Introduction

By Assistant Professor David Letson, Associate Professor Daniel Suman, and Research Associate Manoj Shivlani; Division of Marine Affairs University of Miami.

Editor's note*: This overview defines pollution prevention (P2), states its relevance in general and for the coastal zone, describes how economists and marine policy analysts view P2 conceptually, reviews major legislation, presents an overview of the four case studies in this compendium, and generalizes the lessons applicable to pollution prevention in the coastal zone.*

Does an ounce of prevention equal a pound of cure for pollution? Many think so.

On Earth Day 1993, President Clinton said that "[o]ur long-term strategy invests more in pollution prevention . . ." (Freeman, 1995). Recent activities of the European Community, the Organization for Economic Cooperation and Development, the United Nations Industrial Development Office, and the North Atlantic Treaty Organization also back pollution prevention (P2) as an alternative to traditional, medium-specific technological mandates (Freeman, 1995). The 1987 Montreal Protocol on Substances That Deplete the Ozone Layer and its subsequent amendments necessitate preventative strategies because industrial nations must cease production and use of chlorofluorocarbons by 2000. Similarly, Chapter 21 of Agenda 21 (the Programme of Action for Sustainable Development) calls for reducing the production of wastes, formulating operational waste minimization policies, applying the integrated life cycle management concept, promoting a range of regulatory and non-regulatory incentives to encourage industries to adopt clean technologies, and preventive waste management approach focused on changes in production and consumption patterns. Water pollution prevention and control are key activities of Chapter 18 of Agenda 21.

In the U.S., the Pollution Prevention Act of 1990 and Executive Order 12856 (August 3, 1993), "Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements," set as national policy the preference for prevention over control.

The U.S. Environmental Protection Agency (USEPA) defines P2 as "the use of materials, processes, or practices that reduce or eliminate the creation of pollutants or wastes at the source" (USEPA, 1990). P2 is synonymous with source reduction, explicitly excluding out-of-process recycling. The Pollution Prevention Act (42 U.S.C. §13101(b)) offers a four-tier hierarchy of waste management options, ranked in descending order of preference: (1) prevention and reduction; (2) recycling and reuse; (3) treatment, and (4) disposal.

As an anticipatory, comprehensive approach that might save money and avoid end-of-pipe regulations, P2 warrants careful consideration. Successes will come from changing people's behaviors or from changing the technologies they use. Limitations for P2 may be more social than technological, given the sweeping changes in products, material cycles, manufacturing facilities, and lifestyles that P2 requires.

The Coastal Zone

This compendium focuses on the coastal zone because of its unique geographical characteristics, its ecological and economic importance, and the increasing pressures on its integrity. The Coastal Zone Management Act defines the coastal zone as "coastal waters and the adjacent shorelands, strongly influenced by each other and in proximity to the shorelines of the several coastal states . . ." (16 U.S.C. §1452(1)). Although coastal zone boundaries remain somewhat flexible and are defined by each state individually, the coastal zone clearly includes the land/ocean/air interface. Interconnection between adjacent terrestrial and marine ecosystems characterizes the coastal zone; human activities that occur on coastal lands can affect — and be affected by — coastal waters. Once pollutants enter coastal waters, they may be dispersed readily by the aqueous medium, affecting more distant coastal waters or lands, as well as associated living resources.

Although only a narrow zone, the coastal ocean is the most productive area of the world ocean. Estuaries, for example, may display levels of primary productivity that are 20 times those of the open ocean and comparable with the productivity of lands dedicated to intensive agriculture. Nutrient inputs from the land, relatively warm waters, and abundant light stimulate these high levels of productivity, the base of the food web. Other coastal waters (especially coral reefs) contain high levels of marine biological diversity. Most of the 20,000 species of fish and 30,000 species of mollusks are coastal (Oregon Sea Grant, 1996). Estuaries and coastal wetlands are often important nursery grounds for many of the world's fisheries. Both coastal waters and lands provide uniquely productive habitats, such as estuaries, coral reefs, mangrove forests and other coastal wetlands, and seagrass beds.

As a result of these ecological characteristics, coastal areas are sites of a number of important economic activities and functions, such as commercial fisheries, mineral extraction, tourism and recreational opportunities, navigation, and barriers from natural hazards. Coastal waters provide about 95% of the world marine fish catch (IPCC, 1994). About 25% of world's oil production originates from offshore wells (Frankel, 1995). Coastal tourism in many regions is of great economic importance. For example, tourism in the Caribbean accounts for 43% of that region's GNP (Miller & Auyong, 1991). Often, these multiple uses of the coastal zone are incompatible with each other and with maintenance of environmental amenities.

At the same time, much of the world's waste ends up in the ocean. Nutrients, metals, synthetic organic compounds, petroleum hydrocarbons, radioactive materials, runoff from land-based activities, and domestic wastewater discharges eventually flow into coastal waters. In some circumstances, atmospheric deposition may be the principal transport mechanism of pollutants to coastal waters. Perhaps 90% of these land-based pollutants have a "sink" in the coastal waters, sediments, and biota and never reach the deep ocean (Oregon Sea Grant, 1996). Thus, these pollutants and human activities of the coastal zone impact the richest and most productive areas of the ocean and reduce the capacity of coastal ecosystems to respond to stress (National Research Council, 1995b). Perhaps the most serious pollution problem throughout the coastal ocean is eutrophication—excessive nutrient enrichment that degrades water quality, increases algae growth, and depletes oxygen (UNEP, 1990). Other pollutants enter the coastal waters directly from ocean-based activities such as maritime transportation, offshore oil production, and ocean dumping. Marine pollution is essentially pollution of the coastal ocean, particularly of estuaries that receive pollutants from drainage basins (UNEP, 1990).

Human population patterns are a principal indicator of coastal pollution. More than two-thirds of the world population live within 80 km of the coast; in the U.S., the percentage is 53% (Edwards, 1989; IPCC, 1994; Oregon Sea Grant, 1996). Half of the major cities of the world are located near estuaries, and 18 of the world's 25 largest cities are coastal (IPCC, 1994). Culliton et al. (1990) project that population in U.S. coastal counties will measure 127 million in the year 2010, an increase of 60% from 1960. During this period, Florida's population will have grown by the largest percentage (226%) among coastal states, from 5 to 16 million. Coastal population density in 1988 was 341 persons per square mile, more than four times the national average (Culliton et al.; IPCC, 1994).

Management of human activities within the coastal zone and in catchments that drain into the coastal zone presents administrative and regulatory challenges. Institutional authority in coastal waters and lands is often fragmented among different levels of government (federal, state, local); functional specializations (research, planning, permitting, taxation, enforcement, public education); and economic sectors (protected areas and recreation, fishing, pollution control, harbors and ports, oil and gas production, shipping). Fragmentation at so many levels may lead to institutional overlap and conflict, lack of institutional coordination, duplication of effort, ineffective implementation of policies, and public confusion. These administrative realities may pose obstacles to effective regulation of pollution-generating activities and adoption of P2 strategies in the coastal zone.

For example, the land-based origin of much coastal pollution suggests that the agency monitoring coastal water quality may not be the permitting or enforcing agency. The diffuse nature of many small pollutant sources could create enforcement difficulties, such as high regulatory costs and limited monitoring personnel.

The geographical and temporal separation between discharge into the aqueous medium and observance of deleterious effects may increase the scientific uncertainty surrounding the cause-and-effect relationships and preclude adoption of preventive strategies.

As a vital, threatened resource, coastal areas provide an excellent opportunity to examine the usefulness of the P2 approach, as well as the obstacles it faces. Before examining our case studies, however, some conceptual analysis may help to define the empirical questions.

Federal Statutory Framework for Pollution Prevention

Federal legislation touches only indirectly on P2 in the coastal zone. However, much of the federal P2 legislation also has applicability in coastal areas. The Pollution Prevention Act defines P2 and establishes a hierarchy of waste management strategies embodying the concept; source reduction, rather than recycling or disposal, is the preferred national policy.

The geographical reach of the Federal Water Pollution Control Act (Clean Water Act) (33 U.S.C. §1251 *et seq*.) extends to all the Nation's waters, including the coastal oceans. Its broad goal is the elimination of discharges of pollutants into navigable waters. This "Zero Discharge" goal can be reached through "prevention, reduction, and elimination of pollution" (33 U.S.C. §1251(b)). Under this Act, the U.S. EPA has broad authority to promote P2.

The legislation grants the EPA the authority to establish industry-specific effluent limitations that are technology-based. While effluent limitations usually do not mandate adoption of a specific methodology, industrial sources have tended to favor end-of-pipe approaches rather than P2. The EPA may prohibit the discharge of certain toxic water pollutants or propose effluent standards based on the best available technology economically achievable (33 U.S.C. §1317(a)(2)). EPA standards for toxic or conventional pollutants may recommend and, occasionally, do mandate specific technologies that potentially promote source reduction. The agency possesses broad authority to develop effluent limitations based on preventive technologies.

Site-specific permits granted under the National Pollutant Discharge Elimination System (NPDES) are central to the implementation of the Clean Water Act. The EPA has broad authority and ample discretion to regulate NPDES permitting and impose conditions "as [it] deems appropriate." (33 U.S.C. §1342(a)(2)). Because P2 is a goal of the legislation, the EPA or authorized states may require Best Management Practices or other P2 technologies as conditions for issuance of NPDES permits. Issuance of an NPDES permit may also be linked to the development of a P2 plan.

The policy of the Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA) (33 U.S.C. §1401 *et seq*.) is to prevent or strictly limit ocean dumping of materials that could adversely affect human health or the marine environment. The MPRSA originally authorized the EPA to implement a permitting regime for regulation of ocean dumping of industrial wastes and sewage sludge. However, Congress amended the MPRSA through the passage of the Ocean Dumping Ban Act in 1988 to prohibit ocean dumping of sewage sludge or industrial wastes by the end of 1991. The phaseout of the ocean disposal option for these substances required producers to rely on alternative terrestrial disposal sites. Depending on comparative costs and availability of technologies, the congressional mandate may be an incentive for adoption of source reduction technologies.

Other federal legislation, specifically the Marine Plastic Pollution Research and Control Act of 1987, adopted into U.S. legislation MARPOL Annex V (the London International Convention for the Prevention of Pollution from Ships, as Modified by the Protocol of 1978 Relating Thereto, Annex V, Regulations for the Prevention of Pollution by Garbage from Ships), an international agreement to restrict the ocean disposal of garbage from vessels. Annex V prohibits the discharge of plastics or garbage containing plastics anywhere in the ocean. The agreement prohibits dumping of any garbage within three nautical miles of the coast. Annex V establishes several distinct zones between 3 and 25 nautical miles from the coast in which garbage dumping restrictions become more lenient with distance from the coast. These requirements force off-loading and land disposal of much vessel-generated garbage, increasing costs for vessel operators. These increased expenses may provide an incentive for adoption of various P2 technologies that would minimize the amount of vessel garbage.

The Coastal Zone Management Act of 1972 (CZMA) (16 U.S.C. §1451 *et seq*.) sets out policy goals and substantive requirements for state-developed coastal zone management plans. Federally approved state programs obtain initial federal grants, as well as the promise of federal consistency with state coastal zone programs. The CZMA Reauthorization Amendments of 1990 enacted a requirement that states with approved CZM plans develop a coastal nonpoint pollution control program that would restore and protect coastal waters. The program must identify land uses that contribute to degradation of coastal waters, delineate critical coastal areas, and implement additional management measures to better regulate the land uses that degrade water quality of the critical coastal areas. The CZMA opens the door for states to implement new pollution control measures, such as P2, specifically related to land-based nonpoint pollution activities that would "reflect the greatest degree of pollution reduction achievable through the application of the best available nonpoint pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives" (16 U.S.C. §1455b(g)(5)).

Many jurisdictions have attempted to control nonpoint pollution sources through mandatory and voluntary applications of best management practices (BMPs). For example, agricultural BMPs may include animal waste controls, crop rotations, streambank fencing, and fertilizer application limitations. Some urban BMPs limit impervious surfaces and require stormwater collection basins. BMPs for marinas might recommend collection basins for waters produced during high-pressure hull washing and sandblasting, as well as the substitution of low-volatile organic compound (VOC) or water-soluble paints for traditional high-VOC paints.

In this section, we have cited federal legislation that may promote P2 approaches to reduce pollution of our coastal waters. In some of these examples, the responsible federal agencies may have direct regulatory authority to require adoption of preventive technologies. In other cases, limitations or prohibitions on discharges may simply provide incentives for industries to voluntarily adopt P2 approaches.

Conceptual Economic Framework

Should regulatory agencies focus on end-of-pipe strategies for pollution reductions, or is a more anticipatory and comprehensive approach, such as P2, economically desirable?

Economists address this question conceptually by comparing effluent, input and output policy instruments for reducing pollution (e.g., Holtermann, 1976; Griffin & Bromley, 1982; Helfand, 1991, 1996; Braden & Segerson, 1993). Helfand (1991), for example, compares the efficiency of standards for effluent, inputs, or outputs. The comprehensiveness of P2 challenges any formal rendering, however, since any source reduction qualifies. That would seem to include all three types of strategies, eliminating any basis for comparison. P2's anticipatory emphasis discourages a focus on effluent, however, in preference for reductions in output or in polluting inputs. We assume that policies that reduce the flow of inputs and outputs reflect P2, while policies directly focusing on effluent belong to the control paradigm. This assumption enables us to make the following observations.

A general result of this literature is that, while addressing inputs or outputs may be more feasible in some cases (e.g., toxics or nonpoint source pollution) than a direct focus on effluent or pollution, the former achieve a social optimum only under highly constrained circumstances. The advantage of an effluent approach is that it can equalize the marginal costs of abatement across sources, thereby minimizing the costs of pollution reduction (*See* Baumol and Oates, 1988). Addressing inputs or outputs may be easier, but it also reduces economic welfare. Specifically, Holtermann (1976) shows that, to achieve the efficiency of a pollution tax, each input that contributes to pollution must be taxed; additionally, Griffin and Bromley (1982) demonstrate that the input taxes must be differentiated by source to account for locational effects. Braden and Segerson (1993) argue that, instead of a single policy instrument, combinations of such "indirect" strategies may be the optimal approach. Qualitatively similar, although more complex, results follow if the policy instruments are standards or quotas rather than taxes.

Setting tax rates (equal to marginal damages) for each source and input would likely be an administrative nightmare, if in fact it were legal or enforceable. Could an authority, for example, require sellers of fertilizer to charge a higher price of those customers in riparian areas? How would they determine the correct set of prices, and how could they prevent resale opportunities? In practice, the policy decision depends on whether the administrative ease of addressing inputs or outputs (an anticipatory approach) is worth the consequent economic distortions. A necessary condition is that the input policy should reduce pollution damages.

Whether that is true depends on the relationships between the inputs in producing output and pollution. Pollution damages will fall unambiguously only if the inputs are complements in production and if none of them abates pollution. Here, taxing or restricting an input clearly reduces both output and pollution, and taxing or restricting output clearly reduces use of polluting inputs. Otherwise, the input or output strategy will induce substitution into other polluting inputs or out of abating ones, possibly increasing pollution. For example, agricultural programs that limit crop acreage can increase pollution because land may be an abating input and because farmers often respond by substituting potentially polluting inputs such as pesticides and chemical fertilizers. When inputs are complementary and non-abating, anticipatory strategies will reduce pollution damages.

These empirical circumstances appear to be met for toxic substances, where the latter stages of production merely "pass through" the externality, implying complementarity with other inputs. Policies focusing on inputs or final outputs can reduce damages from toxic pollution; moreover, the exorbitant costs of enforcement and remediation for toxics suggest that anticipatory strategies likely are optimal. Not surprisingly, P2 strategies have met with greatest success in reducing toxic pollution. Empirical research should consider where else these circumstances are met.

Empirical Approach

Our choice of case studies in this compendium is partly a reaction to what we see as deficiencies in the empirical literature. Much of the case for P2 thus far has been in establishing its "obscured profitability" (Dorfman *et al*., 1993). According to this view, sources voluntarily engage in ostensibly costly pollution reduction activity because the outcome, in fact, is greater profits. Reduced material and energy use, alternatives to hazardous materials, improved corporate image, and avoided remediation yield the profits. More sources would reduce pollution if the profitability of doing so were easier to see. Contributing to the opaqueness are:

- inertia
- lack of knowledge of sources of waste
- lack of a system of rewards or incentives that involve plant employees in finding source reduction opportunities
- lack of a system to account the full dollar costs of ongoing waste generation back to its source (Dorfman *et al*., 1993)

Porter & van der Linde (1995) argue that a long list of case examples suggests that innovation "commonly" offsets the cost of complying with environmental standards (e.g., Bonifant and Ratcliffe, 1994; Bonifant, 1994 a,b; van der Linde, 1995 a,b,c).

Palmer *et al*. (1995) take strong issue with the notion of obscured profitability. They argue that the private sector does not systematically overlook profitable opportunities for innovation and that, even if that were the case, regulatory authorities would not be able to help. For support, they cite estimates from the Environmental Economics Division of the Commerce Department's Bureau of Economic Analysis, that cost offsets in 1992 were $1.7 billion, less than two percent of estimated environmental expenditures (U.S. Department of Commerce/Bureau of the Census, 1993).

The spirited debate over the profitability of environmental standards misses the point, economically speaking. The desirability of environmental standards in general and P2 in particular depends on a comparison of social benefits versus the costs of achieving them, as Palmer *et al*. (1995) and countless other economists have noted, rather than private sector profits. With hundreds of thousands of firms subject to environmental standards in the U.S. alone, certainly some polluting firms do voluntarily overcomply with standards or benefit from regulation. Highlighting these cases does not establish the profitability of P2, as Palmer *et al*. (1995) note, and makes no reference to social benefits. We aim for a better approach by examining cases that are visible more for the resource values at stake, as evidence of benefits, rather than for the *a priori* profitability of P2.

Our Four Case Studies

The materials that follow present four case studies of P2 experiences in the coastal zone: Boston Harbor (wastewater treatment), Chesapeake Bay (nutrients from land-based activities), Broward County, Florida's, P2 program for marinas (toxics), and the cruise line industry (garbage). We selected these four case studies because they represent a variety of circumstances in the coastal zone: point and nonpoint source pollution; land-based and ocean-based pollution sources; mandatory versus voluntary P2 approaches; localized and regional approaches; small-scale versus large-scale responses; and pollutant-generating activities that range from agriculture and wastewater treatment to maritime transportation. The case studies sometimes illustrate successful application of P2 principles and also exemplify some of the obstacles to this in coastal areas. They do not always present obvious P2 success stories, but represent examples of coastal industries and activities that are moving toward P2 and are grappling with the need to do so. These cases all have visibility in the coastal zone management and marine policy communities. Although they are site-specific examples, we believe that their underlying principles and lessons are generalizable to other regions and circumstances.

Boston Harbor

Prompted by court order and by passage of the Ocean Dumping Ban Act, Boston's Massachusetts Water Resources Authority (MWRA) ceased the discharge of sludge into the Harbor in 1991. Thus, MWRA faced an enormous disposal problem, some 1.6 million gallons of sludge per day (Thompson, 1996). MWRA had several options for sludge disposal, all of them costly.

Out of two dozen proposals, MWRA chose that of the New England Fertilizer Company (NEFCo)'s Biosolid Drying Process. Dry heating converts sludge into low-nutrient, organic fertilizer pellets, thus reusing nutrients while minimizing the harmful effects from other disposal techniques. Probably the most noticeable advantage to biosolid drying is that the final product is typically 0.5–7% of its initial volume. With such a reduction in water content, the pellets are also lighter than wet sludge, minimizing both transportation and handling costs. Through this drying technique, every ton of pellets produced costs approximately $360 and only returns $40 upon sale (Thayer, 1996). MWRA is willing to take a significant loss on the product, however, because other forms of sludge disposal would cost more. Pelletization minimizes costs and facilitates reuse of an otherwise wasted and potentially detrimental resource.

The Quincy Pelletization Plant is a visible part of the Boston Harbor Clean-up Project. Pelletization is not the highest form of P2: it falls into the category of "external waste recycling and reuse," which, while one tier below "source reduction" is still a clear improvement over previous Bostonian sewage disposal. Moreover, the pellets encourage other states to move toward source reduction of pollutants by offering a leach-resistant, oil-conditioning fertilizer. Elsewhere in the Clean-up Project, improvements in combined sewer overflows and connector pipes also represent moves up the P2 hierarchy. Perhaps most importantly, the choice of pelletizing prompted industrial wastewater pretreatment, so that the pellets would comply with land application standards.

Probably the clearest P2 policy was the creation of the Toxic Reduction and Control (TRAC) Task Force by the MWRA. The regulations that govern the land application of sludge pellets forced MWRA to reduce the amounts of toxics and metals in digested sludge. The present system of primary treatment does little to eliminate these contaminants (Thompson, 1996). Thus, an alternative form of controlling these substances had to be developed, if marketing of Bay State Organic fertilizer were to become feasible. If not, MWRA would not be able to sell the pellets and instead would have to resort to costly landfill.

The solution was industrial pretreatment and source reduction. Once regulations established pellet standards, MWRA determined the daily allowable amounts of toxics tolerable by the system. TRAC divided these quantities among the 5,500 contributing industries and began to enforce compliance. TRAC possesses the authority to perform surprise inspections and secret monitoring as well as to assess and collect fines for noncompliance.

The sheer scale of the Boston Harbor Cleanup Project makes it an important subject of coastal policy. Because other U.S. coastal cities share Boston's concerns about a decaying infrastructure, the role P2 might play in the Boston Harbor Cleanup clearly is of interest to policy officials. The limiting factor in the role for P2 in Boston, however, is land use. High land costs make internal reuse of sludge prohibitively expensive. Thus, the biggest opportunities for P2 for Boston Harbor probably lie in growth management. While technological options do exist for source reduction in sewage treatment (Peterson, 1993), they are not cost-effective in densely populated urban centers like Boston. Source reduction clearly has occurred as part of the Cleanup with leaded solder removal and industrial pretreatment. However, the most important cleanup efforts have been, first, to upgrade treatment and extend it to more of Boston's wastewater and, second, to promote external reuse of sewage sludge. While the P2 hierarchy is a holistic and comprehensive tool for assessing waste management options, it does not obviate socioeconomic concerns.

Chesapeake Bay

The Chesapeake Bay Agreement provides an opportunity to examine the role of P2 in a large, multi-jurisdictional (Pennsylvania, Maryland, Virginia, and D.C.) effort to reduce nutrient enrichment. Increased chlorophyll production from excessive nutrients has reduced dissolved oxygen levels below those that can maintain a healthy ecosystem. The resulting loss of submerged aquatic vegetation threatens many commercially and recreationally important species such as blue crabs, oysters, and juvenile fish. Agricultural and household fertilizer runoff, air pollution, sewage and industrial outfalls, deforestation, and urban development all contribute to increased nutrients entering the Bay.

The Agreement calls for 40% reductions in nutrient discharges by each state but does not specify guidelines for how states and intrastate authorities should meet reduction goals beyond the broad charge to develop tributary strategies. Nor does it make specific references to P2 or source reduction. Nevertheless, signatories have moved steadily away from the uncontrolled release and treatment strategies at the bottom of the pollution prevention pyramid to higher-order efforts to reduce nutrient inputs at their sources.

Source reduction strategies include banning the use of phosphates in household detergents, creating special zoning areas to control coastal development, and establishing riparian buffers that reforest along river and stream banks. Nutrient management and best management practices on farms and biological nutrient removal at sewage treatment plants also have become core strategies to reduce nutrients under the Agreement. While nutrient management and best management practices on farms rank high on the pollution prevention pyramid, sewage treatment plants rank lower. However, a new technology, biological nutrient removal, is a cost-effective method for reducing nitrogen loads, which have lagged behind phosphorous reductions.

Each state and the District of Columbia have implemented or at least planned several nutrient-reduction strategies in order to meet the goals established in the Chesapeake Bay Agreement. In opting for voluntary measures as a large component of the program, officials are broadly delegating responsibility for environmental policy across the different levels of government and to local communities and individuals. The Agreement stresses public involvement at all stages of activities—in fact, the many agencies and organizations involved in implementing the Agreement have all developed strong public outreach campaigns (Flanigan & Dunn, 1994). In addition, each signatory to the Agreement has had to work collaboratively to identify the roles that the federal, state, and local authorities must play for their P2 strategies to be successful in the Bay watershed.

The state nutrient reduction strategies allow for political and economic flexibility for individual states' efforts in the protection and restoration of the Bay. Maintenance costs for reduction techniques, such as streambank fencing and fertilizer Best Management Practices (BMP)s, are less expensive for the user than the more traditional cleanup strategies that have been prevalent in the past. However, strategies need to make sense and be cost-effective and manageable for those using them because of the largely voluntary nature of these programs. Those farmers who have implemented BMPs have done so not only to reduce nutrient loading into the Bay, but also to promote their own economic interests.

Nevertheless, voluntary, incentive-based strategies such as P2 could be applied more broadly under the Agreement if more strongly endorsed and funded by government leaders. Funding is a limiting factor, but all funding for P2 plans does not need to come from traditional government programs. The states could apply many creative financing mechanisms under leadership of the Chesapeake Executive Council. One of the most important tasks for state officials is working out the issue of insufficient funding, and the states must complete this before the terms of the Agreement can successfully be met.

Broward County Marinas

Broward County, Florida, a center of recreational boating in the U.S., has adopted a list of BMPs for its marinas. Marinas, a coastal-dependent activity, are sources of sewage, toxic substances, and petroleum hydrocarbons to coastal waters. In the aggregate, this activity can seriously degrade water quality. The BMPs attempt to reduce pollution to coastal waters from marina boat maintenance and servicing activities and foster a P2 attitude in the marina industry. These guidelines, which are applicable in all commercial boat-docking facilities and recreational facilities with 10 or more slips, were developed through a cooperative venture between county environmental regulators and representatives of the marina industry.

Some guidelines refer to vessels' discharge of garbage and wastewaters; others focus on vessel maintenance activities such as hull washing and cleaning, paint removal, spray-painting, and cleaning engine parts. For example, pressure cleaning is restricted to impermeable surfaces with retaining walls that ensure that wastewater is collected. The BMPs recommend techniques for spray painting that reduce solvent evaporation. A final set of BMPs focus on fuel storage and handling and promote activities that reduce the potential release of these substances to the environment.

The BMPs for marinas have encouraged activities that range throughout the pollution prevention hierarchy. Some measures are examples of source reduction, such as substituting low-VOC paints for traditional paints or using the High-Volume/Low-Pressure paint application technique. Other innovations promote recycling, such as the plastic media system that removes bottom paint by reusable plastic particles.

Many incentives exist for marinas to adopt P2 measures in addition to compliance with county regulations and the BMPs. Present-day investment in new technologies may facilitate compliance with future more stringent regulations. Employing P2 technologies may increase a marina's "green image" and expand its client base. A P2 program also has the potential to create direct economic benefits for marinas. After the initial investment in the new technology, costs for raw materials and waste disposal may decrease. Many marinas also levy "environmental surcharges" on their services; these can offset the adoption of new P2 technologies.

Cruise Line Industry Based in Miami

The large Miami-based cruise line industry provides increasingly positive examples of P2. Cruise liners generate a large amount of waste that, historically, was disposed of at sea. The average passenger may generate several kilograms of garbage per day (National Research Council, 1995a); the largest vessels carry more than 3,000 persons and often remain at sea for a week or more. Cruise lines may be responsible for 75% of ship-generated waste in the Wider Caribbean (International Maritime Organization, 1994). Today, however, stricter international and U.S. legislation, more public scrutiny, and growing industry awareness are all encouraging the cruise line industry to adopt P2 techniques or at least avoid ocean disposal. Many cruise lines are voluntarily adhering to comprehensive waste management strategies that emphasize source reduction and recycling over disposal to the marine environment.

While international agreements, specifically MARPOL Annex V, do not directly promote source reduction strategies, they do close some traditional disposal routes, such as ocean disposal of plastics. Ocean disposal of other vessel garbage is permitted only in certain zones at varying distances from land. The U.S. and many Caribbean nations have ratified MARPOL Annex V. In recent years, the U.S. Coast Guard has levied fines on several cruise lines whose vessels have violated the restrictions on ocean dumping of garbage. These enforcement actions and the resulting negative public opinion have encouraged the companies to alter their traditional practices and adopt new disposal strategies, which may include source reduction, shipboard or external recycling, and disposal on land.

Vessels could adopt a source-reduction strategy by reducing packing materials, terminating the use of disposable items, and limiting wasteful activities. One cruise vessel's boiler system has been retrofitted to utilize oil sludge from other vessels as an alternative fuel source, thus reducing the fleet's fuel consumption. Other vessels have implemented co-generational systems that heat the water used aboard the vessel with heat from the ship's engines. All these activities reduce the overall energy required to operate the vessel.

To avoid disposal of garbage to the marine environment, vessels must store waste onboard until it can be recycled externally or disposed on land. Cruise vessels use equipment such as compactors, shredders, and crushers to reduce the volume, but space limitations and sanitation concerns restrict the usefulness of these measures. While vessels incinerate some wastes, they are adopting cleaner incineration technologies and, in some cases, are even using some of the heat for co-generation. These lower-level P2 activities represent the majority of cruise lines' waste management strategies.

Despite this progress, obstacles still exist to greater adoption of P2 technologies. The logistical difficulties of enforcing the restrictions on sea dumping, as well as calls to foreign ports, create incentives not to adopt source reduction technologies, especially if they do not appear to be cost-effective. The lavish and consumptive nature of the cruise experience produces a large amount of garbage per person and suggests that finite social limits exist to possible adoption of source reduction technologies. Nevertheless, the industry appears to be moving up the pollution prevention hierarchy as evidenced by several cruise lines' voluntary adoption of the "zero discharge" rule, which refers to no discharge of solid wastes into the sea.

Conclusions on the Role of P2 in the Coastal Zone

As a distinct geographical region, the coastal zone possesses particular attributes that affect the nature of P2 activities adopted there. The aqueous medium may transport pollutants released in coastal lands and waters far from the source, affecting sensitive habitats and economically valuable resources. Coastal areas are highly exploited; population densities are high, and multiple uses compete for coastal space and resources. Due to high levels of human activity, many coastal areas have serious pollution problems. Perhaps we have loved our coastal areas too much.

Materials in this compendium are based on the premise that the coastal zone is a good situs for adoption of P2 strategies because vulnerable coastal resources receive high exposure to a broad suite of pollutants. Coastal planners have begun to realize the advantages of P2 and its comprehensive and anticipatory approach. P2 strategies parallel *integrated coastal zone management* in the sense of their comprehensive consideration of the ecosystem and the life cycle of substances classified as "pollutants."

All the P2 examples cited in this compendium face significant obstacles that may be political, legal, or economic.

Political factors may include lack of grassroots acceptance, weak political will at appropriate governmental levels, and poor cooperation and communication between the regulators and the regulated community.

On the legal level, problems may arise when regulations are excessively mandatory and do not permit regulated industries to select approaches that they consider to be most cost-effective or most socially acceptable. Enforcement is often a weak link and may be complicated by the large number of geographically dispersed small sources that, in the aggregate, may generate significant amounts of pollution. The voluntary nature of many P2 campaigns may reduce the enforcement burden somewhat, however.

Economic limitations may include weak incentives to support adoption of clean technologies, the high cost of adapting or replacing the current technologies with others that are higher on the P2 hierarchy, and the lack of a systematic accounting structure that considers the positive values of enhanced environmental amenities.

For example, the BMPs for Broward County marinas contain a *de minimis* exemption for small marinas (<10 slips), allowing many marinas remain outside the formal P2 program. Despite the cooperative development of the BMPs between county regulators and the marina industry, many marina owners oppose the BMPs and are suspicious of the county's motives. Public education and cooperative ventures with the regulated industry appear to be factors that assist the successful adoption of P2 strategies. Recognizing that clean technologies may be costly, state and local governments could provide stronger economic incentives.

Compliance with international and national restrictions on ocean disposal of garbage has stimulated adoption of some P2 strategies by the cruise line industry. However, despite these restrictions, enforcement remains problematic. The vast size of the ocean presents logistical problems for monitoring and surveillance of vessels. Many cruise ships are not registered in the U.S. and sail in waters beyond the jurisdiction of U.S. authorities. Some foreign ports, receiving garbage from vessels sailing from U.S. ports, may not possess equivalent recycling or garbage-handling facilities. The cost differential may inadvertently subvert U.S. P2 initiatives. The consumptive nature of this industry implies that source reduction may have only limited acceptance. Additionally, older vessels would require extensive retrofitting to install new garbage treatment systems.

Nutrient reduction in the Chesapeake Bay watershed provides numerous examples of P2 in a land-based pollution scenario. Focusing on the Chesapeake Bay watershed, this effort is ecosystem-based and of necessity multi-jurisdictional. With the overall nutrient reduction goals established by the interstate agreement, each jurisdiction has the flexibility to select its own cocktail of strategies based on political and economic factors. Strategies may embrace land management techniques, agricultural BMPs, phosphate detergent bans, and nutrient reduction from sewage plants. Obstacles to the adoption of P2 strategies include the magnitude of the effort, which requires administrative coordination on a multistate level. Lack of political will at the highest levels of some states may derail the original agreement. Even where political will exists, funding limitations may restrict the programs' full effectiveness.

The revitalization of urban wastewater treatment facilities may include technologies that have a P2 orientation. In the case of some of the nation's older northeast cities, a national ban on ocean dumping of sewage sludge was a mandate for considering alternative disposal strategies. The selected option, pelletization, represents external waste recycling and reuse. While pelletization only recoups about 10% of the costs and is thus not "profitable," this narrow equation would be altered if we were to quantify the avoided environmental harm as well as the comparative costs of alternative disposal techniques.

The coastal zone activities that we consider here are all increasing in magnitude due to the growing coastal populations, as well as high levels of consumption. Therefore, even if coastal economic sectors adopt P2 strategies, no guarantee exists that the total levels of pollutants released to coastal waters will decrease. Nevertheless, the suite of P2 alternatives present options for coastal pollution management that we must seriously consider and that, taken across economic sectors, can minimize releases of pollutants to coastal waters and enhance the amenities of these unique resources.

References

Baumol, W. J., & W. E. Oates. 1988. *The Theory of Environmental Policy.* New York: Cambridge University Press.

Bonifant, B. 1994a. "Competitive Implications of Environmental Regulation in the Electronics Manufacturing Industry." Washington: Management Institute for Environment and Business.

———. 1994b. "Competitive Implications of Environmental Regulation in the Paint and Coatings Industry." Washington: Management Institute for Environment and Business.

Bonifant, B., & I. Radcliffe. 1994. "Competitive Implications of Environmental Regulation in the Pulp and Paper Industry." Washington: Management Institute for Environment and Business.

Braden, J. B., & K. Segerson. 1993. "Information Problems in the Design of Nonpoint-Source Pollution Policy," in *Theory, Modelling, and Experience in the Management of Nonpoint Source Pollution*. Boston: Kluwer Academic Publishers, 1–36.

Culliton, T. J., M. A. Warren, T. R. Goodspeed, D. G. Remer, C. M. Blackwell, & J. J. McDonough. 1990. *Fifty Years of Population Change along the Nation's Coast, 1960–2010*. Second Report of the Coastal Trends Series. Rockville, MD: U.S. Department of Commerce/NOAA.

Dorfman, M., A. White, M. Becker & T. Jackson. 1993. "Profiting from Pollution Prevention — Better Environmental Protection; Improved Economic Competitiveness," in C*lean Production Strategies,* ed. T. Jackson, 189–206. Boca Raton, Fla.: Lewis Publishers.

Edwards, S. F. 1989. "Estimates of Future Demographic Changes in the Coastal Zone," *Coastal Management* 17:229–240.

Flanigan, F. H., & C. A. Dunn. 1994. "Involving the Public in Developing Nutrient Reduction Strategies for Chesapeake Bay," in *Changes in Fluxes in Estuaries: Implications From Science to Management*, ed. K. R. Dyer & R. J. Orth, 429–434. ECSA 22/ERF Symposium, Institute of Marine Studies, University of Plymouth, International Symposium Series. Friedensborg, Denmark: Olsen & Olsen.

Frankel, E. G. 1995. *Ocean Environmental Management*. Englewood Cliffs, NJ: Prentice Hall.

Freeman, H. M. 1995. *Industrial Pollution Prevention Handbook*. New York: McGraw-Hill.

Griffin, R. C., & D. W. Bromley. 1982. "Agricultural Runoff as a Nonpoint Externality: A Theoretical Development," A*merican Journal of Agricultural Economics* 64:547–552.

Helfand, G. 1991. "Standards versus Standards: The Effects of Different Pollution Restrictions," *American Economic Review* 81(3):622–633.

———. 1996. "Controlling Inputs to Control Pollution." Presented paper, 1996 ASSA Meetings, San Francisco.

Holtermann, S. 1976. "Alternative Tax Systems to Correct for Externalities, and the Efficiency of Paying Compensation," *Economica* 43(1):1–16.

Intergovernmental Panel on Climate Change (IPCC). 1994. *Preparing to Meet the Coastal Challenges of the 21st Century: Conference Report of the World Coast Conference 1993*.

International Maritime Organization. 1994. *The Caribbean —A Very Special Area: Wider Caribbean Initiative for Ship-Generated Waste*. Port of Spain, Trinidad: Media and Editorial Projects.

Miller, M. L. & J. Auyong. 1991. "Coastal Zone Tourism: A Potent Force Affecting Environment and Society," *Marine Policy* 15:75–99.

National Research Council. 1995a. *Clean Ships, Clean Ports, Clean Oceans: Controlling Garbage and Plastic Wastes at Sea*. Washington: National Academy Press.

———. 1995b. *Understanding Marine Biodiversity*. Washington: National Academy Press.

Oregon Sea Grant. 1996. *Coastal Zones of the Pacific: A Descriptive Atlas*. Corvallis: Oregon State University.

Palmer, K., W. E. Oates, & P. R. Portney. 1995. "Tightening Environmental Standards: The Benefit-Cost or the No-Cost Paradigm?" *Journal of Economic Perspectives* 9(4):119–132.

Peterson, S. 1993. "Alternatives to the Big Pipe," *Oceanus* (Spring 1993): 71–75.

Porter, M., & C. van der Linde. 1995. "Toward a New Conception of the Environment-Competitiveness Relationship," *Journal of Economic Perspectives* 9(4):97–118.

Thayer, M., Massachusetts Water Resources Authority. July 1996. Personal Interview in Boston.

Thompson, W. B., Director of the Deer Island Treatment Plant, Massachusetts Water Resources Authority. March 1996. Personal Interview in Boston.

van der Linde, C. 1995a. "Competitive Implications of Environmental Regulation in the Cell Battery Industry." St. Gallen, Switzerland: Hochschule St. Gallen.

———. 1995b. "Competitive Implications of Environmental Regulation in the Printing Ink Industry." St. Gallen, Switzerland: Hochschule St. Gallen.

———. 1995c. "Competitive Implications of Environmental Regulation in the Refrigerator Industry." St. Gallen, Switzerland: Hochschule St. Gallen.

United Nations Environment Programme. 1990. *GESAMP: The State of the Marine Environment*, UNEP Regional Seas Reports and Studies No. 115.

United States Department of Commerce, Bureau of the Census. 1993. "Pollution Abatement Costs and Expenditures, 1993," *Current Industrial Reports* MA200(93)-1.

United States Environmental Protection Agency. 1990. *Environmental Protection Agency Pollution Prevention Directive* (May 13, 1990).

National Pollution Prevention Center for Higher Education
430 East University Ave., Ann Arbor, MI 48109-1115
734-764-1412 • fax: 734-647-5841 • nppc@umich.edu

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