Pollution Prevention Opportunity Assessment: Foundation of Pollution Prevention for Waste Management*

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Executive Summary

The objective of this paper is to promote the Pollution Prevention Opportunity Assessment (PPOA) technique as a fundamental of pollution prevention for waste management. All key elements of an effective PPOA program are presented. These key elements include impacts of environmental laws on pollution prevention, PPOA concepts and overview, waste minimization opportunities assessment, reporting and monitoring waste minimization progress, and PPOA program implementation.

As environmental laws evolve the focus is shifting from end-of-pipe pollution control to front-end source reduction. Waste minimization was mistakenly interpreted to mean the reduction of hazardous waste after generation in the past. The Pollution Prevention Act of 1990 has clearly defined its requirement on resource reduction. Waste reduction can be viewed as a criterion to assess all industrial processes and operations.

The fundamental approach of PPOA focuses on a mass balance concept. This concept deals with tracking of chemicals from the point of purchase, through storage, utilization in the process, and waste generation at the end of process. In other words, PPOA is a technique to analyze this input/output process. By applying PPOA techniques, the framework of applicable compliance requirements to the current operation process is established. Furthermore, documentation of PPOA itself can meet as documentation requirements for environmental compliance.

In general, the PPOA process consists of two phases. The first phase involves input and output process description and waste characterization. The second phase is an opportunities assessment for waste minimization from input/output waste characterization. These two phases are explained in detail in the paper.

Once a PPOA has been performed, quantitative waste data can be fed into a database to monitor waste reduction progress toward waste minimizaton goals. All waste streams identified through the assessment serve as a baseline for setting the goals in the waste reduction plan. There should be periodical waste data collection to update the database for waste reduction monitoring purposes. It is through this continuing process that the waste reduction program can be effective.

PPOA program implementation covers both programmatic issues and a step-by-step guide of "how-to's". Programmatic issues include the following elements: knowing PPOA requirements, getting management buy-in, creating a network of waste minimization coordinators, providing technical PPOA training, and making it part of managers' performance assessment. The systematic approach of PPOA how-to's include: gathering data, developing process flow diagrams, describing the process, quantifying chemical inputs and waste outputs, characterizing wastes, and identifying waste minimization opportunities. These elements and steps are discussed in detail in the paper.

Finally, potential PPOA technology transfer to the Pacific Rim countries will be addressed. The author uses Taiwan as an example to identify the needs for enviornmental cleanups in the island and to demonstrate the potential market for the PPOA technologies as part of waste management technology transfer between the U.S. and the Pacific Rim countries.

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1. Why Pollution Prevention Opportunity Assessments ?

With increasing pressures imposed on waste generators to properly handle their hazardous wastes and waste management costs eroding the corporate profits, more and more businesses are looking for solutions for their environmental issues. The objective of this paper is to promote the pollution prevention opportunity assessment (PPOA) technique as a fundamental of pollution prevention for waste management. In order to get the point across, we will first look at the impact of environmental laws on industry and the general public in terms of environmental awareness. This will help us understand why businesses have to commit to toxic waste reduction. Second, the concepts of pollution control versus waste reduction will be introduced. This will help management to focus on its waste reduction program. Third, a systematic approach to an effective pollution prevention program will be addressed with focus on two major elements of the program. This includes a technical assessment (i.e., Pollution Prevention Opportunity Assessment) to quantify wastes and a waste reduction reporting system to track waste reduction data. Finally, we will focus on PPOA program implementation.

2. Impacts of Environmental Regulations on Industries and Communities

Environmental movement in the U.S. started since 1970s with several pieces of legislation to guide and control hazardous waste materials. The Resource Conservation and Recovery Act (RCRA) and Hazardous and Solid Waste Amendments (HSWA) of 1984 require the generation of hazardous waste be reduced or eliminated to minimize the threat to human health and the environment. A waste minimization strategy was set up in HSWA to require waste generators to include a description of reduction efforts and results of these efforts. Unfortunately, there was no consistent definition of waste minimization, and it was often interpreted to mean the reduction of hazardous waste after generation. Furthermore, no waste minimization entity was established in the EPA, nor did waste minimization become a budget item. Section 313 of the Superfund Amendment and Reauthorization Act (SARA) Title III (Community Right-to-Know) required companies using hazardous chemicals to report use, on-site recycling, and the percentage of material in the product. The Toxic Substance Control Act (TSCA) of 1976 prohibits the manufacture, process, or distribution of any new chemicals. The Clean Air Act (CAA) of 1970 promotes prevention and control of air pollution by establishing the National Ambient Air Quality Standards (NAAQS) to regulate conventional pollutants, the National Emissions Standards for Hazardous Air Pollutants (NESHAP), and the standards for new stationary sources. However, this law does not necessarily discourage the generation of waste. The Clean Water Act (CWA) of 1972 established legal discharges, including National Pollutant Discharge Elimination System (NPDES) and discharge emitted into publicly owned treatment works (POTW). Again, this law does not promote source reduction, but simply establishes emission standards at the end-of-pipe.

As we can see from the development of these environmental laws, the federal government did not focus on true pollution prevention until recently, with initiation of the Pollution Prevention Act (PPA) of 1990 and its extension into Title III of the Superfund Amendments and Reauthorization Act (SARA). The PPA requires increased reporting of source reduction and recycling efforts by most industrial facilities as part of the 1992 Toxic Release Inventory (TRI) reporting effort. Under the PPA, Congress declared that pollution should be prevented or reduced in an environmentally safe manner; pollution that cannot be prevented or recycled should be treated in an environmentally safe manner. The PPA states that disposal or other releases into the environment should be employed only as a last resort. The importance of the PPA over HSWA is its emphasis on source reduction and minimization of release to all media. As mentioned above, an extension of the PPA is the mandatory reporting of source reduction and recycling activities under SARA Title III, Section 313. This section, better known as Form R reporting, now requires most facilities to annually report their waste minimization activities. Finally, there are non-regulatory activities influencing pollution prevention. One major initiative is EPA's Industrial Toxics Project, more commonly called the 33/50 Program. This program invites the largest dischargers of 17 priority pollutants to voluntarily reduce their releases or off-site transfers. The goals of the program are a 33 percent reduction by 1992 and a 50 percent reduction by 1995 in releases of these priority chemicals, using 1988 Form R releases as a basis.

This changing environmental regulations result in various violations by industry, thus forcing them to commit their efforts to toxic waste source reduction.

3. Pollution Control versus Waste Reduction

As environmental laws evolve, the focus is shifting from end-of-pipe pollution control to front-end source reduction. In the past, waste minimization was mistakenly interpreted to mean the reduction of hazardous waste after generation. The Pollution Prevention Act of 1990 has clearly defined the requirement for resource reduction.

Understanding the difference between pollution control and waste reduction is critical since they both have different economic impacts on business operations. Pollution control focuses on end-of-pipe emissions and there is no major disruption to the production process, although it requires an initial capital investment which includes facilities to be built. Operating pollution control devices is usually costly and, worst of all, pollution control may still subject various organizations to cradle-to-grave liability for their off-site waste disposal. Pollution controls do not solve problems; they only alter the problem, shifting it from one form to another. The form of the waste may be changed, but it does not disappear. In another words, pollution control is an environmental paradox. It takes resources to remove pollution, and pollution removal generates residue. It takes more resources to dispose of this residue and in the process creates more pollution.[1]

On the other hand, waste reduction focuses on source reduction. Source reduction is the true waste minimization and a foundation for environmental compliance. In order for source reduction to be effective, investments for R&D efforts, material substitutions, and process modifications are necessary and can also be costly. However, overall production costs due to source reduction will decrease as a result of less capitalization costs required for pollution control devices. By using materials more efficiently through source reduction, organizations can reduce the generation of waste and achieve the desired protection of human health and the environment. As a consequence, the costs of waste management and regulatory compliance can be lowered and long-term liabilities and risks can be minimized. Like any other profit making decision in the corporation, the decision to make a change that will minimize waste is based on economic factors. The cost from waste management and regulatory compliance can easily offset the present cost for implementing the waste reducation change and show an attractive rate of return. Consequently, waste reduction certainly has favorable economic impacts to the corporation than pollution control.

In most of industries that are heavily regulated by environmental laws, companies are concerned about competing resources between implementing a toxic waste reduction program and carrying out long-standing EPA compliance issues. However, those organizations must understand that waste reduction can pay for itself relatively quickly, especially when compared with the investment in time and resources needed to comply with existing programs regulating waste disposal. It is essential that industries focus their toxic waste reduction program on the concept of source reduction and demonstrate management support toward waste minimization efforts. Waste reduction must be seen as an attractive alternative by both management and employees in order for the waste reduction program to be successful.

4. Pollution Prevention Program

4.1 Pollution Prevention Opportunity Assessments

Waste reduction can be viewed as a criterion by which to assess all industrial processes and operations. To help organizations establish an effective waste reduction program, we must perform Pollution Prevention Opportunity Assessments (PPOAs) on all operations to track chemicals from the point of purchase, through storage, utilization in the process, and waste generation at the end of the process. PPOA is a technique to analyze this input/output process. PPOAs also provide an overview of operational processes for further investigation of applicable legal compliance.

In general, the PPOA process consists of two phases. The first phase of PPOA involves input and output process description and waste characterization. The second phase is an opportunities assessment for waste minimization using the input/output waste characterization.

In the first phase, the PPOA provides development of a waste flow diagram and a quantitative mass balance for the inputs and outputs of the process operations. As indicated in Figure 4.1, incoming materials are obtained by procurement. Following delivery, the materials are placed in storage areas. The materials are then distributed from storage to be utilized in plant processes. As these incoming materials undergo physical and chemical process changes, products are created, streams are recycled, and wastes are generated. The process waste that is generated is then accumulated through a collection system and placed in storage, waiting for further on-site or off-site

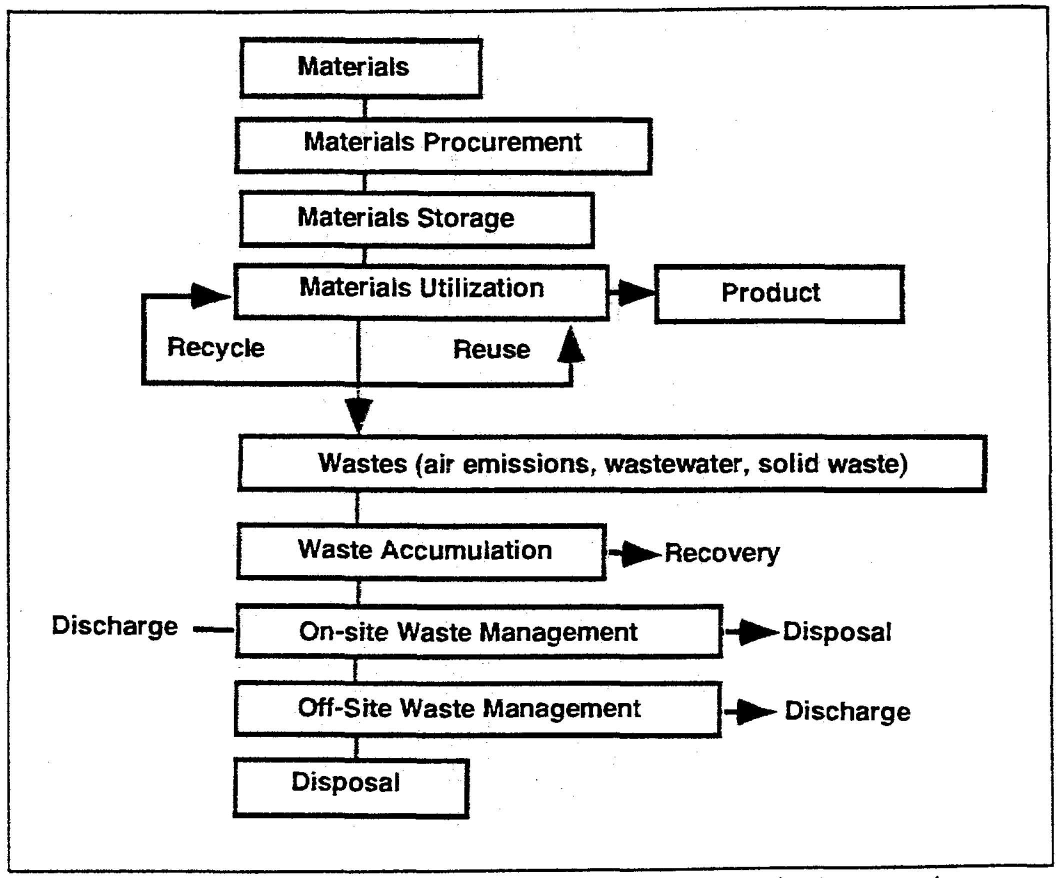
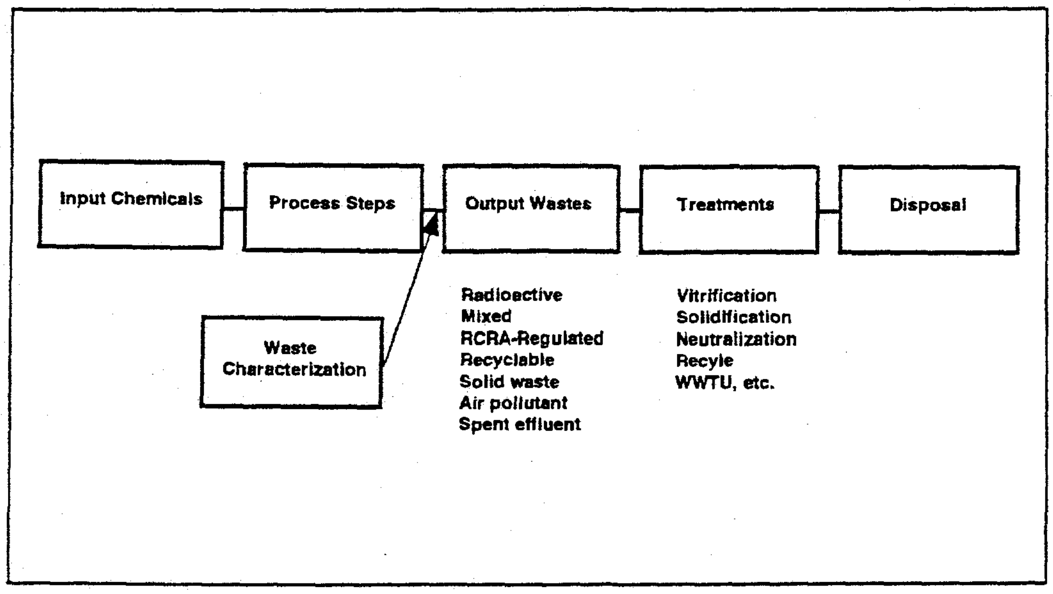


Figure 4.1 Fundamental Waste management Concept

disposition.[1]

The concept of PPOA is shown in Figure 4.2. There are five major elements in the Pollution Prevention Opportunity Assessment: input chemicals, process steps, output wastes, waste characterization, and disposal. The development of this inputs/outputs waste flow diagram requires a thorough understanding of the process engineering, the chemical and physical properties of incoming materials, characteristics of output wastes, and the overall process flow of the system.

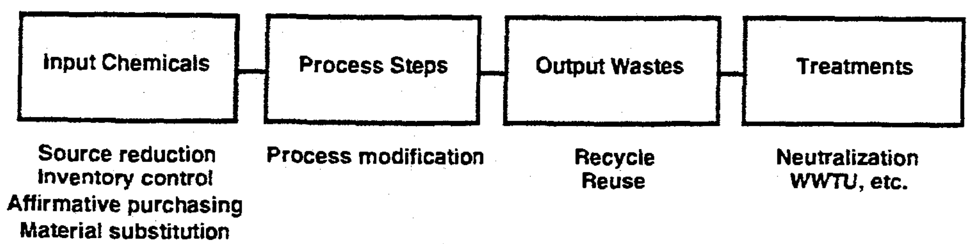
Figure 4.2 Pollution Prevention Opportunity Assessment Overview



An approach for collecting data to develop the waste flow diagram begins with involving operations, maintenance, environmental, procurement, and other personnel who manage the day-to-day activities of the processes. Based on historic records, conversations with plant personnel, and site visits, an accurate qualitative flowchart can be produced.

The second phase of a PPOA is the opportunities assessment for waste minimization using the inputs/outputs waste characterization. Figure 4.3 shows opportunities identified from the process. Inventory control, material substitution, affirmative procurement and good operating practices are opportunities for source reduction. Process and equipment modifications as a result of opportunities identified through process steps can also accomplish waste reduction. Finally, opportunities for recycling and reuse are identified from output wastes to further minimize wastes. Out of those opportunities identified above, substitution of raw materials and intermediate materials in the production process has the most

Figure 4.3 Opportunities Assessment Overview



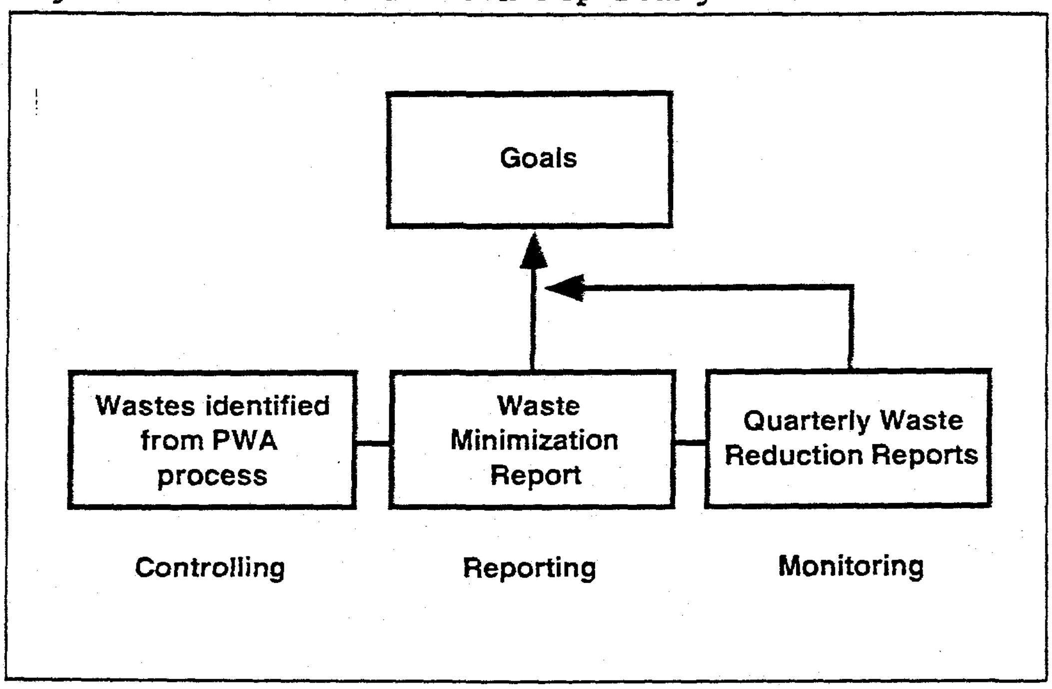
potential to reduce many hazardous wastes. Material substitution also requires R&D investments to implement new technologies.

There are concerns in industry regarding material substitution which may affect product quality by changing an industrial process or substituting materials for the purpose of reducing waste. It should be understood that waste reduction poses no inherent threat to product quality as long as the company has an effective QC/QA program. Another issue related to technology implementation as a result of material substitution is that the decision to implement the technology depends partially on the economics of a product and often includes production, finance, and marketing considerations. Therefore, market analysis is critical when technology implementation and material substitution decisions are made. As long as the substituted raw materials produce equivalent quality products, then market analysis will only need to focus on consumer perceptions. Consumers are usually indifferent toward combinations of products and services that give the same amount of perceived satisfaction. As a matter of fact, products made of disposal cost which consumers end up paying for. Proper advertising promotions for the products that are environmentally safe may even improve consumer perceptions, corporation profits, and public acceptance.

4.2 Waste Reduction Reporting

Once a Pollution Prevention Opportunity Assessment process is established, quantitative waste data can be fed into a computer database to monitor waste reduction progress toward waste minimizaton goals. As indicated in Figure 4.4, all waste streams identified through the assessment serve as a baseline in the waste reduction plan. Waste reduction goals are then set based on the

Figure 4.4 Waste Reduction Reporting Overview



established baseline. There should be periodic waste data collection to update the waste collection system for monitoring purposes. It is through this continuing process that the waste reduction program will be effective.

There are two primary concerns involved with setting goals and measuring waste reduction. First, because any waste reduction program must based on the per-unit-concept, an inadequate per unit measurement can lead to a problem in achieving goals. Second, there is a concern that goals are not realistic since the potential diminishing return of waste reduction improvement did not get factored into the measurements.

Often, waste reduction goals based on the per-unit concept do not account for a reduction in the toxicity of materials used, nor do they account for waste materials being recycled. As a result, this per-unit measurement provides a negative incentive for organizations to implement and measure waste reduction efforts. Because this type of measurement exclusively emphasizes the amount of waste generated, organizations would not be credited for, and would therefore be disinclined toward using less toxic materials or recycling. Furthermore, although promoting recycling activities may miss an opportunity to encourage substitution or reformulation and to reduce worker exposure, we believe recycling efforts should be recognized and credited to motivate people to further their efforts toward source reduction goals. It is also important that the per-unit measurement be capable of measuring production-related wastes, maintenance-related wastes, and clean-up wastes.[2] This will eliminate problems in using the per-unit measurement for waste reduction. In conclusion, the per-unit measurement must be flexible enough to be applied to varied situations and to reflect credits from recycling activities.

Besides the issue of the per-unit concept, the other concern about the goals being difficult to achieve is the potential diminishing return of continued waste reduction improvement. In order to help us understand this concern, we need to first understand the nature of goal setting. In reality, it is usually impractical to completely eliminate the production of hazardous waste from an industrial process. Therefore, the "minimization" of waste volume is a realistic and desirable goal. Any quantitative goal setting will always have its shortcomings in term of monitoring the true performance. As long as goals are set with the intent of waste minimization, management should allow goals to be flexible to reflect true performance of waste reduction improvement.

In order for waste reduction to work in an effective manner, top management must have a strong commitment to support such a program, including goal setting. Everyone in the organization must focus on this important issue, for only when people devote time and effort to accomplish desirable environmental goals are innovative solutions for waste reduction achievable. It is this bottom-up involvement and commitment that will result in an effective waste reduction program. In conclusion, waste reduction succeeds only when it is part of the everyday consciousness of employees and managers involved in the operations, rather than only those who are responsible for policy making to comply with environmental regulations.

5. Implementing the PPOA Program

As mentioned, the PPOA process can be used as a fundamental tool for an effective pollution prevention program. This section discusses further the implementation of the PPOA program in the organization. The implementation consists of planning and organization to get the program started, and a systematic approach to perform the assessment for a facility.

Proper planning and organization for PPOA implementation contributes to the success of the waste minimization program. Potential benefits of the program must be conveyed to the management of the company in order to get their support. Getting management commitment and direction are fundamental to the program implementation. The benefits include economic advantages, regulatory compliance, reduction in liabilities associated with waste generation, improved public image, and reduced environmental impact. Management commitment can be conveyed to employees through a formal policy statement.

Besides the management commitment, employee involvement also contributes to the success of the PPOA implementation because they are closest to the generation of waste. Periodic in-house seminars, workshops, or meetings must be conducted to provide continual guidance, assistance, and follow up. This will help to promote a network of waste minimizaton coordinators in the company. It is important to set company timetable for PPOA completion and incorporate the resulting goals into the appropriate individual departmental goals.

The strategies used in PPOA implementation are similar to those of the Crosby Quality Education System (QES). The approach used in QES is usually referred as " total quality management". The QES process has been identified by many companies, particularly manufacturing industries, to improve product quality and production efficiency. The process involves regular meetings of workers and supervisors to evaluate employee-suggested improvements. Total quality management consists of identifying requirements, using prevention, analyzing problems, developing process flow diagrams, setting goals, and brainstorming opportunities through teamwork. The essence of PPOA implementation is to involve the production people who are closely associated with the operations, and foster participation in and commitment to improvement.

The first tasks of the PPOA implementation are to identify and characterize the facility waste streams. Ideally, all waste streams and plant operations should be assessed. However, prioritizing the waste streams and operations to assess is necessary when available funds are limited. Therefore, a graded approach should be used to prioritize waste streams to be assessed.

The prioritization of the assessments should concentrate on the most important waste problems first, such as compliance with regulations, cost of waste management, potential environmental liability, quantity of waste, etc. Waste streams with lower priority problems can be assessed when resources permit.

A systematic approach to performing a PPOA consists of the following five steps: gather data, develop process flow diagram, describe process, quantify chemical inputs and waste outputs, characterize wastes, and identify and implement waste minimization opportunities.

Information for input materials, process information, and output waste streams can come from various sources. Characteristics of input chemicals can be obtained easily from Material Safety Data Sheets (MSDS) and chemical inventory records required by SARA 312. Process information can be obtained from Job Hazard Analysis (JHA) required by the OSHA regulations. Other sources of information on waste streams include hazardous waste manifests, biennial reports, NPDES monitoring reports, and Toxic Release Inventories (TRI) reports prepared under the "right to know" provision of SARA Title III, Section 313.

The second step in PPOA How-To's is to develop process flow diagrams. The flow diagrams should be prepared to identify important process steps and to identify sources where chemical materials are consumed and wastes are generated. A process flow diagram includes equipment layout, location of input chemicals and output wastes. A well designed flow diagram serves as the foundation upon which material balances are built. The material balance (or mass balance) is represented by the mass conservation principle: Mass in = Mass out + Mass accumulated in the process. Mass balance can assist in determining concentrations of waste constituents released into multimedia in the environment. This information provides a baseline for measuring performance.

After the flow diagram is developed for the process, the next step is to qualitatively describe the flow diagram. This includes identifying material consumed and waste generated in each step of the process. Description of the flow diagram also includes quantitative input chemicals and output wastes based on the material balance concept mentioned above.

Once the origins and causes of waste generation are characterized and understood, the assessment process enters its next step, which is to identify a comprehensive set of waste minimization options and to implement those options that are most feasible. The optimal waste minimization options are those that are both technically and economically feasible. Technical evaluation for waste minimization options must consider product requirements, facility constraints, procedural constraints, organizational constraints, and technological constraints. The economic evaluation to determine the optimal options includes profitability techniques such as payback period, return on investment, and net present value. While the economic evaluation is important in deciding whether or not to implement an optimal option, other factors such as risk reduction and regulation compliance may be even more important. It must be kept in mind that the implementation of waste minimization activities must be supported by both management and employees in order to be effective.

6. Potential PPOA Technology Transfer to the Pacific Rim Countries

As the general public in the U.S. starts to focus on true pollution prevention, most of the Pacific Rim countries are gradually recognizing the importance of their environmental issues. The author uses Taiwan as an example to demonstrate the potential PPOA technologies that could be part of waste management technology transfer to the Pacific Rim countries. Two key factors will be mentioned in this section. First, a brief background of Taiwan's environmental problems will be discussed to identify the potential needs for environmental cleanup on the island. Second, the economic status in the island will be addressed to further identify the potential technology transfer to the island.

Taiwan's environmental problems are a result of policy choices made over the last several decades. The policy of fostering development with little attention to the island's ecology could be characterized as "get rich quick, clean up later.[3] Besides the Government policies contributing to the environmental problems in the past, the most important factor that underlies Taiwan's environmental problems is the island's population density. Taiwan's population of 20 million shares a land space of only 36,000 square kilometers. Only 3-5% of Taiwan's residential units are hooked up to a sewage treatment system. There are 283 motor vehicles per square kilometer, compared to only 19 in the United States. The air quality of the city is roughly three times worse than that of Los Angeles. To make matters even worse, acid rain caused by smokestack industries fouls the air and damages the enviornment, imported and domestically produced heavy metals contaminate rice paddies, pesticides pollute water, and coal-fired generators cloud the sky.

By the mid-1980s, Taiwan was stifling in bad air, awash in contaminated water, and blanketed in its own waste, 90% of which went into landfills. Even though Taiwan's gross national product has grown 10% or more each year for the past two decades, this highly productive island nation is paying the price.

As a result of its economic growth, Taiwan has become an economic powerhouse and the second most wealthy economy in Asia, after Japan. Annual per capita income in Taiwan is expected to approach that of the U.S. $7,000, the second highest in Asia. Foreign exchange reserves stand at $75 billion, second highest in the world.[4] Taiwan's economic development has reached a point where the public is demanding a higher quality of life.

The decline of Taiwan's ecosystem has begun to generate significant public reaction. Surveys reveal Taiwanese are willing to sacrifice some growth for a better environment. In response to the growing crisis, a consensus toward improved environmental protection has emerged within the political, social, and economic leadership. In light of an active grassroots environmental movement, factory owners have become increasingly concerned about their potential liability and are beginning to seriously invest in waste management technologies and pollution control equipment.

U.S. firms will have an advantage as Taiwan looks to even its balance of trade and make use of their advanced technology and experience in environmental cleanups. Of the total Taiwan market for pollution equipment, approximately 65% is supplied by foreign firms, Sales of U.S.-built equipment account for about 35% of total imports. Through improved marketing by U.S. suppliers, the American share of the market is growing. The greatest demand over the next ten years will be for solid and hazardous waste treatment systems. This also reveals the potential demand for pollution prevention methododogies such as the PPOA techniques.

In conclusion, we believe that the PPOA technologies can be part of the waste management technology transfer efforts between the U. S. and the Pacific Rim countries, especially Taiwan.

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