major departure from traditional permissive policies toward the Great Lakes that permitted releasing a variety of pollutants.[138] As in the UN Straddling Stocks agreement, in this case the United States is now an advocate for precautionary action. While the IJC statement of principles has been criticized as lacking force, it should be recognized as a genuine vote of confidence and an endorsement of cooperative stewardship for the marine environment.

THE POLLUTION PREVENTION ACT

A major first step toward precaution and prevention in domestic environmental law is the Pollution Prevention Act of 1990 (PPA).[139] What is unusual is that the act was created in conference committee when enabling language was inserted in the Omnibus Budget Reconciliation Act of 1990. Thus the PPA did not appear in House or Senate budget bills.[140] The forward-looking PPA explicitly establishes a four-level ranking for preventing pollution. Source reduction (or pollution prevention) is clearly listed in the act as the most desirable option. Failing that, the PPA lists waste recycling as next best option. Waste treatment follows when recycling is unworkable. Finally, waste disposal is seen as a last resort.[141] And thus the environmentally popular option of recycling is also recognized as inferior to either eliminating or reducing waste at the source. The act intentionally leaves the initiative for pollution prevention with the states to take advantage of local knowledge. Indeed, "States have been at the forefront of the pollution prevention movement . . . [with] programs occasionally serving as a model for federal programs."[142]

Making prevention the number one priority is a novel idea. It is also common sense; it can be more economical than command-and-control methods that for decades mandated end-of-pipe thinking. Thus engineers and scientists are increasingly being asked to find clever means to avoid waste in the first place. An earlier attempt at source reduction was the Resource Conservation and Recovery Act of 1976, amended by the Hazardous and Solid Waste Amendments of 1984. However, it has been more narrowly interpreted than PPA and has generally had little success.[143] But times change. As reported in *Science*, a chemist at the Environmental Protection Agency was "tired of being an environmental cop." Rather than track the "hundreds of known toxic and carcinogenic substances released into the environment each year as they move from air to water to land and back again, he would rather replace his police uniform with a lab coat, and promote research into ways chemists can redesign existing compounds to render them harmless to humans and the environment."[144]

Engineering environmentally safer substitutes for current methods and products is clearly possible but too rarely tried. A new mind set can facilitate innovative thinking and enable the redesign of substances like dyes, paints, solvents, pesticides, weed killers, and other chemicals. In just this fashion, a safer way was found to manufacture quinoic acid, used in photographic agents and other chemicals; bacteria are incorporated in making the acid so that it releases sugars in place of benzene.[145] In another industrial setting, the commercially important polymer polytrimethylene terephthalate (3GT) is now being made without heavy metals, petroleum, or toxics. Instead it is produced using glucose from cornstarch, which is cheaper to boot. And all the liquid effluent in its production is now biodegradable. Further, this 3GT polymer can easily undergo methanolysis to reduce polyesters to original monomers, for indefinite recycling.

A strikingly different and yet ultimately similar strategy is seen in the Toxic Diet Project promoted by Save the Bay of Rhode Island.[146] Here the emerging aims of pollution prevention are being achieved by a combination of waste-water monitoring, together with education to encourage individuals to buy less toxic products for home use. It shows that a more sensible alternative to water contamination, and thus to costly sewage treatment, is to voluntarily reduce toxins at their source. Ideas like the Toxic Diet are an exciting, low-cost, and rational means to prevent pollution among the broad public.

Yet few federal dollars earmarked for the environment are being spent on prevention. In 1990, roughly $115 billion went toward all pollution control efforts in the United States, an immense figure that will rise to $170 billion by the year 2000. Yet, according to a GAO report, the EPA spends "less than 1 percent of the agency's annual budget for source reduction activities."[147] While hundreds of billions of dollars have initiated much eco-business for environmental cleanup or treatment, these dollars typically are directed to remediating damage after it has occurred.

Prevention has not been embraced more strongly in part because of problems in implementing the Pollution Prevention Act. According to a report from the General Accounting Office that evaluated PPA programs nationwide, the primary goals of the act are not being met. While some state antipollution programs created by the PPA are properly focused on source reduction, many of them wrongly emphasize recycling, waste treatment, and even waste disposal. A curious result is that some state programs are awarded federal funds for pollution control but have neglected to ascertain if prevention is possible—an outcome inconsistent with the goals of the act.[148]

Another potential issue is that some 80 percent of the state PPA programs are nonregulatory, volunteer efforts. While this voluntary (nonmandatory) feature might be the smartest approach to prevention, without strong financial support the goals of PPA could be too easily overlooked. An information base for industry was created to disseminate knowledge on ways to prevent pollution at its source. The results included a Pollution Prevention Office and a Source Reduction Clearinghouse, and the GAO report notes that these should be expanded. Prevention must be strengthened by new outreach efforts if pollution prevention, reduction at the source, is to develop any momentum. And some way of assessing current PPA efforts will be necessary to ascertain which state prevention programs are working and which are not, and exactly why.[149] The EPA notes in its defense that stronger goals are not part of its mandate under PPA, which requires only that states "promote" reduction at the source.[150]

Realistically, preventing pollution is a daunting task. While the dollars are there for after-the-fact cleanup, no infrastructure or constituency truly supports pollution prevention. Moreover, for political reasons, PPA targets for voluntary action are deliberately vague to avoid entanglements with manufacturers who resist any limitation on their business decisions. Nonetheless, fiscal incentives and market tools to eliminate or reduce harms at the source ought to be considered. These include "green" subsidies and taxes. For instance, a levy on manufacturers that use virgin materials in making paper, plastics, glass, aluminum, and metal products can promote greater efficiency and recycling.[151] Carefully tailored "green" taxes can be incentives for prevention and reduce currently externalized environmental burdens. Revenues generated from "green" taxes should then be earmarked for new PPA action, creating a self-sustaining process.

Other attempts at source reduction should encourage industry to voluntarily reduce the use of problematic chemicals. The EPA's 33/50 program is one example. The program, begun during the Bush administration, sought to reduce releases of seventeen specified chemicals by 33 percent in 1992 and 50 percent in 1995. Generally speaking, the program has been a success as far as it attempted to go. But several issues still need to be solved. For example, because it relies on data from the toxics release inventory as the sole means to measure reductions, it is difficult to ascertain the true success rate because the inventory does not indicate specifically how reductions were made. While it shows changes in the total weight of chemicals released or transferred, it does not give good data on whether these were a result of closing a facility, of paperwork changes like new methods for calculating estimates, of transfers offsite such as for incineration or recycling, or of true source reduction.[152] Toxic release inventory data show that even though the reported release of certain chemicals into the environment has been dropping, the total amount of waste generated by industry continues to rise.[153] Nonetheless, the 33/50 program is a worthy first step.

During the 1990s the EPA began other new programs for incorporating pollution prevention into business, industrial, and consumer decision making. These include the Green Lights Project, which promotes the idea that more efficient practices can cut the use of electricity for lighting by 50–75 percent.[154] Other pollution prevention projects include the Energy Star Computers, which draw on less power when inactive, since 25–40 percent of computers are left on overnight, and the Water Alliances for Voluntary Efficiency, in which participants seek to reduce their water usage by some 2.25 billion gallons per year. This is a purposeful effort to move away from sector-specific, command-and-control regulations that had characterized earlier EPA actions.[155]

Looking Ahead: Industrial Ecology and Design for the Environment

The preceding discussion shows that the design phase is crucial to reducing waste and pollution in manufacturing. According to the National Research Council, roughly 70 percent of the costs associated with a product's development, manufacture, and use are determined at the outset—during the product's initial design stage.[156] More relevant here is that design decisions deeply influence a product's ecological impacts—from cradle to grave. At the design stage there is greatest flexibility to determine what materials to use, to choose benign manufacturing techniques, to consider ecological risks, and to determine the characteristics of waste streams.[157] The design phase is the best moment to apply new concepts of industrial ecology and design for the environment.[158]

In 1989 Robert Frosh and Nicholas Gallopoulos introduced the idea of industrial ecology to the public.[159] The aims of industrial ecology are to advance a more cyclical approach toward manufacturing design in which natural resources are used and reused as efficiently as possible. "This contrasts with the traditional linear model of manufacturing, in which materials are extracted, used in production, and then discarded."[160] Industrial ecology strives to emulate the cyclical processes found in ecosystems, since natural systems abhor waste. In nature one organism's waste is another's sustenance. In fact, many technological advances have been made by imitating patterns found in nature; dragonflies once served as a model for improving helicopter designs.[161]

The objective is to "network" industrial plants so that they work more like biological systems. A network of interrelationships could take the unwanted effluents from one plant, or "organism" (such as heat, waste water, surplus gas, steam, organic debris), and use them as input for other processes. By design, the by-products of metabolism (manufacturing) can be coordinated so that effluents support a much larger system. Although the biological metaphor is not perfect, the current state of industrial production could be compared to a stage of primitive life on earth when there was very little recycling of material and toxic wastes accumulated to the point where they presented problems for survival.[162] Microorganisms evolved over time to become consumers of other organisms' wastes. Once evolved from a primitive anaerobic to an aerobic metabolism, thus able to exploit what had been poisonous oxygen, the web of living systems grew more integrated and stronger because of its biological diversity.

A manifestation of the efficient ecosystems approach is design for the environment (DfE), an adaptation of the "Design for X" idea (DfX) in manufacturing. "In DfX, a desired product characteristic (such as safety or durability) is integrated as a goal into the design process. In DfE initiatives, environmental considerations become an integral part of the design of a product."[163] Like nature, DfE has many faces. In Germany, for instance, legislative initiatives have led to new product designs that incorporate ease of disassembly, recyclability, and pollution prevention into original specifications. More broadly, German law is beginning to require companies to check their production processes to identify by-products (waste) that may be used by other industries.[164] Such technology forcing is bound to improve ecological efficiency. Thus an enzymatic process was found to reduce wastes from one industrial process by about 90 percent while also making the remaining waste nontoxic.

On a larger scale, the DfE idea may be applied to the eco-industrial park. Here zoning is applied not only to set aside space for manufacturing but also to prevent pollution by initiating more sophisticated and interconnected business relationships. Industrial systems are viewed through a prism of biological systems using (where feasible) ecological ideas like materials flows, carrying capacity, resilience, and connectivity. Outputs from one plant are raw inputs for other plants in a process that both increases profits and minimizes wastes.[165]

There are many potential avenues for achieving environmental efficiency, materials recycling, and gaining ecological wisdom—all in a spirit of DfE. Possibilities include integrated pest management and aggressively designing houses and whole communities for greater energy conservation. In the fertile Salinas Valley of California, a smart new company has developed one such business that reflects DfE thinking.[166] A large agribusiness there had been processing several tons of lettuce daily for packaging, discarding unwanted vegetable pieces as waste. In an entrepreneurial fashion, this company now takes the excess and converts it into compost, which is then sold to farmers. This composting business supplants potentially harmful chemical fertilizers and reuses organic materials that otherwise would be wasted (by being thrown away in landfills). Any action that productively returns a product to the soil is the greatest recycling act of all.

Another example of the application of industrial symbiosis is a Danish biotech company named Novo Nordisk and the interrelationships among industrial plants in the small city of Kalundborg, Denmark. It cost an estimated $60 million to build this complex system, which has returned some $10–12 million per year, for a $120 million payback so far. The web of interrelationships works like this: a local oil refinery sells its waste—cooling water, waste water, and surplus gas and steam—to a local power plant. The power plant sells its waste, including heat, to some 5,000 homes; it sells gypsum to a plaster board factory; and it sells heated water to a fish farm. Waste in the form of steam is sold to the Novo Nordisk biotech company. At the same time, Novo Nordisk sells to farmers a nitrogen-rich biomass from its enzyme fermentation vats. Surplus yeast from Novo Nordisk's insulin production goes to farmers as fodder to feed animals.[167] This cooperation not only is commercially sound but also makes common sense.

Conclusion

In sum, present U.S. laws are just beginning to exhibit precautionary action. However, the government has started to play a needed catalytic role, as seen in the Design for the Environment program at the U.S. Environmental Protection Agency.[168] This voluntary DfE program offers selected industries information on ways to prevent pollution while also increasing profits by designing products and/or processes with an awareness of ecological consequences. That thinking is establishing cooperative government-industry partnerships for both precautionary action and pollution prevention. These are sophisticated, multifaceted approaches to solving the problem by going to the source of pollution.[169]