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INTEGRATING HAZARDOUS WASTE MANAGEMENT INTO A MULTIMEDIA POLLUTION PREVENTION PARADIGM: A PROTOTYPE REGULATORY PROGRAM FOR PETROLEUM REFINERIES

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ABSTRACT

An emerging trend in environmental regulatory management promises enhanced environmental protection and more flexibility for regulated entities. This trend reflects three concepts. First, regulations designed to reduce one type of environmental pollution (e.g., air pollution) should not increase other types of pollution (e.g. hazardous waste). Second, pollution prevention is an important alternative to end-of-pipe control requirements. Third, offering polluting entities the flexibility of meeting certain performance criteria may produce better environmental results than prescribing specific technologies or approaches. A significant body of literature supports the need to develop regulatory programs that incorporate these concepts. However, there is little evidence that these concepts have been integrated into actual multimedia regulatory programs. Argonne National Laboratory and the U.S. Department of Energy are developing a prototype regulatory program for petroleum refineries that embraces these concepts. The development approach in this case study comprises several steps: (1) identifying and evaluating existing regulations governing petroleum refineries (if any); (2) characterizing expected future operating conditions of refineries; (3) setting goals for the regulatory program; (4) identifying and evaluating options for the program; (5) developing a prototype based on selected options; (6) identifying and addressing implementation issues; and (7) testing the prototype on a pilot basis. The approach being used in this U.S. effort is flexible and can be used in environmental management efforts throughout the Pacific Basin — in both developing and developed countries.

INTRODUCTION

Today, most Pacific Basin countries have laws limiting pollutant releases into the environment. Some have regulations to implement those laws. Others, (e.g., Bangladesh, Cambodia) are in the process of developing environmental regulations. The success of regulatory implementation varies among Pacific Basin countries. In India, for example, violations of environmental laws are considered criminal acts, but crowded criminal dockets and procedural protections limit enforcement.

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Fines are typically not high enough to discourage pollution (Chandak, 1995). The Philippines have environmental laws and regulations but lack mechanisms to penalize polluters and reward responsible operators. Thailand has several hazardous waste management laws, but implementing jurisdictions are spread among numerous responsible ministries (Eamsakulrat, 1995). Many countries have insufficient resources to manage and monitor for environmental enforcement. Some countries have functioning regulatory enforcement systems in place, but suffer from other problems. For example, critics of some programs charge that overly prescriptive regulations force the use of specified technologies and approaches to meet environmental goals, thereby preventing flexibility and discouraging innovative approaches. For example, U.S. hazardous waste regulations forbid wastes that contain even minute quantities of listed hazardous wastes to be disposed of on the land until such wastes have been treated using waste-specific technologies. Such regulations are costly and may not provide commensurate benefits to public health or the environment. Regulators and regulated entities seek regulatory reform to address these kinds of problems.

While regulatory development and enforcement vary, Pacific Basin countries often share common environmental management goals. For example, most agree that pollution prevention is preferable to "command and control" or "end-of-pipe" treatment. Thus, a regulatory program should encourage prevention of pollution. Also, pollution reduction should maximize net environmental benefit. That is, reducing pollutant releases into one medium should not result in a greater releases into another medium. Minimizing cross-media transfers can help limit net environmental impact. Another common goal is that environmental protection should be cost effective. No country has the resources to assure a pollution-free environment. An environmental regulatory program should be cost effective both for regulated entities and for regulating agencies.

No single environmental regulatory program can be designed to meet the needs of all Pacific Basin countries simultaneously. Variabilities in culture, industrial development, geography, population, government, and other factors must be reflected in regulatory programs if those programs are to succeed. A case study of a prototype regulatory program under development for petroleum refineries in the United States may provide ideas for other Pacific Basin countries to consider as they strive to meet environmental goals with limited resources. This paper describes the development of a prototype multimedia pollution prevention program for "next generation refineries." "Next generation" refers to refineries that will be operating in the future under conditions that will differ from operating conditions today. The paper also describes how such a program and the approach used to develop the program could be applied by other Pacific Basin countries.

IMPETUS FOR THE PROGRAM

In 1993, the U.S. Congress funded the President's Environmental Technology Initiative (ETI) as part of a national strategy to encourage innovative environmental technology development, commercialization, and use. In administering the program, the U.S. Environmental Protection Agency (EPA) has stressed the need for partnerships with the private sector and federal agencies. The prototype multimedia regulatory program for next-generation refineries is an ETI project that uses the expertise of U.S. Department of Energy (DOE) and its national laboratories to develop a regulatory program to address the concerns of U.S. refineries operating in a future characterized by the need for new technologies. The project strives to develop a multimedia environmental regulatory program that will encourage the use of innovative technologies.

The focus on petroleum refineries is twofold. First, U.S. petroleum refineries are subject to costly and increasing environmental requirements. In 1990, U.S. petroleum refineries spent \$3.7 billion on compliance with air, water, waste, and other environmental regulations; in 1993 they spent \$5.7 billion, or roughly 50% more than in 1990 (API, 1995). These expenditures were greater than the entire U.S. EPA budget in those years and do not include reserves for future activities, fines and penalties, or lost business opportunities. Regulations under development will require additional expenditures. Future Clean Air Act Amendment (CAAA) capital costs alone are estimated at \$35 to \$40 billion (Lichtblau, 1992). EPA acknowledges that it may be more economical for some refineries to close down than to upgrade their facilities to meet the new standards (U.S. EPA, 1995). The second reason for the refinery focus is that the industry functions in an increasingly challenging operating environment. The overall quality of crude oil input to the refining process is declining, thereby requiring additional processing to yield an equivalent product. At the same time, the CAAA mandates specific product qualities to reduce environmental impacts of downstream use of the product. Table 1 outlines some CAAA provisions regarding product reformulation and how refineries will likely respond. Many of these requirements entail significant process changes and capital investments. Petroleum refineries need the ability to develop and use new technologies that will both facilitate the refining of heavier crude, and meet expanding environmental requirements at the refineries.

PETROLEUM REFINING CHALLENGES IN OTHER PACIFIC BASIN COUNTRIES

Other Pacific Basin countries face many of the challenges described above. Several are changing their motor vehicle fuel specifications. For example, Thailand has new clean fuel standards to be implemented by the year 2000. To meet the standards, several refinery modifications must be made. A deep gas oil hydrotreater will be installed to enable the production of 0.05 wt.% sulfur diesel oil. A fluid catalytic cracking unit will be added, and modifications will be made to the existing naphtha reformer to produce high octane, low aromatic and low benzene gasoline. Equipment and facilities will be installed to enhance environmental mitigation systems (World Bank, 1996a). Pacific Rim refineries may be subject to increased environmental controls from external pressures as well. For example, on May 18, 1996, the World Bank called for a global phaseout of lead in gasoline, citing health problems caused by leaded gasoline in urban areas of developing countries. Such a phaseout will require refinery modifications (BNA, 1996a).

The quality of input crude is also declining in other Pacific Basin countries. As demand for refined products increases, lower-sulfur Asian supplies must be supplemented with higher-sulfur, heavier Middle Eastern crudes. China, for example, had been a net exporter of petroleum; now it is

TABLE 1. CAAA Requirements for Product Reformulation and Associated Refinery Needs

CAAA Program	Product Reformulation Requirements	Associated Refinery Needs
Oxygenated Fuels Program	Gasoline sold in carbon monoxide nonattainment areas must have a minimum of 2.7 wt.% oxygen for at least four winter months. California winter fuel oxygen content is 1.8 to 2.2 wt.%	Increased capacity to produce oxygenates.
Highway Diesel Fuel Program	Sulfur content of all highway diesel fuel must be reduced from 0.5% to 0.05%. Cetane index must be at least 40.	Increased construction of desulfurization units, such as catalytic hydrocracking and hydrotreating units.
Reformulated Gasoline Fuels (RFG) Program	Requires RFG in certain metropolitan areas. RFG must have a minimum oxygen content of 2 wt.%, a maximum benzene content of 1% by volume, and no lead or manganese. By 2000, toxic emissions are to be reduced by at least 20%, VOC emissions by at least 25%, and NO_x emissions by at least 5%.	Gasoline formulation to be upgraded. Hydrotreating units needed for meeting lower sulfur specifications.
Leaded Gasoline Removal Program	Sale of leaded gasoline for use in motor vehicles prohibited after 1995.	Clean Air Act of 1970 reduced lead content substantially; provision not expected to require significant changes.

a net importer of crude. Crude oil recoveries from the South China Sea are small relative to the amounts of crude needed to fuel local product demand. Outside of Japan, most Asian refineries are simple. Until recently, these refineries could meet local needs, but in the past 10 years, as automobile use has increased, the need for more complex refinery operations has grown. Singapore, Taiwan, and Malaysia are upgrading their refineries to handle heavy, sour crude. New technologies are required for such modifications.

Other pressures on Pacific Basin refineries relate to rapid economic growth and industrialization. In Indonesian urban areas, for example, the number of vehicles is increasing by more than 20% annually (BNA, 1996b). Growing foreign investment magnifies this growth. In Vietnam, foreign investment increased by 50% between 1991 and 1995, and the country hopes to attract $41 billion in new investments by 2000 (BNA, 1996c). Petroleum products will be needed to support transportation and industrial growth; extraction and refining can be expected to increase in the area. Table 2 shows existing petroleum refining capacity and capacity under development in Pacific Basin Countries.

TABLE 2 Existing and Projected Refining Capacity in Selected Pacific Basin Countries

Country	Capacity (1,000 Barrels per Calender Day)			Country	Capacity (1,000 Barrels per Calender Day)		
	Exist-ing	Projected Additions*	% Change		Exist-ing	Projected Additions*	% Change
Australia	732.7	76.4	10%	Malaysia	320.7	266.8	83%
Canada	1,848.5	29.0	2%	Mexico	1,520.0	153.7	10%
China	2,867.0	335.0	12%	Philippines	323.1	1.5	0%
India	1,086.4	1,021.2	94%	Singapore	1,170.0	151.3	13%
Indonesia	804.7	149.5	19%	Taiwan	542.5	0	0%
Japan	4,867.0	572.7	12%	Thailand	425.8	625.9	147%
Korea	1,315.0	551.5	42%	U.S.A.	15,354.1	461.6	5%

* Through 2000
Source: PennWell, 1995

Accompanying the pressures on refineries to produce more high-quality fuel are increased concerns about the overall environmental effects of growing economies and industrialization. India's rapid economic, population, and industrial growth is causing severe environmental degradation and pollution problems. The Klang Valley in Malaysia suffers from air quality problems related to increased automobile traffic and burning of fuel oil for electricity. Some developing countries fear that environmental concerns will delay progress in material and social improvement (Anwar, 1995). In Singapore, where industrialization and modernization continue to gain momentum, environmental measures and standards are being reviewed and upgraded where possible (Tay, 1995). All of these concerns suggest the need for cost-effective environmental programs to help ensure that industrial development and growth continue without unacceptable risk to human health and the environment.

ADVANTAGES OF A SECTOR-SPECIFIC MULTIMEDIA POLLUTION PREVENTION PROGRAM

Many Pacific Basin countries are making progress in controlling pollution, but more needs to be done. In several Chinese provinces, the amount of pollution generated per unit of output has decreased over the last 10 years as the result of industrial efficiency gains, cleaner technology, and environmental regulation. However, the absolute level of industrial growth has diminished the significance of this relative improvement. As a result, the national government has made improved industrial pollution control its primary environmental target of the 1996-2000 planning period (World Bank, 1996b).

Sector-Specific Approach Allows for Timely, Phased Development

A system developed for individual industrial sectors can focus on the issues specific to each sector and can be developed in phases. While a multisector approach might be more effective in reducing net environmental pollution, such a system may be too difficult to design and implement in a reasonable time frame. By focusing on individual industrial sectors, significant progress can be made, and lessons learned from one sector-specific program can be applied to others. The entire process can continually improve over time. An optimal approach for developing sector-specific systems would be to assess the environmental and health impacts of various industrial sectors and then successively develop regulatory programs for those with the greatest potential for harm. Indonesia, in its Industrial Environmental Management Project, selected industries to become recipients of pollution management appraisals based on their relative potential risk to health, welfare, and environment (Jardine et al., 1995). Taiwan has taken a similar approach in selecting industries for demonstrating waste minimization technologies. Industries that cause serious pollution, have a large number of plants and a wide range of pollutants, generate hazardous pollutants, and that meet other criteria are eligible for waste minimization plan development assistance (Chen et al., 1995).

Multimedia Approach Considers Releases from All Sources

A multimedia pollution prevention program considers releases of pollutants from all sources within a facility as a whole rather than as separate emitting sources. This helps ensure that all major sources are considered. Under existing single-media programs, some important release sources can be missed. For example, in countries with highly prescriptive, source-specific regulations, such as the United States, air pollution regulations restrict air emissions from various types of manufacturing or process equipment, but not necessarily from fugitive emissions. Similarly, federal hazardous waste regulations prescribe technology-based treatment standards for wastes determined to be hazardous, but leave treatment requirements for nonhazardous industrial wastes to states. Because federal laws exclude certain wastes that may contain hazardous constituents (e.g., oil and gas exploration and production wastes, wastes from publicly owned treatment works) from federal hazardous waste regulation, it is possible that such excluded wastes, even though they may contain the same constituents as a hazardous wastes, may be subject to less stringent requirements at the state level, because they are considered nonhazardous.

Multimedia Program Reduces Cross-Pollutant Transfers

Differences in the costs of controlling releases to individual media can shift pollution releases to the medium with the least expensive control costs. However, the least costly approach may not result in the most acceptable risk to human health or the environment. Bans on land disposal of hazardous wastes under the Resource Conservation and Recovery Act (RCRA) in the United States, for example, have increased toxic releases from incineration of those wastes (U.S. EPA, 1991). Emission controls designed to capture these releases may create toxic ash and wastewaters, which must then be disposed of. Further, releases to one medium may be transferred to another. Land disposal may generate air emissions or leach toxics to groundwater; contaminants in air emissions may be deposited on land or in surface water. Finally, focusing on the single-medium regulatory approach ignores chemical or physical transformations that may occur once a pollutant is released. Air quality standards written to protect against inhalation health effects do not address transformations that occur when air emissions (e.g., sulfur dioxide) combine with water vapor to form sulfuric acid and contaminate soil and water when deposited. In contrast, a multimedia program strives to limit the transfer of pollution from one source to another by viewing the releases to all media holistically, and regulating the total emissions of a particular pollutant from a facility. It also reduces the chances for duplication of regulatory requirements and the associated drain on resources. For example, in the United States, certain substances (e.g., benzene) are regulated by several authorities. In countries with fewer prescriptive and potentially conflicting regulations, a multimedia program may help companies meet legislatively established goals, thereby avoiding the need to establish and maintain multiple, media-specific enforcement offices.

DEVELOPMENT OF A MULTIMEDIA POLLUTION PREVENTION PROGRAM

Developing the prototype program described in this case study consisted of three phases, with two to three steps in each phase. In applying the case study to Pacific Basin countries, however, the distinctions among the phases are not important. Therefore, the development approach is discussed in terms of the steps rather than the phases. The steps in the development process are summarized in Figure 1.

This approach is extremely flexible and is not intended to be followed exactly. It should reflect a country's goals, culture, and current environmental situation. Some steps may be deleted or modified, and other steps may be added. For example, if no environmental regulatory program exists, step 1 can be eliminated. Similarly, prototype testing (step 7) may not be required. Indeed, in the petroleum refinery case study, consideration is being given to substituting a modeling approach for the pilot test to determine feasibility. Other steps may be added. For example, in the case study a step was added at the very beginning to establish guidelines and principles for the entire activity. Also, in the case study, provision was made for "stakeholder review." Involving interested parties can be conducted at several stages in the overall approach; it can be conducted simultaneously with the other steps; or, depending on the country or legislative philosophy, may not be conducted at all. The remainder of this section describes the process used for developing the petroleum refinery regulatory prototype and suggests how individual steps may vary for other countries choosing to use a similar approach. These suggestions are neither exhaustive nor exclusive; the presentation merely offers alternatives to consider when developing regulatory programs.

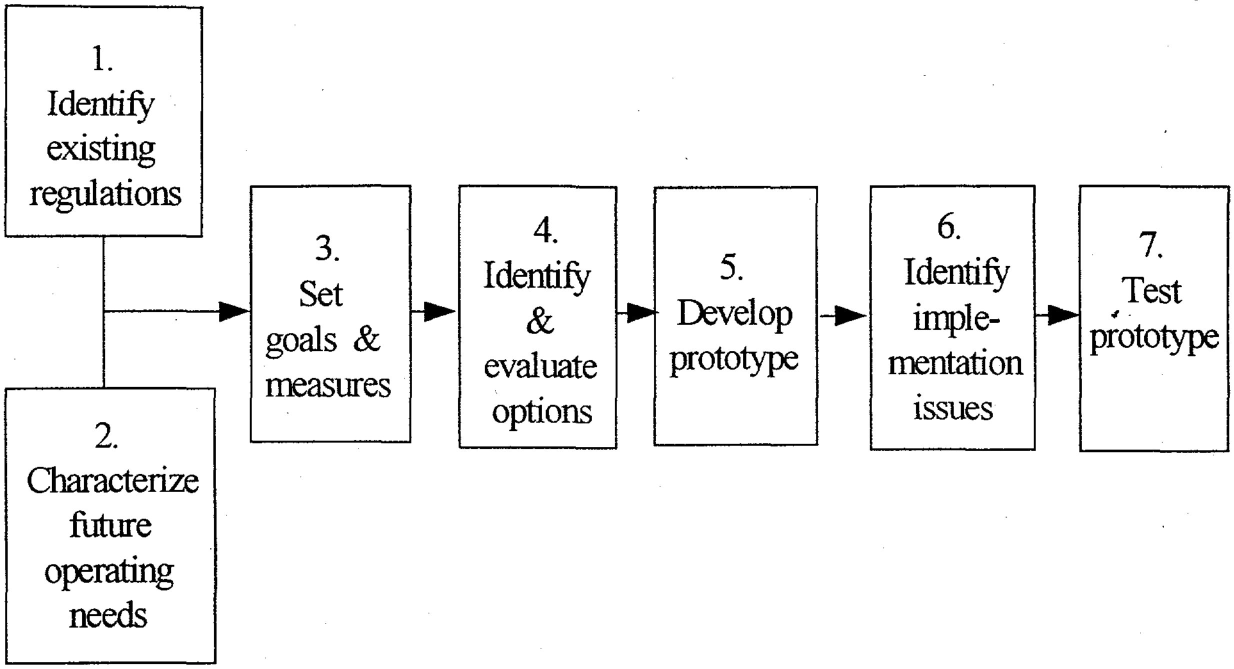

Figure 1 Steps in Prototype Development Process

Establish Guidelines and Principles

Before undertaking the process to develop the regulatory program, it can be useful to establish guidelines and principles to set the bounds for the regulatory approach and provide a reference against which proposed options can be checked. This step is not included in the approach per se, but was added to provide a common understanding and to help reduce potential conflict or misunderstandings among industry, government, and other interested parties as the approaches are actually developed. For this case study, three operating guidelines were set:

1. Refineries continue to play an important role in the U.S. economy. Thus, the regulatory program should not restrict the future viability of U.S. refineries.

2. Prototype regulatory approaches will be limited to refinery activities; extraction of crudes and use of finished products will not be addressed.

3. Prototype regulatory approaches shall ensure protection of human health and the environment.

Specific principles were also established. Examples of specific principles include, but are not limited to the following: Prototype regulatory approaches shall be rooted in the ethic of pollution prevention; Prototype regulatory approaches shall encourage, stimulate, and reward innovation; and

Prototype regulatory approaches shall focus on reducing net environmental impacts associated with refinery operations. Guidelines and principles will vary with the sector for which the regulatory program is being developed and with the culture, economics, and other factors specific to individual countries and regions. In Australia, for example, state governments have developed a set of principles to help guide policy for a national environmental law model. These principles include precaution; intergenerational equity; conservation of biological diversity and ecological integrity; and improved valuation, pricing, and incentive mechanisms. In addition, several concepts have been considered. These include effective integration of economic and environmental considerations in decision-making processes and maintenance and enhancement of international competitiveness in an environmentally sound manner (Robinson, 1995).

Step 1 — Evaluate Existing Regulatory Program

The first step in the case study approach was to establish the regulatory/pollution prevention baseline for petroleum refineries. Evaluating the existing regulatory program helps identify issues to be addressed in the improved program. In the case study, existing laws and regulations governing refining operations in the United States were outlined and reviewed to determine which appeared to be effective and which caused concern. Barriers and incentives for pollution prevention and opportunities for innovation were considered. Once the regulatory system was reviewed, implications of that system for an improved regulatory program were identified.

Case Study Results — Regulatory Environment: Petroleum refining is a resource-intensive industry. It ranks among the top 10 emitting sectors in the United States according to EPA's Toxic Release Inventory, which reports emissions to environmental media from U.S. manufacturing industries. U.S. petroleum refineries must meet regulations promulgated under the Clean Air Act, the Clean Water Act, the Safe Drinking Water Act, RCRA, and the Emergency Planning and Community Right to Know Act. The Comprehensive Environmental, Response, Compensation, and Liability Act and the Pollution Prevention Act also affect refineries. Regulations are either category specific (e.g., effluent guidelines and standards for the petroleum refining point-source category) or are more broadly encompassing (e.g., standards applicable to generators of hazardous waste). In addition, petroleum refineries are subject to permitting processes for air emissions and water discharges under state programs. Also, many refineries must have RCRA permits for hazardous waste incineration units or energy recovery through the combustion of hazardous waste as fuel.

In general, these regulations are media-specific and provide little flexibility. Barriers to pollution prevention are significant. Institutional barriers hinder efforts to implement effective prevention strategies because regulators focus on specific media rather than multimedia concepts. Technical barriers, which typically affect small and medium-sized companies more than larger companies, hamper the ability to implement process changes to reduce pollution. Financial barriers constrain facilities (especially smaller ones) from pursuing process changes, and resource limitations affect the ability of regulatory agencies to provide technical assistance. Political barriers can reflect pressure from dischargers. Thus fearing that mandatory programs could lead a company to relocate its facilities, some state and local governments prefer voluntary programs. Regulatory barriers also impede pollution prevention. For example, even though RCRA mandates that waste generators must have a waste minimization program in place, RCRA's prescribed acceptable control technologies for hazardous waste land disposal restrictions can divert resources from waste reduction. RCRA regulations can result in a preference for disposal over recycling. Permit and storage restrictions impede waste minimization. In most cases, standards are based on best practices, best available technology, or best performers. This approach can keep companies from introducing newer, more efficient control technologies, because they fear that regulators would then require such technologies to be used as best available in applications where they may be less appropriate.

Evaluation of Existing Regulatory Programs in Other Pacific Basin Countries: At the risk of oversimplifying the undertaking of this step in other countries, this section provides examples of potential regulatory findings in other Pacific Basin Countries.

In Singapore, current laws promote end-of-pipe treatment. Regulations include penalties for noncompliance but offer few if any incentives to "go beyond compliance." A program that lacks incentives (as does the U.S. program) can hinder multimedia pollution prevention and technology development efforts.

India has also borrowed from the U.S. command and control regulatory approach and implements environmental regulations through a disincentive structure. The Central Ministry of Environment and Forests has enunciated a policy for integrating environmental and economic aspects in development planning, which stresses pollution prevention and promotion of technological inputs to reduce industrial pollutants. However, few structured programs exist to implement the policy, and emphasis remains on end-of-pipe controls. Also, some regulatory gaps remain. These gaps include limited focus on past contamination of soil and groundwater, lack of pollution control equipment performance standards addition, and little if any regulation of hazardous air emissions (Chandak, 1995).

Indonesia's regulations have also encouraged end-of-pipe waste treatment. This strategy increased awareness of environmental issues, but because of difficulties in enforcement and compliance, produced mixed pollution control results. End-of-pipe controls were found to be expensive and often inadequate in limiting pollution to desired levels. As a result, the Indonesia Environmental Impact Management Agency initiated a results-oriented Cleaner Production Program. The program focuses on a priority industrial sector in each year and provides for technical assistance to industry, information systems, training and awareness, and incentives development (Jardine et al., 1995).

Step 2 — Characterize Expected Future Operating Environment

This step provides information on the industry for which the program is being developed. It is designed to look forward and identify changes that may affect future regulatory programs. Recognizing how current operating environments for individual sectors may change can aid in the design of pollution prevention requirements and performance-based regulatory programs that include the flexibility to react to unanticipated future changes.

Case Study Results — Future Operating Environment: Density and sulfur content are two key characteristics of crude oil. High-density crude feedstocks, which have fewer gasoline and distillate fractions than low-density feedstocks, are less desirable for current and projected U.S. product needs. Sulfur content is important because it may limit potential processing alternatives. High-sulfur crudes are difficult to refine and environmentally dangerous when burned because they lead to smog and acid rain formation. Over the past 10 years, the density and sulfur content of crude oil processed in the United States has increased, and the trend is expected to continue. Lower-quality feedstocks require additional processing. Heavier crudes need "bottoms upgrading capacity," and high-sulfur crudes require desulfurization and other processes to reduce releases of sulfur to the environment. U.S. refineries will need additional equipment and new technologies to meet these needs.

The output side of refinery operations is also changing. Over the past several years, the mix of refinery output has moved toward lighter products. This trend is due to expanded transportation use, which requires lighter fuels; reduced residual fuel oil demand, which results from lower-priced natural gas; growing demand for light petroleum products for plastics and chemicals production; and environmental regulations demanding lighter, higher-quality fuels. The trend is expected to continue as additional but not-yet-determined motor-fuel-specification requirements take effect in the year 2000. Flexibility in product and process development is also needed. Variabilities in testing methods, for example, may require additional changes in product quality. Also, more segregation of products will be required and products may need to be stored so that they are not commingled with other components. Future profitability will require improved overall plant performance. New technology developments will help refiners meet these types of requirements.

Case Study Results — Implications of Operating Environment for Regulatory Program: The need for new technology to meet the demands of changing input quality and output mix suggests several factors that need to be reflected in a multimedia regulatory program for next-generation refineries:

- The program must be flexible. For example, refiners should be able to plan changes to refinery operations assuming that they need to meet a performance-based standard as opposed to a process-specific, technology-based standard.

- Regulations should focus on refinery-wide releases rather than source-specific releases within the refinery. New processes and changes in existing processes will produce emissions from a variety of sources. Regulating sources separately will be less efficient than regulating emissions from the refinery as a whole.

- The program must allow for the incorporation of new knowledge about health and environmental effects and development of new technologies.

- Because releases have multiple sources and the potential for cross-media pollution is significant, the regulatory program needs to be multimedia.

Characterizing the Operating Environment in Other Pacific Basin Countries: An analysis similar to the one described above could be conducted in other Pacific Basin Countries. If done for petroleum refineries, adjustments for fuel use restrictions, quality of crude, and other factors would be required. Similar analyses could be undertaken for other industries. For example, increased automation presumably would be a factor in textile and tanning industries, and restrictions on logging could be a factor in the pulp and paper industry. Other factors may need to be considered. Many Pacific Basin countries have limited land area for waste disposal, implying that disposal costs can be expected to increase. Many developing countries have limited access to technological information, and the technical information available from abroad often is not relevant, appropriate, or affordable for industries in developing countries. Such factors must be considered as part of characterizing the operating environment.

Step 3 — Establish Goals for Regulatory Program

This step identifies goals for the program that reflect the guidelines and principles established at the outset. The goals reflect the findings and concerns identified in the regulatory review and the characterization of the operating future of the industry. They can also reflect broad national or regional environmental or economic goals.

Case Study Goals and Measures: In this case study, the focus of the proposed regulatory goals is on protection of public health and the environment. Impacts on worker risk and concerns related to cleanups are not addressed. Measures were established to assess how individual options meet each goal. The goals and measures established in the case study are summarized in Table 3.

Goals and Measures for Other Pacific Basin Countries: Regulatory program goals and measures will differ among countries and industries. In the Philippines, the Department of Environment and Natural

Table 3. Prototype Regulatory Program Goals and Performance Measures

Program Goal	Performance Measure
Economic Performance. The program should not weaken economic performance; U.S. refiners should remain competitive in the global market.	• Environmental capital costs decrease. • Environmental O&M costs decrease. • Environmental administrative costs decrease. • Regulatory uncertainty costs decrease.
Environmental responsibility. The program should allow refineries operating in the future to demonstrate that they are environmentally responsible.	• Quantity of residuals produced decreases. • Quantity of residuals released decreases. • Toxicity of residuals produced decreases. • Toxicity of residual released decreases. • Use of nonfeedstock toxics decreases. • Public participates in development process.
Pollution prevention technology innovation and use. The program should increase use of technologies that reduce pollution and increase efficiency.	• Promotes penetration of new technologies • End-of-pipe technology use decreases

Resources' (DENR) Industrial Environmental Management Project has a goal of encouraging sustained economic growth in the industrial sector while reducing pollution and improving worker health. While not a comprehensive regulatory program, it contains the elements of goal setting and measuring addressed in this step. Thus, the goals of economic growth, increased employment, and reduced health risk are measured by increased savings or profits in target industries resulting from adoption of pollution prevention and control measures, and reduced waste generated by participating facilities (Araza et al., 1995). In some countries, increased public and industrial awareness may be a goal of pollution prevention. Some of the measures developed in the case study may be inappropriate for other countries. For example, in developing countries, decreasing capital costs for environmental protection may not be a measure of environmental performance. In some countries, public participation in the development process may not be an important measure.

<u>Step 4 — Identify and Evaluate Options</u>

This step identifies and evaluates potential regulatory options for use in the actual prototype. Each option is evaluated according to the measures defined in step 3. Options that do not "measure up" are eliminated. Those that remain can be used to form the prototype.

<u>Case Study Options Development Process:</u> In developing options for the petroleum refinery case study, "a wide net" was cast to avoid missing potentially important options. Analysts identified over

60 options, ranging from broad overall approaches to narrow procedural approaches. Examples included intra-plant risk-based trading, industry self-regulation, contaminant-specific (as opposed to media-specific) regulations, pollution prevention revolving loan program, substitution of multimedia permits for single-media permits, enforceable agreements, fee-based incentives, tradeable permit systems, consolidation of federal and state permits, and many others. When evaluated against the measures defined in step 3, most of these approaches will meet the goals. While none of the approaches could be eliminated from further examination (as had been intended), it became evident, on closer evaluation, that two key approaches emerged and that several individual options could be incorporated into these two. The two approaches (a release-based approach and a risk-based approach) were developed further in the next step.

Options Development Process in Other Pacific Basin Countries: Regulatory prototype options are vast, and the relevance of an option to a country's situation needs careful evaluation. Provided below are some examples of the types of options under consideration in other Pacific Basin Countries.

- Indonesia's cleaner production program includes the use of economic incentives. These incentives supplement or substitute for traditional command and control approaches, use markets to influence behavior, and focus on results rather than methods. Incentives under consideration include ecolabeling, an annual industry award for companies most effectively employing cleaner production, and taxes on wastewaters (Jardine et al., 1995).

- Australia's EPA has introduced a system of accreditation for companies that have approved environmental management systems, improvement plans, and audit systems. Such companies receive simplified licences, which set environmental outcomes for the sites, allowing the companies to manage their environmental affairs without regular compliance checks and with minimal approvals. Licences fees are also reduced (Robinson, 1995).

- Recognizing the need for sustainable pollution reduction programs while allowing for individual choice in meeting industry objectives, the Philippines' DENR is investigating market-based incentives that include a fee per unit of pollutant discharged to the environment; markets for the purchase, sale, and transfer of waste products; surcharges on recyclable or reusable products; risk and liability insurance to cover costs of environmental, economic, and health remediation; and user fees on raw materials (Araza et al., 1995).

- Options being considered for implementing industrial pollution prevention policies in India include government dissemination of information on pollution prevention options; revised pricing of natural resources to curb wasteful consumption; mandates to incorporate pollution prevention; government funding of demonstration projects to mitigate the "not me first" syndrome; pollution taxes; international demonstration projects; and information exchanges with developed countries (Chandak, 1995).

- To promote pollution prevention, Singapore is considering providing financial incentives for companies that adopt pollution prevention well in excess of legal control requirements. It is also considering tax incentives for investments based on case-specific merits. Evaluation criteria would be the use of cleaner processes or technologies that substantially exceed the basic standards required for the industry, and forming strategic technical alliances with overseas institutions.

Step 5 — Develop Prototype Based on Selected Options

In this step, the options identified in step 4 are further refined and consolidated. Because one of the objectives in the case study was to develop an overall regulatory program, individual options needed to be combined into a comprehensive scheme. The intent was to develop two or three comprehensive approaches to be reviewed by interested parties. On the basis of comments from these parties, refinements would be made and one approach would be selected for pilot testing. However, aggregating options may not be necessary in all situations. In some countries, selecting one or two individual options for implementation may provide measurable results.

Case Study Prototype Development: This section describes two multimedia regulatory prototype program options. Both programs have three key elements that are reflected in a common format. These elements are (1) establishing a baseline, (2) setting limits on releases of pollutants, and (3) assuring compliance. One approach, the "negotiated performance agreement," is release-based, with the objective of reducing releases. The other, the "risk-based bubble," is risk-based, with the objective of ensuring that releases do not pose unacceptable risks to human health and the environment. Table 4 summarizes key components of the two options.

Prototype Development in Other Pacific Basin Countries: Any number of prototypes can be developed. As noted above, it may not be necessary to combine individual options into a comprehensive approach.

Step 6 — Identify and Address Implementation Issues

The draft prototypes raise numerous issues that must be addressed before implementation. For example, parts of the risk-based bubble approach require changing existing laws and regulations. Also, reasonably priced monitoring technologies (which may not be available currently) are needed

TABLE 4 Key Components of Draft Prototype Regulatory Programs

Component	Negotiated Performance Agreement	Risk-Based Bubble
Premise	Release-based	Risk-based
Baseline purpose	To provide for pollution prevention opportunity identification and a base for measuring progress	To provide release data and environmental characterization for setting limits
Baseline contents	• Inventory of residuals • Costs of inputs and environmental management	• Inventory of releases • Characterization of environment
How release limits are set	Based on current regulatory requirements and negotiation	Based on risk
Basis for assuring compliance	• Cooperative interaction • Monitoring • Progressive penalty system • High visibility of failure	• Direct measurement of releases through monitoring and modeling • Incentives

for full implementation. Table 5 identifies several implementation issues that need to be addressed for the risk-based bubble prototype option and suggests approaches for mitigating those issues.

Potential implementation issues may necessitate modifications to the prototype programs. They will undoubtedly require interested parties to develop mutually acceptable approaches. It is conceivable that not every aspect of a given approach will be able to be implemented. However, the knowledge gained during the process can be applied to further regulatory development or reform efforts.

Step 7 — Test Prototype on a Pilot Basis

The final step in the development approach is to test the prototype. In the United States, this would be done at an existing refinery, since no new refineries are being built. In other countries, it may be possible to test the approach on a new refinery. Ideally, the refinery would be selected on the basis of appropriate criteria (e.g., size, location, regulatory climate, local community interest). All program participants, including regulators and industry, should be involved in the selection process. Test results would be fed back into the overall approach, which would be refined accordingly.

Because of the expense and risk involved, alternatives to pilot testing may be investigated. One alternative would be to use a mass-balance computer model of the refinery inputs, outputs, and

TABLE 5 Implementation Issues For Risk-Based Bubble Approach

Implemen-tation Issue	Examples	Possible Mitigating Measures
Statutory changes	Existing statutes are based on single media.	Identify models for statute that would allow for multimedia legislation.
Regulatory changes	Many existing regulations are not risk based. The approach implies that existing regulations may not be met.	Negotiate pilot program with regulators to temporarily lift non-risk-based regulations in lieu of over all environmental improvement. Industry could agree to revert to existing regulation if pilot fails.
Development of risk-based standards	Models and approaches need to be agreed upon by regulated and regulatory community. Development requires significant sources of expertise and can be resource intensive.	Conduct workshop with interested parties to develop standards on a site-specific basis.
Emissions banking and trading	Not all releases are appropriate for banking and trading.	Identify pollutants for which banking or trading are appropriate and feasible. Examine existing trading and banking programs for lessons learned.
Procedural issues	Standards are to be reexamined when conditions (land use, emissions) change or new knowledge becomes available.	Analyze and recommend specific mechanisms for reexaminations, considering responsibilities, time limits, and so on.
Monitoring technologies	Fence-line monitoring is not economically viable today.	Feasibility and costs of fence-line monitoring for various pollutants would be investigated. Models would be identified for those substances that cannot be monitored.
Public acceptance	Many in the public perceive risk-based standards as weakening environmental protection.	Conduct meetings and focus groups with local publics to share information.

environmental controls, and to run that model with different assumptions that embody the concepts of the prototype options. With such "proof-of-concept" testing, an interactive model would allow users to change assumptions and observe the results in real time. The model would help demonstrate the viability of the options and show how costs, product, and environmental releases would change as various assumptions are changed.

CONCLUSION

Throughout the Pacific Basin, refineries will be required to produce ever-increasing amounts of lighter products from heavier and higher-sulfur crude. Often, such production will occur at the same time that environmental regulations become more strict. Stricter operating conditions combined with increasing environmental controls should be met with a regulatory program that allows refineries to operate effectively while not subjecting public health and the environment to unacceptable risks.

Generally, environmental regulatory programs in the Pacific Basin have been based on end-of-pipe controls directed at single media. Such regulations can be costly and may not provide commensurate environmental benefits. To help improve the regulatory environment for petroleum refineries, the U.S. Department of Energy and Argonne National Laboratory are developing a prototype multimedia regulatory program. This effort provides a case study that can be used by other countries and industries seeking improved regulatory programs.

The approach for developing the prototype program consists of seven integrated steps. They include assessing the existing environmental regulatory requirements (if any), characterizing the expected future operating environment of the industry for which the regulatory program is being developed (in this case petroleum refineries), setting goals for the regulatory program, identifying and evaluating options, developing prototypes based on selected options, identifying and addressing implementation issues, and testing the prototype on a pilot basis. The program, although not developed as an ISO 14000 environmental management system per se, can be tailored to meet the ISO 14001 standards, which call for policy development, planning, implementation and operations, checking and corrective action, and review. The case study provides an approach for developing environmental regulatory programs that meet goals, can be revised to reflect changing conditions, offer flexibility to the regulated community, and strive to protect human health and the environment.

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