10

Assessing Environmental Performance of Japanese Industrial Facilities in Kentucky

GARY A. O'DELL

REPRESENTING MORE THAN $7 BILLION invested in more than a hundred plants, Japanese corporations have been the most important source of foreign direct investment in Kentucky during the past decade. The economic impact of this investment is substantial and benefits the commonwealth through direct employment, increased tax revenues, and multiplier effects. Other aspects of the Japanese presence are less easily quantifiable. Although the proliferation of manufacturing firms serves to diversify and strengthen Kentucky's economy, quality of life in Kentucky is not limited solely to economic considerations but includes the state of the environment.

Economic activity places stresses on the environment in the production and consumption phases, for the environment serves as a source of materials and energy, as an assimilator of waste, as a source of amenities, and as a life-support system. Provision of these services is dependent on preservation of the environment and maintenance of in situ natural resources and stable ecological relationships. The concept of sustainable development attempts to unite the need for current economic output with the need to maintain the continued productivity of environmental and natural resources (Pearson 1985). When the ability of the environment to renew materials and absorb waste is exceeded, the environment deteriorates.

Assessment of environmental impacts of human activity may be made using two different frames of reference: absolute and relative. Evaluation on absolute terms requires long-term collection of baseline data against which to measure departures from ambient norms. Evaluation on relative terms does not seek to measure changes but rather to provide an indication of potential environmental impact, using performance criteria.

A primary cause of environmental degradation is the uncontrolled release of waste residuals, or pollution. Many industrial operations produce waste that is potentially harmful to the environment. The amount and types of waste generated by a facility are important indicators of risk to the environment, but more significant is the manner in which such waste is managed. Through production modifications and proper handling, the amount of potentially hazardous waste released into the environment may be greatly reduced. Comparison of waste generation and waste management practices among industrial facilities provides a means to assess the environmental performance of specific facilities or industry segments. The focus of this chapter is to determine whether Japanese-owned firms operating in Kentucky differ significantly from those of other ownership in their environmental performance. Schreurs, in the previous chapter, focused on the development of environmental policies of Japanese industry; this chapter is concerned with their real-world practices.

Performance evaluation of Japanese firms was undertaken using data on hazardous waste generation reported to the Kentucky Division of Waste Management under the provisions of the federal Resource Conservation and Recovery Act (RCRA) of 1976 and the federal Toxic Release Inventory (TRI) established by the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986. Each of these programs requires industrial facilities to report on materials that are potentially harmful to human health and the environment, and each of these programs was established prior to a significant Japanese industrial investment in Kentucky.

An additional assessment of environmental performance was conducted by visiting five large-quantity hazardous waste generators in Kentucky. These facilities were Toyota Motor Manufacturing, Kentucky (Georgetown), KI (USA) (Berea), Zeon Chemicals (Louisville), Universal Fasteners (Lawrenceburg), and Hitachi Automotive Products (USA) (Harrodsburg). The firms visited were selected from the list of large-quantity hazardous waste generators to provide a diversity of industrial types and facility sizes. At each facility, the environmental staff was interviewed concerning environmental policies and practices and the plant was toured to inspect waste reduction measures implemented.

Environmental Performance Assessment

Evaluating environmental performance differs considerably from environmental impact assessment in its approach. Impact assessment generally deals in absolutes; performance evaluation considers relations. Impact assessment is focused on changes that occur in the condition of the environment as a result of human activity. Therivel (1992) describes environmental impact assessment (EIA) as "the process of predicting and evaluating an action's impacts on the environment, the conclusions to be used as a tool in decision making." Since EIA was first formalized following the National Environmental Protection Act of 1969 and the subsequent establishment of the U.S. Environmental Protection Agency, it has been applied primarily to specific proposed actions or projects. The basic steps followed in an EIA are to review the state of the environment and the characteristics of the action and possible alternatives and to then predict the future state of the environment with or without the action (Baker, Kaming, and Morrison 1977).

Ideally this cause-and-effect approach requires that the environment be well enough understood that the effect of various actions can be modeled in some fashion. This requires the accumulation of a substantial volume of data in many categories from which ambient conditions may be determined against which to measure or predict changes. The situation is further complicated because environmental systems—ecosystems—are not static but are constantly evolving in response to both internal and external dynamics. The response to this complexity has been attempts to develop specific indicators that reflect either environmental changes or potential risk to the ecosystem. There is at present no universally adopted set of indicators. In the words of one researcher: "No generally accepted approach is available to measure these local and regional impacts: we do not have an ecological indicator for use on the evening news that is comparable to the GNP" (Karr 1992, 229).

Ecosystems are complex open systems having a constant interaction of material and biological inputs and outputs. For this reason cause-and-effect is not a simple linear association but an intricate set of relationships. Therivel's (1992) discussion of cumulative environmental impacts reflects on this complexity. Environmental impact assessments do not adequately consider cumulative effects of one or more projects or activities. Cumulative impacts include additive, synergistic, threshold/saturation, induced/indirect, or time-crowded and space-crowded effects. An additive effect results in environmental degradation from a sum of activities where any one activity by itself causes little harm. When the total impact of several activities exceeds the sum of their individual impacts, this is a synergistic effect. A threshold or saturation effect occurs when the environment is resilient up to a certain level and then rapidly degraded. Induced and indirect impacts occur where one development project stimulates secondary developments and infrastructure. Time- and space-crowded effects occur when the environment does not have the time and space to recover from one impact before subjected to another.

Indicators for performance evaluation do not attempt to ascertain effects but rather are useful in comparing the potential environmental risk of activities. Tracking environmental performance of specific facilities over time provides a means to ascertain whether potential environmental risks posed by that facility's operations are increasing or decreasing; that is, as a measure of changes in environmental efficiency. Frequently, performance indicators can be used in association with absolute measures to provide an assessment of environmental impact. For example, the most recent edition of the *State of Kentucky's Environment* (Cole, Richards, and Siegel 1999) notes that there has been an overall decline in Kentucky in the average air concentration of sulfur dioxide, a pollutant harmful to human health and other biological systems. The report also notes that industrial emissions of sulfur dioxide have significantly declined since 1980. Thus there is a link between performance evaluation and impact assessment. It is not a direct one-to-one linkage, for there are other sources of contaminants beside industry, but comparison of total annual rates of release of industrial chemicals to ambient air quality implies correspondence.

Environmental impact assessment can be a long and tedious process involving years of monitoring to establish baseline conditions; the larger and more complex is the area of study, the more difficult becomes the task of linking cause to effect. Assessing the environmental impact of Japanese industrial firms in Kentucky, in absolute terms, would be an enormous challenge requiring analysis of many sorts of data. The most troublesome aspect of such an undertaking is the inherent difficulty in isolating effects resulting from Japanese facilities from those produced by the numerous other forms of economic activity in the state. The solution proposed in this study is to use environmental efficiency in terms of waste generation and management as a surrogate for environmental impact. Waste from industrial processes is related to environmental degradation, in that it represents poor resource utilization and places stresses on the assimilative capacity of the local ecosystem. Because waste products also reflect inefficiencies in industrial processes, environmental efficiency is, to a certain extent, a mirror of economic efficiency.

Assessing Environmental Performance of Japanese Facilities in Kentucky

Two data sources provide the primary information used for performance evaluation in this study: state and federal (under the provisions of RCRA) hazardous waste reporting systems and the federal TRI established by EPCRA.[1] Each of these programs requires facilities to report on materials that are potentially harmful to human health and the environment, and each of these programs was established prior to the Japanese presence in Kentucky. Although there is overlap, the programs differ in the classes of materials with which they are concerned.

TRI reporting is more selective than RCRA, in that TRI is concerned with the management of "toxic" substances at industrial facilities[2] whereas RCRA regulates "hazardous" substances that encompass a broader range of materials and include numerous nonindustrial generators. Substances are regulated under RCRA's more inclusive criteria if they exhibit certain characteristics of toxicity or ignitability, corrosivity, or reactivity (EPA 1997). The legislation regulates and manages hazardous wastes from generation to disposal, taking a "cradle-to-grave" approach "intended to protect human health and the environment through proper management practices, to encourage conservation and recovery of valuable resources, and to alleviate the need for future corrective action cleanups. In contrast to the Superfund[3] program, which is designed primarily to clean up contamination from past waste disposal, RCRA is largely prospective in approach" (Openchowski 1990).

There are, however, certain inherent difficulties in the use of data from these sources. Associated problems arise from overlapping causes that may be categorized as data inconsistencies and compilation delays. Data inconsistencies arise from changes in program requirements and definitions and from incorrect reporting of information by facilities. In the first case, federal and state programs are subject to constant modifications by both legislatures and regulatory authorities. Both RCRA and the TRI have been substantially revised on several occasions. This results in data sets that vary over time as to the number of chemical substances included, the reporting requirements for facilities, and the way in which information is organized. Furthermore, the information reported by facilities is not always accurate, sometimes intentionally but more frequently inadvertently, so that figures may be subject to retrospective adjustment. The net effect is to produce substantial delays in report compilation, so that the most accurate data is usually several years old. For these reasons, 1996 has been chosen as the base year for comparison of facility environmental performance, since data collected for more recent years is generally not yet in usable form.

During 1996 there were ninety-one Japanese-owned industrial facilities operating in Kentucky, representing 1.6 percent of the manufacturers in the state (Manufacturers News 1997). In that year, twenty-five of the Japanese firms were classed as large generators of hazardous waste and regulated under RCRA, and thirty-one firms produced sufficient toxic chemicals to qualify for regulation under TRI. These two overlapping segments of Japanese industry comprise the study group for which environmental performance is evaluated.

RCRA Hazardous Waste

The RCRA program in Kentucky is managed by the state Division of Waste Management under federal mandate. Federal and state hazardous waste laws focus on the regulation and management of RCRA hazardous waste produced by large-quantity generators (LQG) regardless of facility type. LQGs are defined as producing more than 2,200 pounds (1,000 kilos) of hazardous waste per month. Less closely regulated, small quantity generators (SQG, 10–100 kg) and conditionally exempt generators (1–10 kg) report on hazardous waste in less detail than LQG facilities.

Through 1990 all facility hazardous waste generation was classed as a single entity. Beginning in 1991, the U.S. Environmental Protection Agency divided this waste into two categories, managed waste and exempt waste. Exempt hazardous waste, more than 90 percent of the total, is primarily corrosive wastewater that is relatively easy to treat and is exempt from most hazardous waste requirements (Cole, Richards, and Siegel 1999). In addition, cleanup or remediation of existing contamination sites can result in large quantities of managed waste attributed to a corporation that is unrelated to the current-year hazardous waste generation for the facility. Because of this restructuring of waste classification, only the data for the period 1991–1996, excluding remediation waste, are used in this paper to analyze waste quantity trends.

The total number of LQG firms in the state increased steadily from 260 in 1981 to a peak of 482 in 1992, since declining to 409 by 1996. In any given year, about one-fourth of LQG are nonindustrial and often transient on the list, consisting of facilities such as gasoline service stations, hospitals, oil and gas pipelines, and universities that occasionally produce moderate amounts of hazardous waste, in addition to some relatively large generators such as military bases. These nonindustrial sites represent, in most years, less than 5 percent of all large-quantity hazardous waste generation. The number of industrial plants generating hazardous waste remained fairly constant during the period 1991–1996, averaging about 300 facilities. In 1996 industrial LQG constituted about 5 percent of nearly 6,000 manufacturing firms operating in Kentucky. Twenty-five Japanese firms were classed as LQG in 1996, about 8 percent of the 309 LQG in that year. Since the 91 Japanese firms then extant constituted only about 1.6 percent of all Kentucky manufacturers, a fivefold greater proportion of Japanese firms were producing hazardous waste than in the general population of industrial companies. The number of firms generating hazardous waste is not in itself necessarily significant, however; of greater import is the proportion of total waste and the manner in which it is managed.

In 1996 Kentucky industrial firms produced 405,867 tons of managed hazardous waste and nearly 17.4 million tons of exempt waste. Of these state totals, Japanese firms generated 9,203 and 86,030 tons respectively in the two categories. The Japanese contribution represents 2.2 percent of all managed waste and roughly corresponds to the proportion of Japanese facilities in the general industrial population. Historically, the trend line for the Japanese contribution as a percentage of total industrial LQG waste is nearly flat, showing neither significant increases nor decreases since 1991 despite consid-

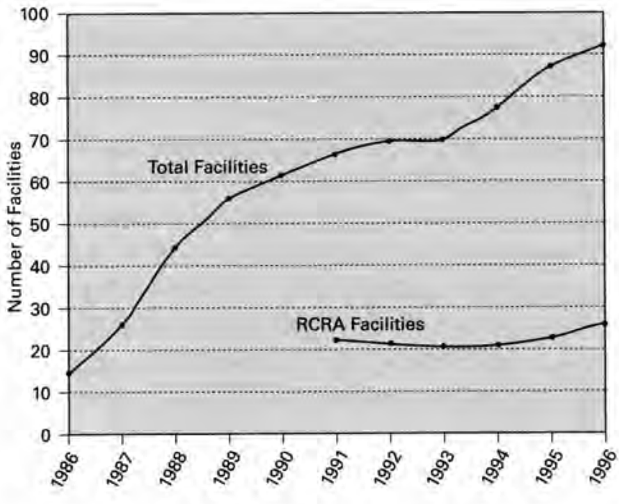


Fig. 10.1. Rate of increase of Japanese RCRA, 1986–1996.

erable increase in both the number and capacity of Japanese plants (figs. 10.1 and 10.2). During the same period, the actual amount of managed waste generated by Japanese firms has increased about 50 percent from 5,830 tons to 9,203 in 1996. This is attributable to growth rather than a decreasing effectiveness in environmental protection.

Another form of analysis may be conducted by "normalizing" the data through removal of extreme cases. About 80 percent of Kentucky's managed waste is generated by only ten firms, none of which are Japanese. Similarly, about 40 percent of the waste generated by Japanese firms in Kentucky is produced by a single facility, Toyota Motor Manufacturing in Georgetown. Discounting the waste production of these top generators allows comparisons that are more representative of general industry. When managed hazardous waste generation by the top ten firms is excluded, waste generation by Japanese firms excluding Toyota is about 6 percent of the total.

The somewhat larger size of Japanese facilities is likely of significance in accounting for the greater proportion of hazardous waste generated by Japanese firms. Excluding firms having more than 3,000 employees, Japanese LQG industrial plants average 450 workers per facility compared to 275 workers per non-Japanese LQG facility. Including the larger plants, in 1996 the 25 Japanese facilities employed a total of 17,400 workers, whereas the 225 non-Japanese facilities, for which information was available, employed a total of 84,000 persons (Manufacturers News 1997). Using 1996 hazardous waste figures, the amount of managed RCRA waste generated per job was substantially less at Japanese facilities than at non-Japanese, 1,060 pounds per worker

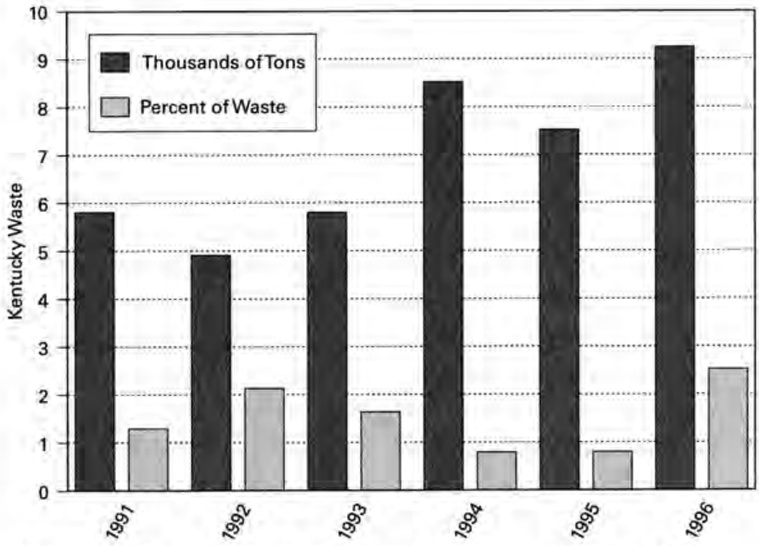


Fig. 10.2. Japanese share of Kentucky's hazardous waste, 1991–1996.

compared to 9,040. Even if the top ten non-Japanese generators are excluded from the calculation, the waste produced per job is still greater for the non-Japanese plants at more than 1,500 pounds per worker. This data appears to indicate a greater efficiency at Japanese plants in terms of waste reduction at the source.

Assessing exempt waste is more problematic because of some serious reporting problems that have recently become evident. The exempt class of hazardous waste, consisting primarily of corrosive wastewater, averaged 4 million to 6 million tons annually between 1991 and 1995. A drastic jump occurred in 1996, to more than 17 million tons. This was not a result of increased waste production but rather from the failure of two of the largest Kentucky generators, Ashland and DuPont, to properly report on this class of hazardous waste in prior years (Cole, Richards, and Siegel 1999), a situation that was corrected in 1996. This implies that the figures for the period 1991–1995 may be substantially underreported by as much as threefold. For this reason analysis of trends in exempt waste must be considered unreliable.

Relatively few of the Japanese facilities produce wastewater as part of the production process. Only five Japanese firms reported exempt class hazardous waste generation in 1996, totaling 86,030 tons or only 0.5 percent of the 1996 Kentucky total. The corrosive wastewater that constitutes most of the exempt hazardous waste is treated and discharged through state water permits to surface waters or to publicly owned wastewater treatment plants.

Toxic Materials

The TRI provides statistical data that may be used to assess the generation of hazardous materials specifically in the manufacturing sector. TRI was established in 1988 as part of the federal Emergency Planning and Community Right-to-Know Act of 1986. The detailed statistics collected under TRI reporting requirements provide a means to assess not only total production toxic waste but also the various ways in which toxics are managed. Generation and management figures, however, are reported by the individual firms and in some cases are best estimates since actual monitoring is not mandated. Furthermore, it is difficult to use the data to indicate trends because the list of regulated substances is constantly evolving. In 1987 there were 300 substances on the TRI list; the number was nearly doubled by the addition of 282 chemicals and chemical categories in 1994. For this reason it is better to consider relative percentages rather than actual volumes of toxics generated.

Companies must report releases and transfers if the facility has the equivalent of ten or more full-time employees and meets established thresholds for manufacturing, processing, or otherwise using listed chemicals. From the program's 1987 implementation through 1990, manufacturers reported annually on the type and amount of chemicals released to the local environment and how much was transferred off the property for treatment or disposal. During 1996, 429 regulated facilities, out of a total production waste of 577 million pounds, released more than 40 million pounds of toxics to the air, water, and land of the commonwealth of Kentucky. Thus a mean 92 percent of production toxics was treated or recycled on or off site and 8 percent was released. During the same year, nearly 76 million pounds were transferred off site for treatment or disposal. Beginning in 1991 facilities also reported on the details of how waste was handled, whether it was treated or recycled on or off site or burned for energy recovery.

About 10 percent of all Kentucky manufacturers produce toxic materials in reportable quantities, compared to one-third of Japanese-owned facilities. Thirty-one of the ninety-one Japanese firms were regulated under TRI in 1996, reporting on just over 11,000 tons of listed TRI chemicals. These facilities represent about 7 percent of the TRI facilities and 3.5 percent of all toxics. Since the percentage of TRI facilities is nearly five times greater than the 1.6 percent Japanese representation in the industrial community yet the proportion of waste generated is equivalent to only twice the overall Japanese component, individual Japanese TRI firms must be producing less toxics than the average manufacturer. This indicates a greater efficiency in source reduction.

The relative size of Toyota's contribution tends to distort the picture. Toyota is among the top ten in the state in the quantity of releases; 1,141 tons of toxics released primarily into the atmosphere is nearly 60 percent of the total for all Japanese TRI. If Toyota is included, the average Japanese release rate of 17.5 percent is significantly higher than the 7 percent average for all. If Toyota is excluded, other Japanese facilities have an average release rate of 10 percent, more nearly par with other industrial facilities in the state.

EPA Priority Toxics

The 33/50 program, established by the EPA in 1991, was named for goals of 33 percent reduction by 1992 and 50 percent reduction by 1995, using base year 1988. Seventeen chemicals were selected from the TRI list as priority chemicals based on relative toxicity, volumes of use, and potential for pollution prevention opportunities. Among the substances Japanese firms have released as wastes into the environment are thirteen of the seventeen on the EPA priority list. These substances are: 1,1,1-trichloroethane, benzene, cadmium and cadmium compounds, chromium, cyanide compounds including hydrogen cyanide, dichloromethane, lead and lead compounds, methyl ethyl ketone, methyl isobutyl ketone, nickel and nickel compounds, toluene, trichloroethylene, and xylene (table 10.1).

Eleven Japanese facilities in Kentucky reported releases of priority toxics in 1996 compared to nine in 1991, despite a 50 percent increase in the number of Japanese firms during the same period. No cadmium has been reported released to the environment from Japanese TRI facilities since 1989, and no dichloroethane since 1990. For each of six of the priority chemicals, three or fewer facilities reported releases during 1996. The primary TRI chemicals released as waste, in descending rank, are xylenes, toluene, lead, nickel, and chromium. Quantities of xylenes and toluene released have doubled since 1991 and now account for 60 percent of all the priority toxics released by Japanese facilities (fig. 10.3).

Comparisons across time can be made for the priority chemicals because all thirteen have been included on the overall TRI list since 1987. Releases of these thirteen chemicals by all Kentucky TRI facilities have shown a steady decrease since 1988, amounting to 30 percent for the period 1991–1996 (fig. 10.4). During the same period, 1991–1996, total releases by Japanese facilities have increased by 30 percent and increased their share of total Kentucky releases from 6.8 percent to 14 percent (fig. 10.5).

The increases in both the quantity and relative proportion of releases of priority toxics from Japanese facilities are primarily attributable to the Toyota facility. Toyota's share of the Japanese priority chemical releases increased from 41 percent in 1991 to 68 percent in 1996, reflecting a doubling of plant capacity in 1994. If Toyota is excluded from consideration, releases from Japanese facilities have remained approximately 4.5 percent of the statewide total for priority toxics since 1991 and thus have not increased their environmental impact despite plant expansions.

Table 10.1. Characteristics of the thirteen EPA priority chemicals released by Japanese facilities in Kentucky.

Substance	No. of Japanese TRI facilities	Usage	Health effects
1,1,1-trichloroethane	1	Many uses as solvent and cleaner.	Exposure to high levels may cause death from depression of central nervous system. Dermal and mucosal irritant at lower exposures.
benzene	2	Used in the manufacture of many products and to make intermediate chemicals. A component of gasoline.	A known carcinogen. Chronic low-level exposure may result in damage to internal orgams; exposure to high concentrations may cause death in minutes.
cadmium and compounds	0	Used for metal plating, in the manufacture of nickel-cadmium batteries, in pigments and plastic stabilizers, numerous other applications.	Probable carcinogen. Chronic low-level exposure may cause lung or kidney damage.
chromium and chromium compounds	4	Used in metal alloys, in plaating, in the manufacture of various compounds, and in many other applications.	A known carcinogen. Has a wide range of possible healrth effects, from minor to severe, depending on compound form.
cyanide compounds	3	Used primarily in electroplating, metallurgy, and production of organic chemicals, the making of plastics, and other applications.	Acute and deadly poisons.
dichloromethane	0	Used in metal cleaning and as solvent in the production of other organic chemicals. Also used as a degreaser and in the electroincs industry. Used in a wide range of consumer products.	Known carcinogen. Exposure has irritant dermal and mucosal effects and may cause central nervous system depression.
lead and compounds	5	Used in production of batteries and certain other items and in metal products such as solder and pipes.	Probable carcinogen. High exposure levels may cause brain and kidney damage. Accumulates in tissures; chronic exposure may cause death or damage to internal organs. Exposure impairs development in children.

(continued)

Table 10.1. Characteristics of the thirteen EPA priority chemicals released by Japanese facilities in Kentucky. (continued)

Substance	No. of Japanese TRI facilities	Usage	Health effects
methyl ethyl ketone	3	Used as solvent, catalyst,a nd in the manufacture of several derived chemical substances, including paint removers, cleaning fluids, and adhesives.	Irritant, wide range of possible health effects, including dizziness, dermatitis, and vomiting. Chronic exposure may cause central nervous system depression.
methyl isobutyl ketone	1	Used primarily as additive to protective surface coatings, also in the manufacture of adhesives, ink, and certain oils. Numerous other uses.	Exposure has irritant dermal and musosal effects and may cause central nervous system depression.
nickel and compounds	4	Used to make steels and alloys, permanent magnet materials, nickel-cadmium batteries, and in electroplating and ceramics.	Several compound forms are probable carcinogens. Chronic low-level exposure produces dermatitis and mucosal damage.
toluene	5	Primarily used as a component of gasoline; also as a solvent in paints, inks, adhesives, and cleaning agents and in manufacture of organic chemicals.	Primary health effect is dysfunction of central nervous system through inhalation. May produce birth defects.
trichloroethylene	2	Used primarily as solvent and cleaner, particularly in automotive and metals industries.	Known carcinogen. Possible death from exposure at high levels and damage to internal organs from chronic exposure.
xylenes	6	Used as solvent, and in gasoline manufacture, raw material for productino of certain organic chemicals, dyes, and insecticides.	Flammable. Exposure to high levels may cause dizziness, passing out, and death. Chronic exposure may damage bone marrow or developing fetus.

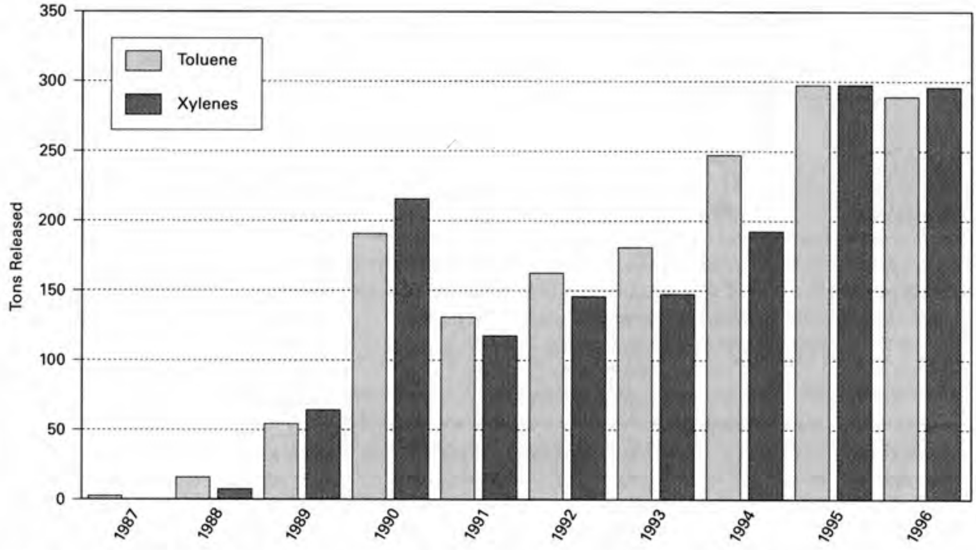


Fig. 10.3. Release of toluene and xylenes by Japanese facilities, 1987–1996.

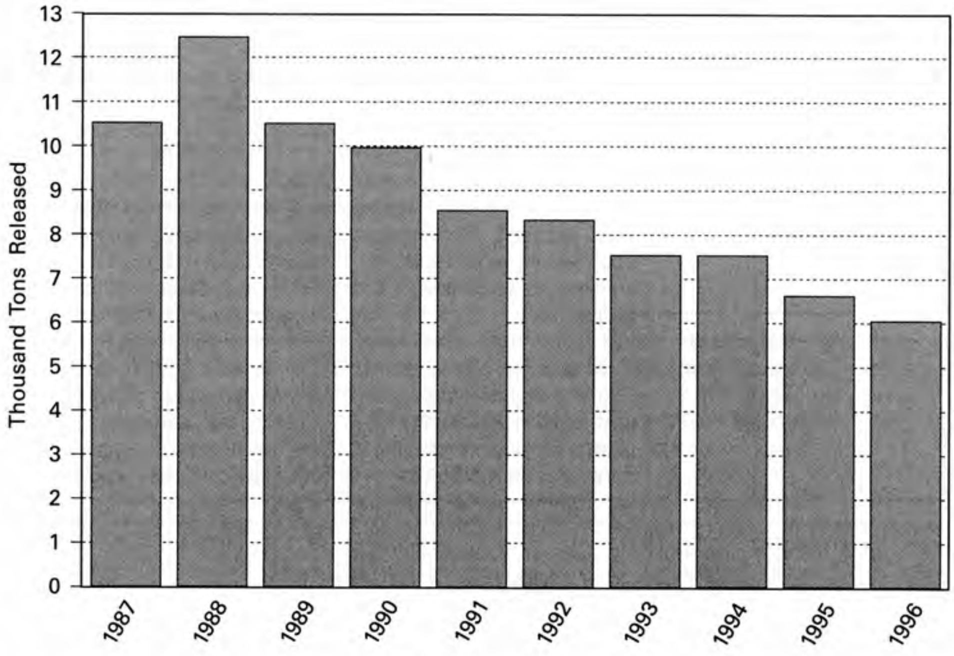
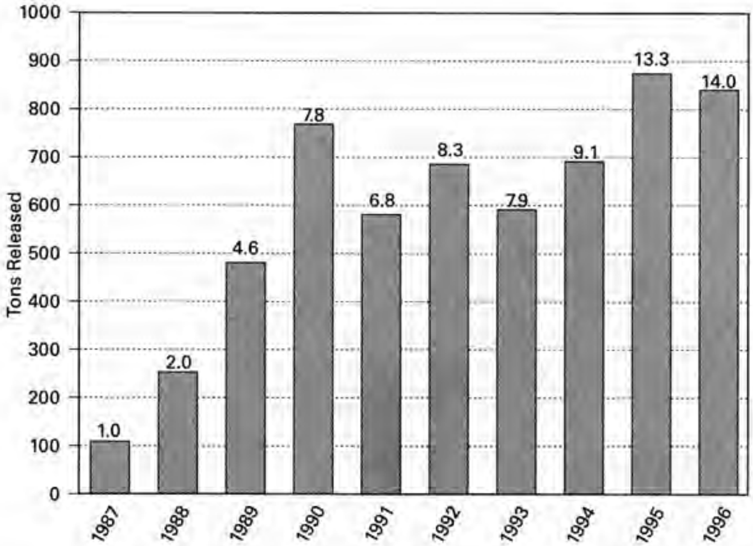


Fig. 10.4. Amount of thirteen priority toxics released by all Kentucky facilities, 1987–1996.



Note: Number at top of bar represents percentage of all KY priority taxes.

Fig. 10.5. Amount of thirteen priority toxics released by Japanese facilities, 1987–1996

Waste Management

While the amount of production waste generated may be considered a measure of the efficiency of resource usage, the quantity in itself is not necessarily harmful to the environment. Not until that waste interacts with the environment, on or off-site, can there be environmental consequences. Thus the waste management policies and practices of a facility do more to determine its actual environmental efficiency than do generation figures. Environmental impact is reduced if practices such as recycling are implemented wherever feasible, following the Japanese model of "continuous improvement," to reduce the amount that is released to the environment or disposed of in landfills.

The role of TRI in identifying the waste management activities of industrial facilities was expanded following the passage of the 1990 Pollution Prevention Act (PPA). Since 1991, TRI companies have been required to report waste management practices in some detail, indicating the quantities of toxics that are recycled or treated on- or off-site or burned for energy recovery, in comparison to that released or disposed of off-site. Source reduction was established as national policy by the PPA as the preferred approach to managing waste. Source reduction is defined by the Act as "any practice that reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) and, reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or

At the Matsushita Electric Motor Corporation of America plant in Berea, Kentucky, waste products are separated and shipped for recycling. The company is dedicated to proactive environmental protection, prevention of pollution, and continual improvement of environmental programs. (Photograph by P.P. Karan)

contaminants." Practices can include equipment, process, procedure, or technology modifications; reformulation or redesign of products; substitution of raw materials; and improvements in maintenance and inventory controls. Facilities must report any source reduction activities.

Source reduction is considered the most desirable form of waste management, followed in ranked order by recycling, energy recovery, treatment, and as a last, undesirable alternative, disposal. Release to the environment is not considered to be a form of management. "Environmentally sound" recycling, according to the EPA (1997), shares many of the advantages of source reduction: "Like source reduction, recycling reduces the need for treatment or disposal of waste and helps conserve energy and natural resources." On-site recycling is recovery of the toxic chemical for further use. Off-site recycling is transfer of the material to a facility beyond the plant boundaries for recovery or recycling. The same on-site/off-site distinction exists for treatment and energy recovery operations. "Treatment" is the destruction of the toxic material in waste treatment operations. "Energy recovery" is limited to just that, concerned with materials that are combustible and release energy, not those that require energy to be incinerated.

About 80 percent of TRI chemicals produced in 1996 at all Kentucky facilities were managed on site (fig. 10.6) through recycling (46 percent), treatment (21 percent), or burning for energy recovery (12 percent). Of toxics

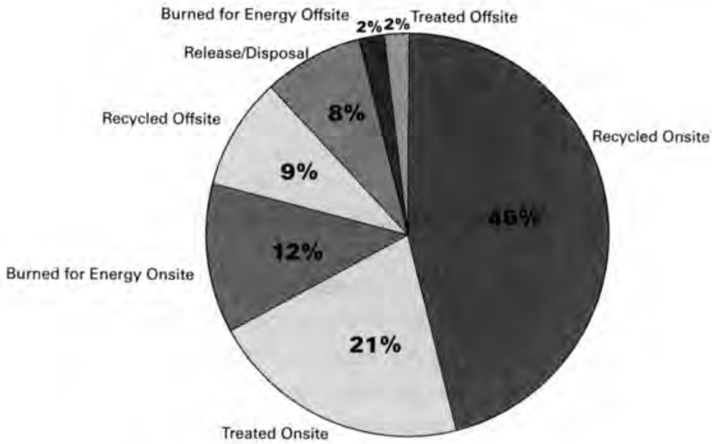


Fig. 10.6. Management of toxic chemical waste in 1996 by all Kentucky TRI.

sent off site, most were handled through recycling. In contrast, Japanese firms depended more on off-site waste management. Toyota sent a little over half of its toxics to off-site facilities for management, most of which was recycled. The average rate of off-site management for all other Japanese plants was one-third of total waste, again mainly handled through recycling. Examination of trend figures for 1991–1996 indicates that there has been very little change in the manner in which waste has been handled by most Japanese facilities (fig. 10.7). The proportions among management categories and whether conducted on or off site has remained relatively stable during the period, although the treatment option did show a slight decrease.

Seventy-six companies with facilities in Kentucky participated in the

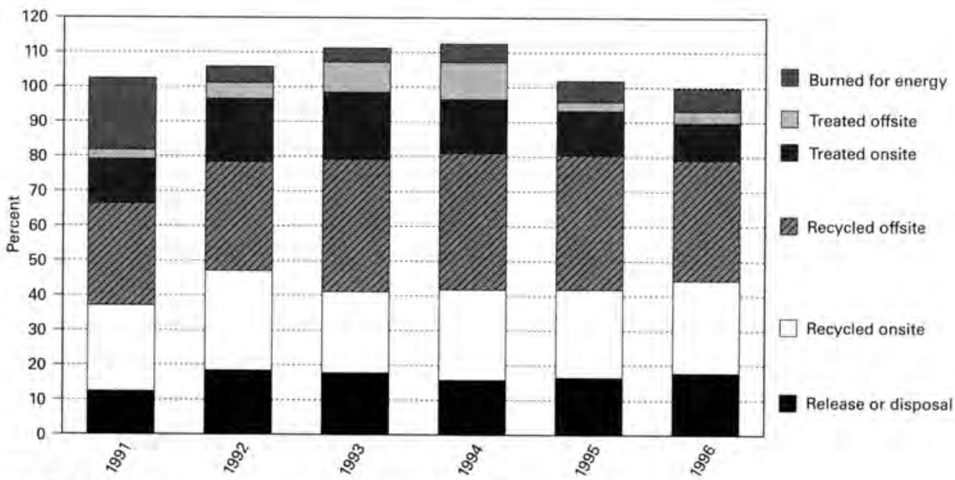


Fig. 10.7. Toxic waste management by Japanese facilities.

33/50 program. The 33 percent reduction goal was met in 1992, but only twenty-four of the companies were able to meet the 50 percent goal by 1995. Among the few companies who achieved the 50 percent reduction goal was A T R Wire and Cable, a Japanese firm.

Case Studies: Environmental Policies and Practices

Five Japanese manufacturing plants, representing a diversity of industrial types and facility sizes, were selected to provide case studies of current environmental policies, practices, and performance. The accounts are based on plant visitations, interviews with environmental staff, company brochures, and data from RCRA and TRI. The facilities investigated were Toyota Motor Manufacturing, Kentucky, at Georgetown, flagship of Japanese enterprise in Kentucky; KI (USA) at Berea; Zeon Chemicals LP at Louisville; Universal Fasteners at Lawrenceburg; and Hitachi Automotive Products (USA) at Harrodsburg. Figure 10.8 shows the location of these facilities.

Although specific problems vary from facility to facility since different industries have different technologies and generate waste in different ways, the firms are linked by common themes and concerns. Among these are the need to meet regulatory standards and reporting requirements and to maximize production efficiency through waste reduction. Toyota, the largest firm with more than 7,800 employees, manufactures and assembles automobiles. Hitachi, with 950 workers, makes electronic controls for vehicle systems. The 312 KI employees produce metal stampings of certain parts for the automotive industry. Zeon, with 290 workers, makes more than one hundred varieties of synthetic rubber, and about half of the company's production ends up in automotive applications. Only Universal Fasteners has no connection, direct or indirect, with the auto industry, since the buttons and snaps made by the facility's 298 workers supply apparel manufacturers.

Four of the five firms, excepting only KI, are classed as LQGs of hazardous waste. All the firms reported release of TRI toxic chemicals during 1991, but only Toyota and Universal Fasteners indicated release of priority toxics.

Toyota Motor Manufacturing, Kentucky (TMMK), Georgetown

Toyota Motor Manufacturing, Kentucky, is by far the largest Japanese facility in Kentucky and certainly one of the major industrial concerns of the state by any measure. The plant, an integrated facility for assembly of three vehicle models, is located on a 1,300-acre tract just north of Georgetown. Ninety percent of the 8,000,000 square feet under roof is production area. Most of the necessary parts are manufactured on site; only a few are brought in from

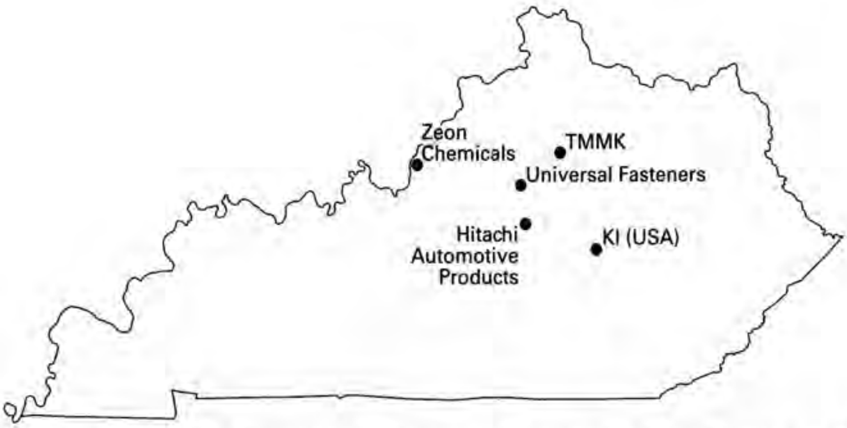


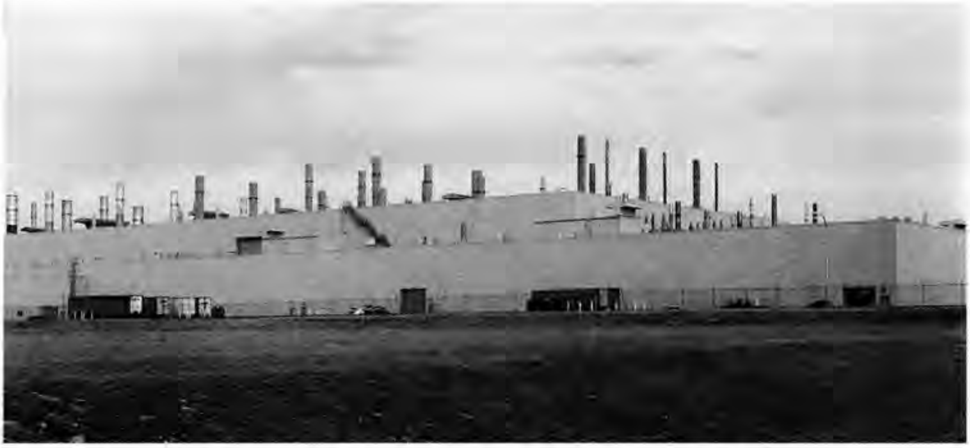
Fig. 10.8. Location of five Japanese Companies selected for case studies of environmental policies and practices.

outside suppliers. The original plant, which began production in 1988, promised to employ three thousand people to assemble two hundred cars annually. After two major expansions, the most recent in 1994, the facility now employs more than seventy-eight hundred workers who turn out nearly a half-million automobiles each year.

Toyota is in the process of obtaining International Standards Organization (ISO) 14001 certification for all of its manufacturing facilities worldwide (Chappell 1998a), and the Georgetown plant is so certified by third-party audit. Staff responsible for primary policy decisions are located at the headquarters in Erlanger, Kentucky, and coordinate among plants in North America. The fourteen-member environmental team at Georgetown is solely concerned with the local operation.

Each of seven specialists on the environmental team has primary responsibility for a certain geographic area of the plant and a specialty focus in a particular program such as water, air, or waste. The specialist in "air" coordinates on matters of that nature with all the geographic area specialists, so that there is a central point of responsibility and a consistency of implementation. On the production floor, each work team has a team leader, who serves to bring ideas and suggestions from the workers. There also are extensively used suggestion boxes, receiving more than eighty thousand submissions each year. Employees receive financial bonuses for ideas that result in savings. Many of the suggestions that come by these routes are concerned with improving the plant's environmental performance.

Each proposed process modification is evaluated for potential environmental impact. Waste management, termed Internal Resource Management, is the primary focus of environmental policy. The environmental team writes a process description and calculates the materials balance, raw materials in



Toyota Motor Manufacturing, Kentucky. Air emissions are the Toyota plant's most serious environmental management problem. Toyota had the best available pollution control technology at the time of its construction in 1987 but has twice the emissions rate of an equal-sized 1994 expansion that incorporated newer technology. Air stack clusters are associated with paint operations for auto bodies and plastic bumpers. (Photograph by P.P. Karan)

versus waste out. The team's operating philosophy is that material that does not become part of the car is a wasted resource. The evaluations are sent back to the shops for ideas and input from the workers. This ensures that more people become involved, that perspectives and ideas derive from more than just the environmental team. To provide incentive, a scoring system was developed to calculate points gained in waste reduction in every aspect of a suggestion, by which means financial rewards to the innovator could be fairly determined. Initially this feedback system was primarily concerned with reducing usage of raw materials, but recently pollution prevention has been added to the evaluation.

The rapid growth of the plant, which doubled in size in 1994, has brought with it some environmental problems. Potential environmental impacts were addressed in the initial design of the plant, and have been dealt with on a continuing basis since production began. Now that the expansion phase at Georgetown has ended, they plan to "take a hard look" at some ways to improve their environmental efficiency. The role of the plant as one of the largest emitters of airborne pollutants in the commonwealth is not an image that the company desires.

The Toyota plant is classed as a LQG of hazardous waste and has increased its generation by nearly 50 percent from the 2,667 tons produced in 1991 to 3,648 tons. Prior to the 1994 expansion that doubled production capacity, hazardous waste generation was stable at about 2,500 tons annually from 1991 through 1994. After the expansion, waste production appears stabilized in the vicinity of 3,500 tons. Production waste in TRI chemicals reported by Toyota for 1996 was 3,440 tons, of which 1,141—one-third—were released into the environment. An additional 11 tons required disposal. Most of the waste was managed by off-site recycling although a substantial portion of the remainder was burned for energy recovery. Releases of priority chemicals during 1996 amounted to half of all TRI releases at the facility, 574 tons of eight different chemicals. More than 90 percent of this was in the form of methyl isobutyl ketone, toluene, and xylenes.

When the plant size was doubled in 1994, next-generation environmental controls were installed, resulting in greater environmental efficiency for the newer facility reflected in the fact that both the quantity of TRI releases and the hazardous waste managed increased by only half. In other words, the newer facility produces half the quantity of toxic releases as the part built seven years before. An example of the difference is in the process modifications made from the older facility to the new. The best control technology available for paint booths in 1986 was installed when the plant was designed, but volatile organic compounds (VOCs) were a major problem. The best technology in 1994 did a better job of handling VOCs, and a materials change in certain production lines replaced solvent-borne paints with water-based coatings.

Paint is one of the most important areas that can be manipulated to reduce environmental impact; for example, air sprays can be replaced with electrostatic painting. This was taken one step further at Toyota when the company found an environmentally friendly solution for the ultimate fate of paint sludge recovered from wastewater. The sludge is shipped to a company in Ohio that processes it into a pulverized building material used by manufacturers to make decorative garden border bricks, roofing material, low-strength concrete, and road-building material (Chappell 1998b).

After pretreatment, about 1.2 million to 1.3 million gallons of wastewater per day are discharged to an adjacent city treatment plant, dedicated solely to serving Toyota, that the company helped build. In 1988, Toyota's wastewater failed an environmental monitoring test and low levels of toxicity—nickel and zinc—were found at the Georgetown treatment plant. Several modifications were made in Toyota's pretreatment system to reduce the metals content of wastewater sent along to the city treatment plant. Success in this endeavor is confirmed by TRI data, which show a trend of decreasing nickel releases.

Planning to improve the Toyota plant's future environmental performance is currently focused on reduction of air emissions, the company's largest vector for releases. Current investigation of materials substitutions may lead to significant source reduction, if solvent-based paints can all be replaced by water-borne or powder coats. One way in which Toyota measures its own environmental progress is through evaluating release of airborne toxics in terms of VOC emissions per car produced. In the past year, largely as a result of focusing on a specific issue—reclaiming solvent sullied by its use in purging or cleaning of paint guns—VOCs released per car dropped from 15.5 pounds per car manufactured to 14 pounds in six months. Additional incentive is provided by a specific regulation addressing automobile manufacturers expected in 2000.

KI (USA) Corporation, Berea

KI (USA) has three manufacturing facilities in Japan and a single international venture, the nearly 200,000-square-foot Berea plant that began production in 1989. The three hundred workers at the facility produce a variety of metal stampings and welded assemblies for the automotive industry. KI products including engine mounts and brake boosters are used by automobile manufacturers such as Toyota, Nissan, Honda, and Ford.

Until recently, environmental management issues at the plant were handled by a specific team, but all such matters are now included among the duties of the engineering manager. The company is dedicated to high standards of product quality, receiving ISO 9000 and QS 9002 certification in October 1997, but has chosen not to seek ISO 14001 certification.

TRI production-related waste from the Berea plant amounted to nearly 4 tons, of which 87 percent was treated on site or recycled off site; most of the remainder was disposed of off site. Less than 1 percent was released to the environment. None of the priority toxics have been released by KI during the period of TRI record-keeping.

About 1,000,000 gallons of wastewater, effluent from surface coating equipment, are annually processed at KI's own treatment center before being released to the Berea treatment facilities. During a recent twelve-month period, the company exceeded the standards for heavy metals in wastewater only once. KI is not classed as a LQG. Hazardous waste resulting from the production process includes a water-based paint containing lead, sulfuric acid used in cleaning, and a petroleum-based oil used in parts stamping. Paint waste is sent to a hazardous materials facility for disposal. Sulfuric acid is recycled or filtered. Most of the oil is constantly reused in the presses; the small amount that temporarily adheres to scrap metal is captured and stored, sent periodically to a recycler for use in making heating oil. Manufactured parts are initially placed in bins equipped with trays to collect oil drips. All nonhazardous materials are sent to local landfills rather than recycled. Cardboard, for example, cannot be recycled because it is frequently oil-saturated.

The facility constantly seeks, in the name of efficiency, to reduce the amount of energy and materials used and waste produced. Installation of metered equipment is currently replacing manual dispensal to reduce the quantity of chemicals used. A reverse-osmosis system was installed in the paint line in September 1998 for the same reason. Parts and supplies are both received and shipped in returnable containers.

Zeon Chemicals, Louisville

The corporate office for Zeon Chemicals LP, a subsidiary of Nippon Zeon Company of Tokyo, Japan, is located at the facility in Louisville. The parent company has four major plants in Japan and a European subsidiary. Additional U.S. plants are located in Texas and Mississippi, while the USA Sales and Product Services Office and a Research and Development/Technical Service Center are located adjacent to the Louisville plant. The 180,000-square-foot Zeon facility, acquired in 1989, employs 290 people to produce a variety of elastomers (synthetic rubber) using an emulsion polymerization process. Zeon's specialized rubber is used in the manufacture of automobile hoses, gaskets, and seals; in many oil field, aerospace, and industrial products; and in a variety of adhesives.

Zeon Chemicals has a full-time environmental team stationed at the Louisville headquarters. The team consists of a corporate environmental manager, whose duties embrace all Zeon's U.S. facilities, and a facility environmental health specialist. The company has ISO 9002 certification but has no immediate plans to seek ISO 14001 certification. Zeon is working with the Kentucky EMS (Environmental Management System) Implementation Alliance and the Kentucky Pollution Prevention Center at the University of Louisville to develop a revised internal EMS that is similar in many respects to the ISO 14001 standards. Because Zeon is part of a much larger industrial complex located in a densely urban region, known locally as "Rubbertown," linkages have been developed with the community to assure coordinated emergency planning and information sharing. A company publicity brochure notes: "We take pride in the fact that in every community in which we are located our own environmental standards place us well ahead of the various regulatory standards."

Zeon is classed as a LQG of hazardous waste, but has shown a steady decline in hazardous waste production during the period 1991–1996, from a peak of 16 tons annually in 1992 to about 3 tons in 1996. Under the TRI program, Zeon reported a total production waste of about 3,100 tons in 1996, of which more than 95 percent were managed without release to the environment. There have been no priority toxics recently released through the production process at Zeon; the use of methylene chloride and 1,1,1-trichloroethane as cleaners was eliminated a few years ago.

Zeon produces somewhat less than one million gallons of wastewater that is treated by a plant shared with three other facilities; Zeon's contribution is about one-third of the total flow through wastewater treatment. Two separate drainage systems serve the Zeon facility. One takes only storm water, and the other collects production wastewater throughout the plant. The storm water access manholes are painted bright yellow with stern warnings not to dump anything into the system. The separate wastewater collection system is continuously supervised through a network of automatic monitors. Hazardous waste is stored in a roofed area with a sump that drains to the wastewater system.

Aboveground bulk storage tanks, transformers, and other stationary objects subject to possible leaks are enclosed by two-tiered spill containment systems. At ground level is a concrete-walled basin with a liner beneath it. The liners vary in their composition according to the type of material stored. Certain air emissions receive treatment in the stacks, going through a catalytic oxidizer. Zeon recognizes both a problem and an opportunity to reduce releases in dealing with airborne styrene and acrilonitrile emissions. Recovery of these two materials is a difficult technological issue. Although a recent process modification attempting to recover a greater percentage was unsuccessful, the plant continues to explore other ways to handle the problem. Zeon's current five-year plan incorporates planning to reduce both hazardous waste and TRI substances.

Environmental management has improved since the facility was acquired by Zeon. Better plant housekeeping and the use of computer controlled flows reduces hazards both to workers and to the environment. Environmental management is enhanced by the company's long-term viewpoint and willingness to accept longer-term payback and benefits from environmental innovations.

Universal Fasteners, Lawrenceburg

Universal Fasteners is the U.S. subsidiary of the privately held Y K K Corporation. Y K K's home offices are in Tokyo, and the corporation conducts operations in more than forty countries. Originally established in 1895, Universal Fasteners was acquired by the Japanese corporation in 1987. The headquarters of its U.S. operation is at the plant in Lawrenceburg. Universal Fasteners has two additional manufacturing facilities in Tennessee and a warehouse location in El Paso, Texas. The Lawrenceburg plant comprises approximately 300,000 square feet in two buildings, of which 160,000 square feet are production space. The facility employs 298 people in production and administration and has a traveling sales force of about 50 people to market its line of buttons, snaps, rivets, and burrs for the apparel industry.

Environmental affairs for the entire U.S. operation are handled by a full-time environmental engineer stationed in Lawrenceburg. Green management principles are set out in the Y K K Environmental Charter of the parent company. The Action Guidelines of the charter promote "conducting business activities friendly to the environment" through technological development, energy efficiency, employee education, and internal review of activities. Universal Fasteners is certified under the ISO and QS quality standards and is pursuing ISO 14001 certification.

The plant recycles nonhazardous material wherever possible. Production of hazardous waste by Universal in 1996 was 57 tons of managed waste and 20,000 tons of wastewater pretreated and released to the local treatment system. Multiyear data indicate an overall trend of waste reduction, although significantly higher figures in certain years have resulted from the voluntary cleanup of contamination sites on the property that date from before the Japanese acquisition. For example, in 1997 more than 20,000 tons of managed hazardous waste resulted from the cleanup of one such site. Universal completed all site remediation during 1999.

According to TRI data, of 410 tons of production waste in 1996 entailing toxics, 1.5 tons, or less than .5 percent, were released to the environment. The primary methods for waste handling were treatment on site and off-site recycling. Priority toxics released by Universal during 1996 included cyanide compounds, methyl ethyl ketone, and xylenes. Priority toxics comprised 57 percent of the plant's TRI releases.

Universal Fasteners has two primary waste streams of hazardous material that result from the paint and lacquer and the electroplating operations. Some relatively simple changes made in the production process in recent years have greatly reduced the amount of waste generated. Paint and lacquer waste has been reduced from a dozen 55-gallon drums generated per month to about three drums monthly by the purchase of a solvent still that distills the solvent back out for reuse.

An even greater reduction was made by dividing a single waste stream into two. Formerly wastewater from the plating and burnishing operations was combined and all the sludge that was separated from this water was treated as hazardous waste. About 40 cubic yards of combined sludge was produced each month. When wastewater treatment was separated into two waste streams, only the sludge resulting from the plating operation qualified as hazardous material. The burnishing sludge was nonhazardous material and could be disposed of in a special waste landfill. Hazardous waste generation from wastewater treatment was reduced from about 40 cubic yards monthly to only about 4 yards per month of plating sludge. The resulting savings in transport and disposal costs allowed the investment to pay for itself in only two years.

Making changes in the production process to implement pollution prevention is not difficult when it can be shown to upper management that proposed changes will pay for themselves in a few years. Administrative staff at Lawrenceburg has authority to approve production modifications.

Hitachi Automotive Products (USA), Harrodsburg

The Hitachi plant in Harrodsburg has grown rapidly from its establishment in 1985 as a facility of only 40,000 square feet to the present structure covering 390,000 square feet and employing more than 650 workers. The plant manufactures a diverse range of automobile electronics including high-technology controls for air, fuel, ignition, and transmission systems. Hitachi products are used in vehicles manufactured by Honda, Ford, Nissan, Isuzu, Subaru, and Toyota. Hitachi facilities are located on every continent except South America and include four plants in the United States. The Harrodsburg plant is the headquarters for U.S. operations.

The Harrodsburg plant maintains a staff of six full-time employees in its Environmental Safety Group. Hitachi has been an industry leader in meeting ISO standards, obtaining ISO 9001 and QS 9000 certification in December 1995 and achieving ISO 14001 status in March 1998. Proposals for new techniques or chemicals to be used in production undergo an approval process to assure consistency with ISO standards. The facility undergoes an assessment every six months by a third-party registrar to assure compliance with the standards and with state and federal regulations.

Hitachi's efforts to improve its environmental performance, particularly in terms of waste generation and management, have been highly successful. Generation of managed hazardous waste was fairly constant during 1991–1996, fluctuating between 15 and 25 total annual tons. TRI records provide data that indicate a progressive reduction of toxics from 1991 to 1996; the 5 tons of toxics reported in 1991 is only 7 percent of the 72 tons generated in 1991. At the same time, releases to the environment were reduced from 90 percent of production waste to less than 1 percent. In terms of actual gain, the 62 pounds released in 1996 is only 0.05 percent of the quantity released in 1991. There have been no priority toxics reported for Hitachi during the period of record.

Near every work station are waste bins. All waste materials, hazardous and nonhazardous, are sorted according to composition. About 90 percent of the nearly 100,000 pounds of hazardous waste (mostly alcohol and lead) annually produced at the plant is recycled, primarily in fuels blending. In addition, each year nearly 2,000,000 pounds of other materials, such as cardboard and aluminum shavings and castings, are recycled. The recycling program earned $138,000 for the company last year. Surprisingly, these earnings are viewed as a failure rather than success, simply because material that needs to be recycled represents inefficiency and waste in the production process.

Hitachi Automotive Products (USA), Harrodsburg, Kentucky. The Hitachi staff continuously seek opportunities to reduce the operation's environmental impact through small, inexpensive process changes. The operation in which alternator windings receive a varnish coating provided an opportunity for hazardous waste reduction by switching from a solvent-based varnish to a water-based coating. Unlike the solvent-based coating, excess water-based varnish could be recycled back into the process. (Photograph courtesy of Hitachi Automotive Products)

The environmental team constantly seeks ways to reduce the environmental impact of Hitachi's operations. For example, alternator windings are coated with a varnish in one stage of the manufacturing process. The varnish cures on exposure to air, so that any excess material becomes quickly unusable. The team is investigating the use of a water-based varnish that requires heat curing, so that the excess can be reused. Another present concern is the necessity to dispose of small containers emptied of nonhazardous materials. The use of large (250-gallon) returnable containers is among alternatives being considered. Many parts obtained from suppliers are received in returnable cartons. In another example, plastic scrap from injection molding is returned to the production process and incorporated, up to 20 percent by weight, into new moldings. In 1995 the company abandoned the use of chlorofluorocarbons (ozone depleter) for cleaning circuit boards and switched to alcohol. One of the highest priorities for the team is to find a way to eliminate lead from the soldering process.

Upper management tends to be receptive to innovations that reduce the environmental impact of the plant when it can be demonstrated that these innovations improve efficiency. Since the reduction of waste in all aspects of manufacturing is a prime concern, such proposals generally receive favorable attention. The Harrodsburg Hitachi facility received the 1998 Kentucky Governor's Award for Environmental Excellence.

Environmental Performance Indicators for Industry

Many possible waste management criteria might be used to evaluate the environmental performance of individual industrial firms. Such criteria may represent simple accounting of total quantities of waste generated during the production process or the totals or percentages attributed to various postproduction methods for recovering or disposing of the wastes. More sophisticated approaches may compare multiple variables, such as waste generation per unit of production, per unit of company revenue, or per worker, in an attempt to define an indicator comparable across different facilities.

Any meaningful indicator of industrial environmental performance must take into account three distinct aspects of waste generation and management: magnitude, potential hazard, and efficiency. Magnitude is concerned with the total quantities of the residual substances involved; hazard refers to the risk posed by different substances to human and environmental health; and efficiency concerns the proportion of waste that is not reused or recovered but escapes the production cycle to interact freely with the environment. A further dimension of waste efficiency involves the hierarchy of waste management strategies, in that options such as source reduction or recycling are both more efficient and more ecologically desirable than treatment or disposal.

The interplay among these factors is critical to assessing environmental risk. For example, a firm that generates a large amount of waste might seem to be a greater environmental threat than a firm that generates a small amount. Waste does not, however, become an environmental hazard until it begins to interact with the environment. If the large-quantity waste producer has implemented strategies that recover nearly all the waste and the smaller producer has not, then the smaller producer may be releasing more waste material to the environment. Further, environmental risk is greatly dependent on the relative toxicity or other hazardous attributes of any materials that are not recovered. A small amount of a highly toxic substance is likely to pose a greater environmental risk than a larger amount of material of low hazard. Thus any single facet of industrial waste generation is wholly inadequate for assessing either environmental performance of the firm or the potential risk to the environment.

Table 10.2 illustrates the complexities inherent in environmental performance assessment. The table depicts several different ways of assessing performance, using either or both of the factors of magnitude and efficiency. The

Table 10.2. Environmental statistics for study group (1996 data)

Facility (# workers)	RCRA HazWaste Generation		TRI Toxic waste generation		TRI toxic waste releases		
	Total (tons)	Per jpb (lbs)	Total (tons)	Per jpb (lbs)	Total (Tons)	Per jpb (lbs)	% total waste
Toyota (6,600)	3,648.3	1,105.5	3,440.54	1,042.6	1,141.43	345.9	33.2
Hitachi (650)	16.5	50.8	5.05	15.5	0.03	0.09	0.6
KI (350)	n/a	n/a	3.94	22.5	0.04	0.23	1.0
Universal (250)	57.4	459.2	410.43	3,673.6	1.52	12.2	0.4
Zeon (165)	3.3	40	3,104.36	37,628.6	137.87	1,671.2	4.4

issue of hazard is partly addressed, in that the classes of materials represented by the RCRA and TRI programs are hazardous by definition, yet there is still considerable disparity among the different substances. Acknowledging, then, that any system that does not fully incorporate all three factors imperfectly represents environmental risk, the two factors of magnitude and efficiency appear suitable to assess environmental performance in terms of a facility's ability to reduce or eliminate waste residuals.

Data for the five case studies facilities are used to make comparisons of environmental performance (table 10.3). The table includes RCRA and TRI data, both evaluated on the basis of total waste generation, and, for TRI only, total releases.[4] Total waste generation, as noted, does not address either production efficiency or environmental risk. Environmental risks can only be assessed if waste generation is compared to waste management practices. Nor can examination of practices alone convey a sense of environmental risk. For example, the release rate for Toyota is 33.2 percent of production waste and for Zeon, 4.4 percent, but a simple percentage figure tells us nothing about the magnitude of the problem. Conversely, the total quantity of releases reveals little about the relative efficiency of the production system in terms of waste management. Clearly, neither comprises a meaningful evaluation when used without other contextual information.

To assess environmental performance, measures of magnitude and efficiency need to be combined in terms of some production ratio generalizable across industrial categories. Toyota's use of waste emissions-per-vehicle-built as an indicator of environmental progress might be applied to automobile

Table 10.3. Environmental performance rating of five Japanese facilities

Zeon	1,655.28
Toyota	345.28
Universal	13.2
KI (USA)	0.20
Hitachi	0.10

assembly plants but cannot be applied to the manufacturers of other products, including automobile parts suppliers, because the units are not comparable. Waste releases per assembled vehicle does not, by any means, correspond to waste releases per auto brake pad, garment zipper, or VCR manufactured. Another method might be to use waste generation per dollar revenue, but accurate information concerning corporate finances at the plant level is often difficult to obtain. This is particularly true for Japanese companies, most of which are privately held. One per-unit measure that may be applied using readily available information is the use of waste releases-per-worker. Whereas releases, when contextualized, are relative to efficiency, the number of workers roughly corresponds to the scale of the operation and is therefore relative to the magnitude of production. The combination of releases-per-worker thus has implications for environmental efficiency.

This is shown in table 10.2, in the column listing TRI toxic waste releases per job. For example, total toxic waste generation for the Georgetown Toyota plant in 1996 was equivalent to 1,042.6 pounds per worker for each of the factory's 6,600 workers. Since the calculated rate of releases for that year is equivalent to 33.2 percent of total waste generation, a rate of 345.9 pounds of waste releases per job can be derived. This provides a measure of environmental efficiency that takes into account both the magnitude of waste generated and of the proportion released and the effectiveness of waste management. Note that, according to this method, Toyota would be credited with a greater efficiency than Zeon even though the automobile maker had nearly eightfold greater releases both in total quantity and as a percentage of total generation. This is a consequence of Toyota's far lower rate of production waste per worker employed.

Although this method provides a measure of environmental efficiency, this should not be confused with environmental impact. The potential impact to the environment from Toyota's airborne emissions is greater than Zeon's simply because Toyota's contribution is much larger. Theoretically, if Zeon operated on the same scale as Toyota, the chemical company's impact on the environment would be greater than the automobile plant because although Zeon's percentage of releases is less, the releases per worker are five times larger. In reality, however, economies of scale would probably invalidate a direct projection of this sort.

The releases-per-worker method, while providing a means to estimate environmental efficiency, is subject to several qualifications. A primary weakness in this system is that it only applies to that select group of facilities who are regulated under RCRA and/or TRI. This group is, however, by definition most likely to have significant environmental impacts. The method does not reflect inherent differences in many classes of industry nor the varying hazard depending on the type of waste produced. Nor does it take account of resource depletion through overconsumption nor of the inefficiency implied by the existence of waste. A low rate, however, is a reflection of the collective environmental effectiveness of the plant's technology, policies, and practices. It means that waste is being managed effectively through various strategies so that there is minimal impact on the environment.

An environmental snapshot consisting of a single year's waste data says little about trends. A more significant evaluation requires the use of multiyear data. Despite the problems with federal waste data previously noted, particularly in regard to data inconsistencies from year to year, performance assessments may often be made over time. This may require examination of a single chemical substance or a group of chemicals that have been in consistent use throughout the period. The case of Hitachi demonstrates a distinct commitment by the firm to reduce or eliminate waste in the production process (fig. 10.9). In 1991 the Harrodsburg plant generated more than 72 tons of TRI toxic waste, of which more than 90 percent was released to the environment. Through process modifications and materials substitutions, by 1996 the company had steadily reduced its total waste production to no more than 5 tons, of which all but 1 percent was recycled. Using the releases-per-worker assessment, Hitachi has achieved a reduction from more than 200 pounds per worker in 1991 to less than one-tenth of a pound in 1996.

The value of environmental performance assessment lies in its ability to permit evaluation of the effectiveness of waste management practices for individual firms, to make comparisons among firms, and to track improvements in environmental efficiency over time.

Economic Efficiency as Environmental Efficiency

Observations from the case studies suggest explanation for the trends evident in the RCRA and TRI data. Waste management is an important concern for industrial firms; efforts are being made to reduce or eliminate residuals from manufacturing by implementing process changes, new technologies, and materials substitutions. Such innovations are not limited to Japanese-owned industrial firms, but Japanese companies appear to be more committed, or at

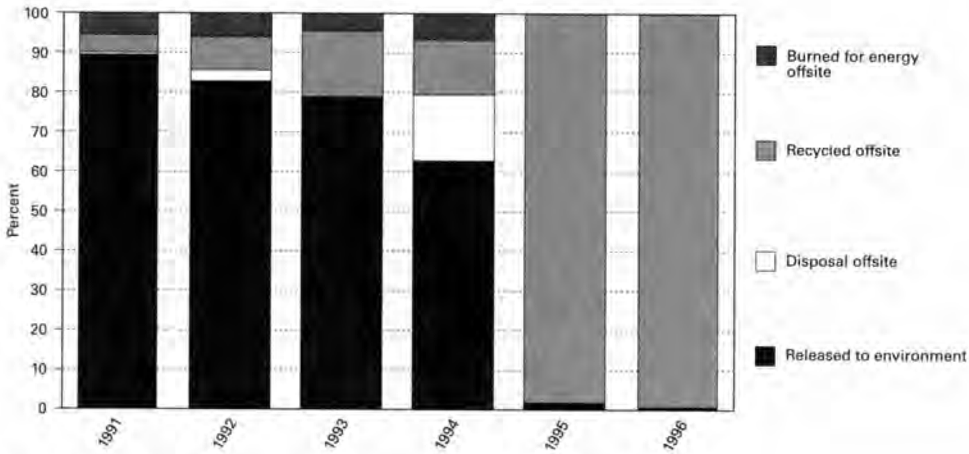


Fig. 10.9. Toxic waste management at Hitachi, 1991–1996.

least more successful, in waste reduction. This is reflected in data trends which indicate that (1) total hazardous waste produced by Japanese firms has remained a stable percentage of the total hazardous waste production for all RCRA firms in Kentucky despite a substantial increase in both number and capacity of Japanese plants, (2) the number of Japanese industrial plants producing toxic waste is proportionately five times greater than for the general industrial population, yet generates only twice as much of this waste category, and (3) releases to the environment of both RCRA and TRI chemicals, when compared on a per-worker basis, are significantly less for Japanese facilities than for those of other ownership.

The evaluations conducted in this essay suggest that improvements in environmental efficiency are carried out by Japanese industrial facilities as part of a process designed to increase their general efficiency and profitably. Every environmental staff member encountered emphasized the concept that economic efficiency and environmental efficiency are tightly linked aspects of industrial facility management. In the words of the environmental staff team leader at Toyota, "environmental protection almost always is the result of an efficiency gain."[5] Policies and practices that reduce waste increase the efficiency of the production process and benefit the environment. Environmental standards and regulations help drive the push toward efficiency.

Toyota's team leader further noted, "Our philosophy is to get as close as possible to the regulatory requirement and to do it better if it results in cost efficiency." This is an indicator of priorities among various incentives for facilities to seek greater environmental efficiency. Cost efficiency remains the primary impetus for facilities to consume fewer resources and produce less waste. This is not surprising, since this is the central premise that underlies a corporation's existence. Cost efficiency and environmental efficiency appear to be converging toward a common goal, that of minimal environmental impact by minimal waste production. Fueling this trend are environmental laws and regulations so numerous and complex that it is often more economical to implement ecologically sound source reduction and waste management practices than it is to cope with mountains of paperwork from myriad agencies and to wield squads of lawyers in litigation.

A further benefit of pollution prevention is that industries that are regulated tend to be classed by certain thresholds, and it benefits the corporate image to be placed in the lower ranks. No corporation wishes to be reviled in the media as a result of belonging to a class considered particularly harmful to the environment. Because of threshold classes such as those in RCRA where a jump in class results in tighter regulation and stricter reporting requirements, there is strong incentive driving facilities to reduce waste generation and thereby sink below the threshold to a less demanding regulatory level, such as from LQG to SQG. Facilities whose numbers are just above or just below a class threshold seek sanctuary by achieving and remaining within a lower ranking.

Evidence from RCRA and TRI data combined with observations and conversations during facility visits suggests a hierarchy of incentives for the improvement of environmental performance. Foremost is economic efficiency, followed by and driven in part by laws and regulations. Following this is corporate image, which affects not only its status in the community but the company's ability to market its products. Interwoven among these concepts are health and safety issues. A facility's workers are not only the plant's direct link to the external community; in many cases they are the community. Degradation of the local environment is likely to affect the health of the population and consequently productivity. For this reason many facilities believe that health and safety issues are of equal or greater import than environmental issues, and sometimes have a separate staff. Environmental issues and health and safety issues are so closely linked that respective staffs tend to work closely together.

Measures taken to improve environmental efficiency are part of an ongoing process in the facilities visited. In the case of Toyota and many other firms, this is part of the company's *kaizen,* or continuous improvement practice. From the examples in the case studies, it is evident that often simple and relatively inexpensive changes made in the production process can result in substantial reduction in the environmental impact of industrial operations. These changes may incorporate new technologies, for as Ayres and Ayres (1996, 24) have observed, ". . . it is not safe to assume (as macroeconomists tend to do) that every technology in place is the optimal choice, as if it had been the winner in a Darwinian competition against all possible candidates." Improvements in environmental efficiency resulting from small technological investments are usually within the means of even aging, less competitive facilities. New plants tend to incorporate newer, more efficient technologies on a larger scale: the dramatic improvement in waste reduction for Toyota's recent expansion is evidence of environmental improvement through newer, "best available" pollution control equipment. For many waste management problems, however, technological solutions have not yet been devised and so the lack of appropriate technology sometimes forms a presently insurmountable barrier to waste reduction. The case studies demonstrated that not all solutions need to be technological. Process modifications as simple as substituting one material for another or dividing a single waste stream into two have paid off both in environmental and economic efficiency.

A facility may be guilty, in both economic and ecological senses, of being inefficient and squandering natural resources by a production process that results in a great deal of wastage. When process modifications are implemented that result in reduced demand for resources and reduced waste production, a significant move has been made toward sustainable industrial production. If process waste is contained or is released to the environment in quantities no greater than the ability of an ecosystem to sustain itself in a healthy condition while absorbing and transforming the byproducts of civilization, then environmental degradation is not occurring. In this way two different but overlapping approaches to environmental assessment can be reconciled.

The economist pursues the goal of efficiency in all phases. This ideal meets the criteria for the ecosystem health paradigm as expressed in Haskell, Norton, and Constanza 1992: "An ecological system is healthy and free from distress syndrome (irreversible process of system breakdown leading to collapse) if it is stable and sustainable, that is maintains its organization and autonomy over time and is resilient to stress"; and in Karr 1992: "A biological system is healthy when its inherent potential is realized, its condition is stable, its capacity for self repair when perturbed is preserved, and minimal external support for management is needed." To both economist and ecologist, the ideal is for zero waste production, and failing that, zero releases to the environment. "Actively seeking zero wastes and pollutants," states Hirschhorn (1992) in an essay aimed at corporation executives, "is still the best path to economic success. This kind of zero-waste vision is key to the economic conversion of costs into profits."

Industrial firms may be proactive within their own terms, promoting environmental efficiency wherever a gain in economic efficiency can be demonstrated, or may be simply reactive, responding only to the extent required by government regulations and public opinion. The data analyzed and the case studies suggest that, while there is still considerable variation in the environmental efficiency among different plants and particularly for different industries, most facilities under Japanese ownership tend to be environmentally proactive insofar as it serves their own interests. The key, perhaps, resides in a greater appreciation by Japanese management that a sustainable environment does, indeed, often serve corporate interests.

Implications for an Industrial Ecology

Conventional industrial systems are primarily linear in nature. Raw materials and energy enter one part of the system and are transformed to products and waste residuals; some wastes are recycled or used within the system, and others are dissipated into the environment. Traditional approaches to managing pollution involve attempts to shift wastes from places where they are potentially harmful to places where this potential can be controlled, or to alter the wastes into forms less damaging to the environment. These end-of-the-pipe approaches do not usually reduce the actual volume of waste. The solution is to use materials more efficiently or to find ways to transform wastes so that they are no longer wastes but become useful economic commodities. The closer that industry comes to achieving these twin goals, the more it has maximized both economic and environmental efficiency.

The manner in which particular wastes are managed is a function of the relative costs of methods of waste management. Conventional economic theory defines a waste residual as a nonproduct that has a market value less than the costs of collecting, processing, and transporting it for use. According to Kneese and Bower (1979), "the definition is time dependent, that is, it is a function of (1) the level of technology in the society at a point in time and (2) the relative costs of alternative inputs at that point in time." As evident from the case studies, more efficient use of resources may involve application of technological innovations, process modifications, or product redesign, so that production wastes are reduced or eliminated. Transforming waste residuals into commodities is usually accomplished by recycling back into the production system on site or through off-site recycling by materials processors. It is again evident from the case studies that efforts to reduce waste are implemented when production costs can be reduced by so doing, or if pressure to reduce waste is externally imposed, as in the case of government regulations or a response to public opinion.

In 1998 the Toyota Motor Manufacturing plant in Georgetown adopted an innovative approach to transforming one class of production waste, paint sludge, into a commodity. Paint sludge is now shipped to an out-of-state facility that detoxifies the waste and turns it into a brick-like building material. As plant officials readily admit, this is not the most economically efficient solution to the problem of paint waste, since the handling costs for this strategy are greater than those that would be incurred by simply sending the material to a landfill (Chappell 1998b). This waste commodification represents, however, not only an astute public-relations exploit but also a substantive experiment in seeking both economic and environmental efficiency by further deviating from a traditional linear industrial system.

This precise sort of waste commodification along with efficient use of resources represent the central concepts in a multidisciplinary body of industrial theory that has become known as industrial ecology. The major focus of industrial ecology, according to Ayres and Ayres (1996), is "to identify opportunities for reducing wastes and pollution in the materials-intensive sectors by exploiting opportunities for using the low-value byproducts (i.e., wastes) of certain processes as raw materials for others." Industrial ecology is a biologic metaphor, reflecting on the similarities between industrial and natural systems. Both industrial and natural systems assimilate energy and materials or nutrients and produce waste. Whereas conventional industrial systems exploit materials and energy in linear fashion, natural systems, however, tend to recycle most essential nutrients and are driven by solar energy.

An industrial ecosystem is therefore conceptualized as a symbiotic relationship among a group of firms that closely emulates nature by utilizing the waste products of each component firm as raw material—food—for another. In such a cyclic system, there is no such thing as waste, in the sense of a material without value; all residues are absorbed within the industrial system and do not impact natural systems. The primary goal of industrial ecology, according to Garner and Keoleian (1995), is to promote sustainable development at the global, regional, and local levels through the sustainable use of renewable resources and minimal use of those that are nonrenewable. More precisely, "industrial ecology as applied in manufacturing involves the design of industrial processes and products from the dual perspectives of product competitiveness and environmental interactions" (Graedel and Allenby 1995).

The necessary components for establishment of an industrial ecosystem are described by Ayres and Ayres (1996). A multifirm industrial ecosystem will usually require a large operational scale and both vertical and horizontal integration. "An industrial ecosystem must look like a single economic entity (firm) from the outside. It will have consolidated inputs and outputs (products). It will compete with other such entities (firms) in both raw material and product markets. It will also compete with other firms for capital. From the inside, however, central ownership with hierarchical management is almost certainly not the optimum solution. Too much depends upon very sensitive and continuous adjustments between the different components of the system" (p. 290).

The authors note that a modern conglomerate, where autonomous units are linked to a corporate parent by a purely financial set of controls, each competing for funds on the basis of profits, also does not provide a satisfactory solution. Industrial ecosystems will require close long-term cooperation and planning between waste producers and consumers, since neither can change either processes or production levels without affecting the other. Thus, internal technological choices and financial transactions must be premised on what is good for the industrial system as a whole, rather than any one firm. An industrial ecosystem is likely to consist of a single major waste exporter with numerous satellite waste converters using the residuals of the primary firm to manufacture other products. The low value of residual materials dictates local use, so that a centralized industrial organization is necessary in which all firms involved are in relative proximity to one another.

The Ayreses identify three current industrial organizational strategies that might serve as models on which to build an industrial ecosystem. The first is the common ownership model of vertical integration, exemplified by corporations such as IBM and GM that own all or most of their suppliers and manage the entire collection centrally. A second model may be found in the retail marketing organization, such as those created by Wal-Mart or McDonald's. Both of these potential models have significant flaws. Vertical integration tends to be cumbersome, often losing markets to more agile competitors due to a centralized decision-making process that is slow to react to changing circumstances. The marketing organization provides little incentive for cooperation among suppliers.

The third model for interfirm cooperation might be derived from the Japanese system of *keiretsu*, a family of firms normally controlled by a large bank, with links to a common trading company, and several major first-tier manufacturers spread over a range of industries. Each of the first-tier companies generally has a number of smaller satellite suppliers. As a model for an industrial ecosystem, the keiretsu suffers from some of the disadvantages of the other organizational types, but it has several advantages, including a primarily horizontal integration and a tendency for close geographical association of unit firms.

At present, industrial ecology remains more of a concept than a practical reality, but points the direction for future industrial production in a sustainable manner. Primary problems associated with realization of the concept are likely to be development of technologies to recover a greater percentage of waste that now escapes capture, development of products and markets based on reclaimed materials, and breakdown of barriers in interfirm cooperation. Toyota of Georgetown symbolically closed one production cycle with a structure constructed of bricks manufactured elsewhere from its own waste products. While this represented only a small fraction of waste generation at the plant, it was a first important step in the development of interdependent linkages in a potential industrial ecosystem.

Acknowledgments

I would like to thank the following industry environmental staff for taking the time to show me around the facilities and discuss environmental issues:

Roy Short and Deanna Helmers, Hitachi Automotive Products (USA); Bruce Freisinger, KI (USA); Tom Herman, Zeon Chemicals; Todd S. Baldwin, Universal Fasteners; and Steve Green, Toyota Motor Manufacturing, Kentucky. Linda Shearer, Hazardous Waste Branch, Kentucky Division of Waste Management, assisted in locating and explaining RCRA documentation. Appreciation is due to Scott Richards and Eric Siegel of the Kentucky Environmental Quality Commission for information and advice.

Notes

1. RCRA information was obtained with the assistance of the Kentucky Division of Waste Management under the Provisions of the Freedom of Information Act. TRI data was obtained on the Internet through the Right-to-Know Network: *http://www.rtk.net.*

2. Federal facilities have also been required to report TRI data, but constitute only about 1 percent of the total. In 1997 the TRI scope was expanded to include additional classes of facilities, including most electric utilities, petroleum bulk stations, and wholesale chemical distributors.

3. Officially, the Comprehensive Environmental Response, Compensation, and Liability Act.

4. Differences between the two federal programs are immediately apparent in terms of total waste generation. The large discrepancies are attributable primarily to the different reporting requirements of the two programs.

5. Interview with Steve Green, Toyota Motor Manufacturing, Kentucky, March 1999.

References

Ayers, R.U., and L.W. Ayres. 1996. *Industrial Ecology: Towards Closing the Materials Cycle.* Cheltenham, UK and Brookfield, Vt., USA: Edward Elgar.

Baker, M.S., J.S. Kaming, and R.E. Morrison. 1977. *Environmental Impact Statements: A Guide to Preparation and Review.* New York: Practising Law Institute.

Barbier, E.B.1989 *Economics, Natural-Resource Scarcity and Development: Conventional and Alternative Views.* London: Earthscan Publications Limited.

Chappell, L.1998a. Toyota Seeks ISO Label by 2001 for All Plants in North America. *Automotive News,* 17 August.

———.1998b. Circle of life: Toyota Is Building Pride and Money by Finding Uses for Paint Sludge. *Automotive News,* 23 February.

Cole, L., S. Richards, and E. Siegel. 1999. *1998–1999 State of Kentucky's Environment: Charting a Path of Progress into the next Century.* Frankfort: Kentucky Environmental Quality Commission.

Garner, A., and G.A. Keoleian. 1995. *Industrial Ecology: An Introduction.* National

Pollution Prevention Center for Higher Education. Ann Arbor, Mich.: University of Michigan.

Graedel, T.E., and B.R. Allenby. 1995. *Industrial Ecology.* Englewood Cliffs, N.J.: Prentice Hall.

Haskell, B.D., B.G. Norton, and R. Constanza. 1992. What Is Ecosystem Health and Why Should We Worry about It? In *Ecosystem Health: New Goals for Environmental Management,* ed. R. Constanza, B.G. Norton, and B.D. Haskell, 3–19. Washington: Island Press.

Hirschhorn, J.S. 1992. Economics of Waste Reduction, Resource Recovery, and Recycling. In *the Greening of American Business: Making Sense of Environmental Responsibility,* ed. T.F.P.

Sullivan, 144–59. Rockville, Md.: Government Institutes, Inc.

Karr, J.R. 1992. Ecological integrity: Protecting Earth's Life Support Systems. In *Ecosystem Health: New Goals for Environmental Management,* ed. R. Constanza, B.G. Norton, and B.D. Haskell, 223–38. Washington: Island Press.

Kneese, A.V., and B.T. Bower. 1979. *Environmental Quality and Residuals Management.* Baltimore: Johns Hopkins Univ. Press.

Manufacturer's News, Inc. 1991–1999. *Kentucky Manufacturer's Register.* Multivolume. Evanston, Ill.: Manufacturer's News, Inc.

Openchowski, C.1990. *A Guide to Environmental Law in Washington, D.C.* Washington, D.C.: Environmental Law Institute.

Pearson, C.S. 1985. *Down to Business: Multinational Corporations, the Environment, and Development.* Washington: World Resources Institute.

Therivel, R., E. Wilson, S. Thompson, D. Heaney, and D. Pritchard. 1992. *Strategic Environmental Assessment.* London: Earthscan Publications Ltd.

U.S. Environmental Protection Agency (EPA). 1997. *1995 Toxics Release Inventory: Public Data Release.* EPA 745-R-97-005. Washington: U.S. Environmental Protection Agency.