces semiconductors for use in both military and private sector electronic devices. The firm uses TCA, a chlorinated solvent, to clean semiconductor wafers in the fabrication of microelectronic devices for use in military aircraft. On the other side of the shop, the firm uses recycled TCA for cleaning wafers used in domestic aircraft. The business, in effect, has two parallel lines, one of which uses virgin solvent and one of which uses recycled solvent. The reason recycled solvent is not employed on the military side of the house is that military specifications prevent its use.

The firm sells its contaminated solvent to a recycler in the area. The recycler reclaims the liquid solvent and sells it back into the market. The sludge is mixed with flammable solvent and sent to the cement kiln in Lebec, California as supplemental fuel in the cement manufacturing process. As such, it is used for resource recovery. The recycler sells the firm the recycled solvent it uses for nonmilitary cleaning.

The Environmental Manager (EM) in the firm is looking for methods of reducing the company's waste. She is investigating available or future alternatives to TCA and examining the possibility of using recycled solvent for the military cleaning operations. Because of the extreme requirements for purity in this technology, only one other potential substitute is available today. CFC-113, a chlorofluorocarbon, might be used in place of TCA but regulations on its use have been proposed by EPA (Fed Reg, 12/87). Even without the regulatory scrutiny it is undergoing, CFC-113 would be a poor alternative because it is more expensive and it could not be used in recycled form either. Chemical companies are sponsoring research on alternatives, but it may be a long time before they are available.

Another avenue the EM is exploring is setting up a consortium of generators in the same situation to approach the military about changing the specifications. She realizes that this option will take a great deal of work, but because there appear to be no viable substitutes presently in use, she will pursue it.

The SEP would oppose the EM's efforts to change the military specifications. If such a change should occur, then it would be cheaper and therefore easier for the firm to continue using the hazardous solvent. This would, in the SEP's reasoning, delay the identification and introduction of a nonhazardous alternative. The SEP in this instance, is willing to allow more hazardous waste to be generated in the short-term so the long-term goal of eliminating hazardous chemicals from society can be realized. The BLP, in this instance, would again choose the path that is most cost-effective.

V. THE SOLUTION LIES IN COMPROMISE

Sections II and III describe the waste management hierarchy and characterize the extreme positions on source reduction. The last section portrays three case studies that capture the positions of the extreme SEPs and BLPs. In this section, I first summarize the main points of the case studies. I then make some comments on the waste management hierarchy. Finally, I stress two fundamental concepts that argue for a compromise position.

DISCUSSION OF CASE STUDIES

The case studies revolve around a common theme. In each instance, we are presented with a problem that has two possible solutions. One of the solutions involves an improvement in the status quo that could be implemented immediately. All such improvements would reduce the amount of waste generated and/or the exposure to hazardous substances; they would also lower the costs of managing the waste. The other solution involves a conversion to a nonhazardous alternative that is in one case available today. In the other two cases, a viable alternative has not yet been identified. The assumption is that such alternatives will be identified and that they will be safe.

In the first case study, the choice is between conversion to an aqueous cleaner within a year on the one hand and purchase of a new vapor degreaser with a delay in the conversion on the other hand. An important point to remain aware of is that conversion to a nonhazardous alternative--water--does not eliminate the toxic waste problem. Toxic sludge components are still generated and they require further management of some kind. Alternatives identified in the future could, like CFC-113 and numerous others in the past, pose a threat to human health or the environment that is not immediately obvious.

The second two case studies raise a slightly different problem. One of the options improves the situation today. The other option is to adopt an as yet unidentified substitute in the future. The assumption here is that such a nonhazardous substitute will be found and that it will be found only if the generators' waste management costs continue to increase. These assumptions may not be valid. The nonhazardous substitute may eventually prove hazardous itself or its use may produce hazardous wastes or simply transfer the problem from one medium to another.

In all three cases, there is a compromise that would improve the situation today, not just in terms of short-term cost-effectiveness, a compromise that would encourage the continued search for safe alternatives but at the same time reduce the present threat to human health and the environment.

In the first case study, the firm could continue to use TCA and purchase the new vapor degreaser to minimize exposure and reduce treatment costs. At the same time the EE could try to find a place in one of the firm's other plants for the new degreaser. If he were successful, he could sell this new degreaser in a year and he could avoid amortizing the equipment in his operation. He could argue to management that the firm should still purchase the aqueous system on schedule.

In the second case study, we could allow the SQG route service to begin but, at the same time, use Peter's list of furniture makers in the county to start an organization of SQG representatives. This organization would be free to the SQGs and its purpose would be to lobby suppliers to search for safe alternatives. Safe substitutes would prevent worker exposure and reduce the future liability of SQGs.

In the third case study, a similar compromise might be appropriate. The EM would continue using the solvent but try to change military specifications to allow recycling. At the same time, she could join together with other firms involved in electronics through a trade organization like the American Electronics Association, for instance. The aim of this group would be to define the characteristics substitutes must have and to encourage solvent producers to search for and develop safe alternatives. Again, the benefit would be lower workplace exposure and reduced liability.

DISCUSSION OF HIERARCHY

In the light of the lessons of the case studies, some comments on the waste management hierarchy would be appropriate. The SEPs believe source reduction and indeed, more specifically source elimination--is the only option that should be exercised. The BLPs will exercise source reduction only insofar as it is cost-effective to do so.

The hierarchy should not be viewed as a rigid ordering of options with those options at the top posing less of a threat to the environment than those at the bottom. Rather, it should be viewed as only a rough guide for thinking about waste management options. Although the ordering is supposedly based on the options ability to provide environmental protection, in certain cases this may not be true. In the first case study, for instance, it may be better to continue using TCA in a good vapor degreaser with recycling than it would be to convert to water. With the TCA option, the metal contaminants may never be mobilized to cause deleterious health affects. On the other hand, if the water and metal contaminants are dumped in the sewer, then many people could ingest the metals in their drinking water. There might be higher exposure in this case and more severe health affects.

The point here is that each waste management problem requires a systems approach. In some specific cases, it may be "better" to recycle or treat a hazardous substance than it is to adopt a source reduction option. The hierarchy is therefore

useful for organizing our approach to waste management. It should not, however, be followed literally and rigidly without taking into account the host of characteristics surrounding each individual waste management case.

FACTORS THAT INFLUENCE SOURCE REDUCTION

The aim of all of us should be to better protect human health and the environment. The various groups just have different ideas about how best to accomplish that end. The BLPs view the world solely in terms of cost and reason that if a source reduction option is cost-effective over the short-term, then it should be adopted. If not, then it should not be implemented. This course will delay the introduction of safe alternatives. In contrast, the SEPs believe that the only way to accomplish source reduction is to mandate the "optimal" set of options. The problem here is that the term "optimal" is not well-defined and the "optimal" set of options today may not be the "optimal" set tomorrow; the "optimal" set in one plant may not be the "optimal" set in another plant with a different operation. A better way of approaching the problem is to focus on making certain source reduction options cheaper so they will be adopted and lead to improvements today. No one in industry, government or environmental organizations is doing this today. At the same time, we should also work toward the more "optimal" set of options that may take many more years of research and development to implement.

The advantage of a compromise approach is that it will involve a smooth transition to ensure that businesses--many of them small and medium sized--do not close. The argument against this compromise approach is that significant source reduction won't occur without pressure. There are two factors, however, that suggest that a compromise position would eventually lead to pronounced source reduction, albeit later than if the source reduction were mandated.

One factor that is influencing firms' decisions to adopt source reduction is the legislation passed in the last few years. The Hazardous and Solid Waste Amendments (HSWA) to RCRA which effectively phase out the land disposal of virtually all hazardous substances within the next few years, have encouraged source reduction to some extent. Because they prevent land disposal, however, they still allow generators to adopt treatment. The Superfund legislation holding generators responsible for joint and several liability at land disposal sites has been more influential in moving generators toward source reduction. They are reluctant because of potential future liability to send any hazardous waste off-site. Proposition 65 in California may also push users toward less hazardous substances.

A second factor moving generators toward source reduction is that such measures can lower waste management costs for many generators. The regulations have led to large increases in off-site treatment and disposal costs and source

reduction is beginning to appear more attractive--particularly to large firms as I discuss below.

There are three tiers of generators in the source reduction arena. The first tier--the chemical firms--have long been active in source reduction. For many years, chemical producers have looked for ways of maximizing their yields; the methods they have adopted, although they were not called source reduction measures, have minimized the waste or unwanted byproducts. The second tier of generators--the large electronics and aerospace firms--have recently implemented ambitious source reduction programs. These firms have little experience with chemicals because they do not produce them but only use them in the course of making another product. Nevertheless, they are now devoting impressive resources to investigating appropriate source reduction measures. Although it will be some years before significant source reduction is achieved, the mechanism is largely in place. The third tier--small and medium sized firms--do not and will not have the resources or training to examine source reduction options in a formal way.

It is this third tier of generators that would be most adversely affected by a source reduction regulation and it is this tier that requires the most help in adopting source reduction. Strict source reduction regulations would only hurt these people by imposing on them costs they could not absorb; it would likely put many out of business altogether. As a compromise effort, over the next

several years, we must establish technical assistance programs to help small and medium sized firms. Over the short-term, it seems reasonable to work toward minimizing the use and waste generation of hazardous substances through recycling and by helping to break down institutional and regulatory barriers making it cheaper for third tier generators to manage their waste. Establishing milk runs to encourage on-site recycling is an example. Over the long-term, we must simultaneously try to design procedures that will lead to identification of safe alternatives. An example here is organizing users to encourage suppliers to conduct research on substitutes.

The compromise approach to source reduction will achieve results. It involves assisting the industries that need the most help in a pragmatic way. It includes encouraging a mix of short- and long-term source reduction measures that eventually will lead to significant reductions in society's use of hazardous substances. This approach does not mandate the "optimal" set of source reduction options over a fixed time period. Neither does it accept the simple rule of cost-effectiveness compared with the status quo. Rather, it attempts to make the situation better at any particular time period for any specific generator, and it works to dissolve barriers that today make options that would reduce the use of hazardous substances too expensive.

V. SUMMARY AND CONCLUSIONS

Source reduction is an important national goal. The questions of what it really is and how best to achieve it have become the subject of contentious debate. This paper tries to clarify the extreme positions and to offer a compromise method of approaching the issue.

One of the extreme groups has as its aim the elimination of hazardous substances from society; source reduction is simply a vehicle for accomplishing that end. The other extreme group advocates limiting source reduction measures to those that are cost-effective over the short-term. Because there have been heavy capital investments in end-of-pipe treatment technologies, options that involve substitution to nonhazardous alternatives often do not meet the cost criterion.

Both sides have an unrealistic view of the future and their ideological views will not solve the waste management problems we face today. Some toxic substances will always be generated and used in society. Similarly, evaluating source reduction simply on the basis of cost-effectiveness will not protect human health and the environment. The compromise solution presented here is a pragmatic one. It suggests a course that improves the situation over the short-term but works toward minimizing use and waste generation of hazardous substances over the long-term.

The case studies presented here suggest two major conclusions. First, a practical approach to source reduction will take into account differences in firms and generators, differences in industries, and the realities of the present waste management system. Analysis of the "best" source reduction options will include a case-by-case assessment. Simplistic ideological solutions like eradicating toxic chemicals or evaluating measures simply on cost will not sufficiently improve the status quo. It is worth noting here that a source reduction regulation mandating source reduction requires a generic treatment of users that may be counterproductive. Indeed, the non-source reduction regulations already in place may provide sufficient incentives for large firms to pursue source reduction. Medium and small users will require technical and institutional assistance.

The second lesson of the case studies is that substitution of nonhazardous substances does not always eliminate hazardous substances. The nontoxic alternatives carry with them a different set of problems, some of them involving toxic materials. This suggests that a systems approach to source reduction is the only reasonable one. Such an approach would trace the implications of substitutions through the complete waste management chain and would reveal the trade offs posed by any choice.

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