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THE INDUSTRIAL GEOGRAPHY OF TOXIC CHEMICAL GENERATION, RELEASE AND MANAGEMENT IN TEXAS

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Over the last 15 years, increasing environmental concern has highlighted the need to increase our understanding of the generation, management and discharge of toxic chemicals resulting from industrial processes. This paper examines overall trends in toxic chemical generation, releases and management in Texas from 1995 to 1999 within the broad context of sustainable industrial production. The continuum of sustainable industrial production strategies calls for the removal of toxic chemicals at the source (i.e. from the product and/or the production process) at one end, recycling in the middle and treatment to reduce/eliminate toxicity at the other end. The results indicate that while the volume of toxic chemicals generated during production continues to increase, releases to the environment have declined substantially. In addition, while treatment to reduce or eliminate toxicity continues to be the preferred management strategy, the use of onsite recycling strategies have increased among industrial sectors generating small quantities of toxic chemicals. The paper suggests that these results are somewhat predictable. Since releases are a more immediate and visible concern firms have concentrated on reductions in releases. Actual source reduction gets little attention because it is much less visible, often more costly, and requires a much greater shift in thinking. *Keywords: industrial geography, toxic chemicals, Texas, sustainable production.*

Over the last 15 years, increasing environmental concern within the United States and Texas (Klineberg 1997) has highlighted the need to increase our understanding of the generation, management and discharge of a variety of toxic chemicals generated from a myriad of industrial processes (Freeze 2000). Toxic chemicals are chemicals that are fatal to humans in low doses or to 50 percent of test animals at stated doses and are generally the most important characteristic in defin-

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ing hazardous waste (LaGrega et al.1994; Miller 1998). Hazardous waste is a broader term, however, covering any substance that poses a fire hazard (ignitable), dissolves materials or is acidic (corrosive), is explosive (reactive) or otherwise poses dangers to human health and the environment (Code of Federal Regulations 1997). Texas is the largest producer and releaser of toxic chemicals in the United States – accounting for just over 20 percent of all toxic chemical generation and 11 percent of all releases in 1999 (United States Environmental Protection Agency 2001).

Efforts to reduce the amount of toxic chemicals produced and released into the environment trace their philosophical roots to the concept of sustainable development. Most widely cited from *Our Common Future,* a book-length report written over a decade ago by the World Commission on Environment and Development (WCED), sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987, 43). Strategies such as green engineering, industrial ecology, closed-loop manufacturing, and design for the environment, focus upon minimizing levels of toxic, hazardous or other substances generated during the production process, consequently reducing our environmental impact on current and future generations. The purpose of this study is to examine trends in toxic chemical production, management[1] and releases by manufacturing industries in the state of Texas with the broad context of sustainable "industrial" development. Specifically, the study seeks to answer the following broad question: Have Texas manufacturers decreased their generation of toxic chemicals? In turn, this generates a number of sub-questions: Have Texas manufacturers decreased the amount of toxic chemicals generated during production? Have Texas manufacturers achieved reductions in releases of toxic chemicals? And what are the dominant trends in the management strategies used to handle toxic chemicals produced during and after the manufacturing process?

Sustainable Development

Since *Our Common* Future was published by the WCED in 1987, the major policy response adopted at a variety of spatial scales has been to argue that sustainable development must form the basis of future economic development (Wallner et al. 1996; Pezzoli 1997; Gibbs et al. 1998; National Science Foundation 2000). As opposed to earlier environmentalist arguments for a "no-growth" policy, sustainable development examines the types of development that can be achieved, with the objective of integrating economic and environmental policies. While policy makers, academics, and industry are generally agreed that sustainable development must form the basis of future economic policy, there is much less consensus on what that actually means.

At one end of the spectrum, in "weak" sustainability approaches environmental concerns assume a higher priority in macro-economic policy, but there is no clear specification of the environmental quality to be achieved and the primary agenda continues to be economic growth, albeit with an environmental "flavor" (Daly and Cobb 1989; Gibbs and Healey 1997; Gibbs et al. 1998). Here the focus is on top-down planning and scientific, technological, and/or design-based solutions within a broad "business-as-usual" philosophy with sustainable development becoming synonymous with sustainable growth. According to many commentators, such definitions of sustainability are doomed to failure because growth and sustainability are essentially incompatible (Lele 1991; Constanza and Wainger 1991; O'Connor 1994) and are often viewed as little more than the latest ideological counterattack of global capitalism (Escobar 1995).

An alternative "strong" sustainability version argues for minimum levels of environmental quality to be achieved prior to consideration of other goals with the presumption that society cannot let economic activity result in a continual decline in the quality and functions of the environment, despite recognition of the positive elements of economic activity (Jacobs 1991; Jacobs and Scott 1992). Targets should be set for environmental impacts, such as emission levels, and regulatory measures that constrain firms and individuals to ensure measurable movement toward the goal of greater environmental quality should be implemented (Gibbs and Healey 1997). However, it is profoundly difficult to determine where to set such limits in an objective manner. Optimal limits are likely to change as the social context and appropriate scale for intervention changes. Also, defined and policed limits predicate particular approaches to sustainable development that may or may not be correct (Drummond and Marsden 1999).

Toxic Chemicals and Sustainability

The production of toxic chemicals and their relationship to industrial sustainability revolve around two related themes: toxic chemical releases to the environment and the generation of toxic chemicals. Human geographers, for the most part, have focused attention upon the impacts of releases to the environment on people. For example, numerous studies have examined issues of environmental justice (Glickman, 1994; Cutter and Solecki 1996; Scott et al. 1998; Tiefenbacher et al.1999). Far less attention has been paid to the industrial structure of toxic chemical generation, management and releases of toxic chemicals, yet releases to the environment depend on both how the chemical is generated and manipulated during the production process and on the growth potential of the industrial sector. Toxic chemicals are an unavoidable byproduct of industrial society and present us with a fundamental contradiction in contemporary Western life: demands for greater environmental quality and demands for more material goods. While the activities of the organic chemical and primary metals industrial sectors account for much of the toxic chemical stream, durable goods, most household, and other consumer products employ toxic chemicals during their production processes also (Freeze 2000). As such, toxic chemicals and their associated environmental releases are likely to remain a significant issue for the foreseeable future.

Sustainable industrial development argues for the removal (or dramatic reduction) of toxic chemicals (and consequent, elimination of releases) from the production process. The preferred method is source reduction or elimination of toxic chemicals that are an intrinsic part of the product (e.g., cadmium in batteries) or the production process (e.g. n-hexane and vegetable oil extraction) (Baker et al. 1991; National Academy of Sciences 1994). Material substitution from the product configuration has proven cost-effective in many situations. For example, the use of non-cyanide bathes in metal plating operations and the use of less toxic solvents in cleaning operations (LaGrega et al. 1994; United States Environmental Protection Agency 1994). Process changes have also proven profitable. For example, recently developed processes for the extraction of vegetable oil no longer require the use of toxic solvents such as n-hexane and have resulted in the elimination of over 3 billion pounds of n-hexane from the vegetable oil manufacturing process (United States Environmental Protection Agency 2001). The ability of individual firms and their motivation to adopt such strategies varies enormously, however. Factors such as firm size, type of production (commodity versus specialty), capital intensity of the production process, availability of and diffusion of new innovations, degree of certainty associated with change, past capital outlays (amortization costs of current capital investment), new capital investment and the perceived competitive advantage of change all play a role in material and process substitution.

Less complex and costly methods of source reduction range from the revision of housekeeping and maintenance procedures to adjustments in waste minimization assessments, environmental audits, loss prevention, waste segregation, and employee education. There are real limits, however, to the amount of toxic chemical reduction that can be achieved without process change or material substitution (Pushchak and Rocha 1998; Gottinger 1997). Most manufacturing processes were designed with product quality and profitability as the primary design criteria rather than attention to the toxics stream.

In the absence of source reduction, toxic chemicals can be reintegrated to the production process or recycled to another process or another plant. Other factors being equal, on-site recycling is preferable because shipping toxic chemicals off-site is expensive and has significant liability and environmental ramifications if accidents occur. Fewer problems with contamination, the increased price of petroleum products and solvents, the decreased costs of recycling systems, and increased costs of disposal all operate to increase the attractiveness of the recycling option. Yet, although there are numerous success stories of recycling operations and the United States Environmental Protection Agency (EPA) estimates that at least 20 percent of all hazardous waste (including toxic chemicals) generated in the United States could be recycled, reused, or exchanged, only about only 5 percent of such waste is managed in this manner (Buchholz 1993; Billatos and Basaly 1997).

Energy recovery through combustion occupies the third level of toxic chemical management[2]. Incineration is used to destroy various chlorinated-hydrocarbon liquids and solids and/or to recover energy (heat) in the process by either adding waste-heat recovery systems to incinerators or firing wastes into existing boiler units. Both approaches can cause problems with emissions of hazardous materials and excessive equipment maintenance (Martin and Johnson 1987) even though both lead to a reduction in the volume of toxic chemicals that need to be treated.

Treatment, a fourth option, is designed to render a toxic chemical less dangerous or harmless so it can be disposed of more easily. A variety of new and emerging technologies can neutralize and even destroy toxic chemicals. Oxidation, bioremediation, carbon absorption, gas absorption, dechlorination, neutralization, precipitation and vitrification technologies are all currently being used in Texas (LaGrega et al. 1994; Gottinger 1997; Texas Center for Policy Studies 2000). Treatment, however, is the least cost-effective and environmentally unsustainable strategy since it is reactive. The chemicals are first produced and then destroyed making the process economically inefficient and increasing the risk of discharge to the environment.

Disposal is at the base of the management hierarchy. Landfill disposal occurs in specially designed excavations or 'cells' which are covered with fill material. While the goal of landfilling is the permanent storage of the waste, wastes can be released from the landfill either accidentally or routinely as leachate or volatized gases. Because of the risk of release, the United States Office of Technology Assessment (OTA) has recommended that land disposal be discouraged and increasingly communities are unwilling to provide sites for hazardous management facilities diminishing the general utility of this option (United States Office of Technology Assessment 1983; Pushchak and Rocha 1998).

Clearly the hierarchy of management strategies for toxic chemicals can be matched to the continuum of sustainability. Source reduction can be equated with strong sustainability since it completely removes the toxic chemicals from the production system and requires an actual and substantial change in behavior. Recycling or reuse is less sustainable since the risk of discharge continues to exist although the need to treat or dispose of the chemical is substantially reduced. Recycling can be placed in the middle of a continuum of sustainable development strategies for toxic chemicals. Energy recovery, treatment and disposal are, at best, defined as weak sustainability in that they seek to manage the chemicals after they have been produced and thus promote a "business as usual" philosophy albeit with more attention paid to the management of the toxic chemicals produced.

Toxic Chemical Data

According to the EPA, the clearest measure of industrial pollution in the manufacturing sector can be found in companies' annual reports of environmental releases of toxic chemicals to the Toxic Release Inventory (TRI) program (United States Environmental Protection Agency 1998). Sections 311, 312 and 313 of the 1986 EPCRA (Emergency Planning and Community Right-to-Know Act) require manufacturers with over 10 employees that manufacture or process over 25,000 lbs or use more that 10,000 lbs per chemical per year of any of 600 chemicals identified by the EPA as toxic to report the locations and quantities of those chemicals they store on site, release into the environment, or ship off-site, to the EPA and state or local government officials. More recently, the 1990 Pollution Prevention Act obliges facilities to report on pollution prevention activities and recycling as well. Manufacturers are defined as those classified in SIC (Standard Industrial Classification) groups 20 through 39[3]. Each year, more than 20,000 manufacturing facilities and 200 federal facilities report releases to the EPA. TRI includes information on what chemicals were released into the environment, the volume of each toxic chemical generated, how the chemical was managed during and after the productions process and how much was transferred away from the reporting facility for disposal, treatment, recycling, and energy recovery. The data are accessible from the EPA's TRI Explorer website (United States Environmental Protection Agency 2001).

TRI data suffer from a number of documented problems. First, there are problems with non-reporting and under-reporting. In the first year of implementation, the United States Government Accounting Office (United States General Accounting Office) estimated that approximately one-third of facilities who were required to report, did not (United States General Accounting Office 1991a), while some states have estimated non-reporting rates as high as 50% (United States General Accounting Office 1991b; Perlin et al. 1995). Second, until recently, TRI did not collect data on non-manufacturers and while seven new industry groups were added in 1997, several others should be considered, including dry cleaners, oil and gas exploration, agricultural operations and federal facilities (Cohen 1997). The exclusion of manufacturing firms with fewer than ten employees and/or producing less than the current thresholds for reporting to TRI is a third problem. A fourth problem lies in changes in the number of chemicals that have to be reported. For example, in the first year of the TRI fewer than 300 chemicals were listed as toxic chemicals that requiring reporting, at present there are close to 600. Currently, accurate longitudinal data on waste generation, management and releases for all 600 chemicals for the original manufacturing industries are only available since 1995[4]. Finally, TRI data are self-reported by companies and are based on estimates rather than hard data, factors that reduce the ability to track trends precisely over time. Despite these limitations, TRI data have become the yardstick by which regulators, advocacy groups, industry officials, academics and other interested parties monitor toxic chemical releases and their environmental effects (Brehm and Hamilton 1996; Tiefenbacher et al. 1997).

Research Hypotheses

The research questions examined were based on expectations from the previous discussion and are driven by the overarching question: To what extent have Texas manufacturers made progress toward the achievement of a more sustainable model of industrial production? In turn, this generates a number of sub-questions: Have Texas manufacturers decreased the amount of toxic chemicals generated through the production process? Have Texas manufacturers achieved reductions in releases of toxic chemicals? And what are the dominant trends in the management strategies used to handle the toxic effects of chemicals generated during the manufacturing process? If manufacturers have decreased toxic chemical generation, reduced toxic releases and increased management strategies based on reuse or recycling, we can conclude that strong sustainability approaches are being followed in the state. On the other hand, if toxic chemical generation and releases have increased, and management strategies rely on treatment strategies, then no progress has been made toward a more sustainable model of industrial development. Finally, if the evidence is not unidirectional, then where do we place Texas manufacturers on the continuum of sustainable industrial development?

Toxic Chemical Generation in Texas

During the latter half of the 1990s Texas manufacturers generated close to 4 billion pounds of toxic chemicals each year during manufacturing processes (Table 1). In 1999 the total increased to 4.67 billion pounds – with 57.6 percent of that increase generated by the Dow Chemical Freeport plant. A small and decreasing proportion (from 7.6 to 5.2 percent) of those chemicals were released to the environment, mostly onsite. The vast majority are managed, mostly onsite, either through recycling, energy recovery or treated to decrease their toxicity with the trend toward greater amounts of onsite management.

As would be expected, the industrial structure of toxic chemical generation is highly skewed with the chemical industry alone accounting for approximately 85 percent of all generation in 1995, increasing by 28.4

Waste Stream	1995	1996	1997	1998	1999
Onsite Releases	7.61	6.23	6.08	6.34	5.15
Offsite Releases	0.38	0.35	0.55	0.48	0.42
Onsite Management[1]	83.26	85.21	85.51	84.86	88.10
Offsite Management[1]	8.75	8.01	7.99	8.35	6.24
Total Waste Generated	3,889,714,842	4,112,973,640	4,009,065,116	3,971,196,492	4,673,453,242

[1]Management includes recycling, energy recovery and treatment.
Source: United States Environmental Protection Agency 2001.

Table 1. The Destination (in percent) and Size (in pounds) of Toxic Chemical Waste Stream Generated by Texas Manufacturing Firms, 1995-1999.

Industry Group	1995 toxic chemical generation		Relative % Shift from 1995 base			
	Total pounds	% of total	1996	1997	1998	1999
Chemical	3,274,841,504	84.19	3.22	4.43	3.72	28.42
Multi-Sic code industry	196,260,800	5.05	-30.95	-89.59	-48.24	-89.33
Petroleum Refining	114,516,511	2.94	72.30	0.86	-6.11	9.69
Primary Metals	90,248,282	2.32	3.09	4.34	4.54	1.04
Paper	85,229,184	2.19	-22.33	-11.16	-19.62	-23.32
Fabricated metal	36,343,846	0.93	95.99	-8.23	4.25	-7.91
Electronic Equipment	20,081,220	0.52	102.50	2.50	-6.05	41.62
Food	17,354,975	0.52	-17.99	-17.60	-18.01	-41.99
Rubber and Misc. plastic	15,604,800	0.40	-1.06	23.47	23.79	3.45
Stone, Clay and Glass	10,713,388	0.28	238.85	196.84	286.53	318.79

Source: United States Environmental Protection Agency 2001.

Table 2. Shifts in Toxic Chemical Generation for Top 10 Industries, Based on "1995 Core Chemicals – Original Industries," 1995-1999.

percent by 1999, to account for 90 percent of the 1999 total (Table 2). Other significant industries include the multiple SIC category (that includes some large chemical/petroleum refining companies (e.g., Phillips 66 Co. Sweeny Complex) and primary metal/fabricated metals companies like Wyman-Gordon Forgings Inc.), petroleum refining, primary metals, and the paper industry. More significant in terms of sustainability, however, are the trends in toxic chemical generation during the 2nd half of the 1990s (Table 2). Of the top 10 industrial sectors (identified in Table 2), only 3 (multi-SIC code, paper and food) industries recorded consistent decreases in toxic chemical generation between 1995 and 1999. The remaining seven sectors increased their generation, including very large increases (over 200 percent in most years) in the stone clay and glass sector – albeit from a small initial base. Other sectors examined had more modest increases overall, although petroleum refining, fabricated metals, and electronic equipment did record very substantial increases in 1996.

Given the dominance of the chemical industry in these trends shifts within that sector were examined more closely. Of the 349 chemical firms that reported TRI data in 1995 and 359 firms in 1999, the top 25 firms accounted for over 70 percent of toxic chemical generation (72 and 77 percent, respectively) reflecting the dominance of large firms within this sector. Two-hundred and sixty firms reported to TRI in both years, with half recording increases in toxic chemical generation. Concentrating on the largest 25 firms reporting in both years, which accounts for 95 percent (or 732,498,507 lbs.) of the total increase generated by the chemical sector, nine recorded decreases totaling 293,733,513 lbs. (40 percent of total change for the top 25), and the remaining 16 recorded increases totaling 1,026,232,020 lbs. (140 percent). Among the smaller generators, 52 percent decreased their generation.

It could be argued that increases in toxic chemical production reflect increases in production that mask unit decreases achieved by individual firms. To examine this argument, shifts in the each industry's trend in toxic chemical generation were compared to trends in two economic indicators: employment and value added (PPI, adjusted, United States Department of Commerce 2000b). Employment trends provide a relatively stable and long-term measure of the health of an industrial sector, while value added (price of a finished product minus costs of production) provide a more direct measure of the relative economic importance of a sector, its profitability and growth. Both the chemical and petroleum-refining sectors decreased employment consistently throughout the period, while the chemical sector also decreased its value added substantially during 1996 and insignificantly in 1999. Primary metals also shed employment in 1998 and 1999, and decreased its value added in 1999. These three sectors recorded increases in toxic chemical generation throughout the period suggesting little correlation between toxic chemical production and production patterns among the most important toxic chemical generating manufacturing sectors. On the other hand, most of the remaining sectors recorded increases in both economic indicators and toxic chemical generation signifying a positive correlation between toxic chemical generation and overall growth among the industrial sectors that produce small quantities of toxic chemicals. Only the paper industry recorded decreases (between 1996 and 1998) in value added, employment (between 1998 and 1999), and toxic chemical generation, while the food industry recorded toxic chemical reduction while achieving consistent increases in both value added and employment (United States Department of Commerce 1997, 1998, 2000a, 2001).

Intuitively these relationships make sense. Change in toxic chemical generation among industrial sectors that produce significant quantities of toxics are likely to result for a myriad of reasons including process or technology changes, market price variation of substitutable chemicals, new product development, as well as economic growth. In contrast, in sectors where the volume of toxic chemicals is small, and hence, the contribution to production costs is less significant, there is less likelihood that technology, process change or market price changes would influence toxic chemical use. And, in addition, since such sectors are much less visible in the toxic chemical hierarchy, there is much less public pressure to modify existing patterns of toxic chemical use. As such, growth of such a sector

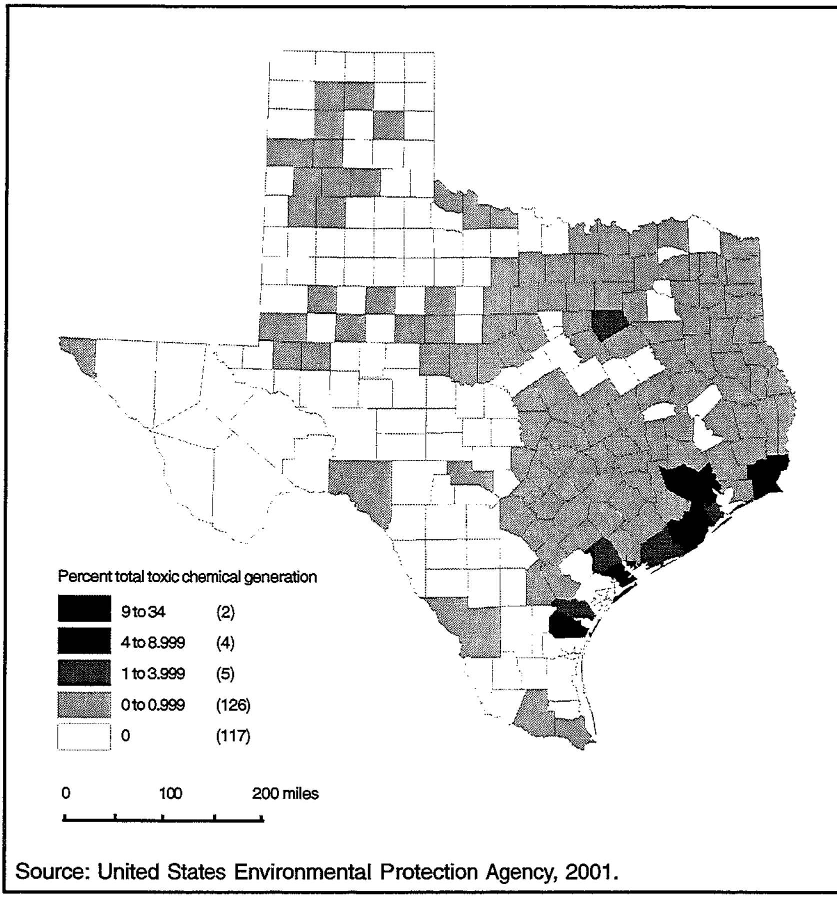


Figure 1. Percent Total Toxic Chemical Generation, Texas, 1999.

would produce corresponding growth in toxic chemical use.

The overall spatial pattern of toxic chemical generation reflects the geography of chemical manufacturing companies in the state and has changed little during the five years of the study (Figure 1). A little less than half (45 percent) of counties generated no toxic chemicals and an additional 51 percent generate less than one percent each. The largest concentrations are found along the Gulf Coast, home to the largest concentration of chemical and petrochemical companies in the country. The largest single

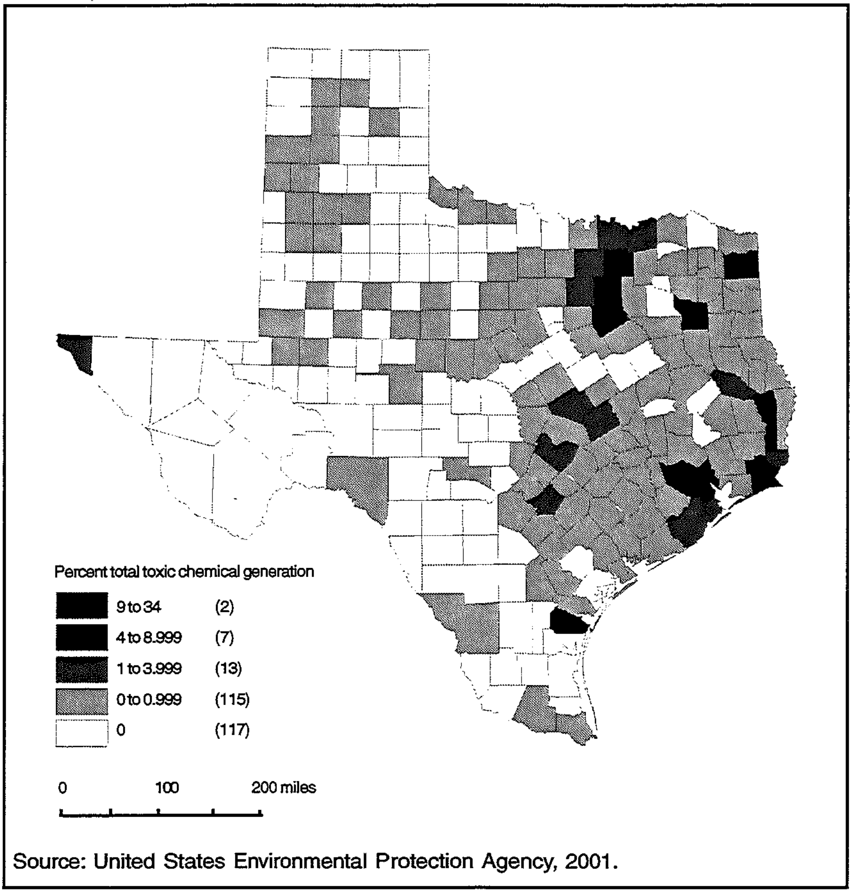


Figure 2. Non-"Chemical Industry" Manufacturer Total Toxic Chemical Generation, Texas, 1999.

concentration is in the Houston-Galveston-Brazoria metropolitan region (approximately 60 percent), followed by Beaumont-Port Arthur, Victoria and rural Calhoun County to the south, and Corpus Christi. Together, these 4 metropolitan areas account for close to 90 percent of the toxic chemical generation in the state in both 1995 and 1999. Austin's toxic chemical generation is negligible and Dallas-Fort Worth's manufacturers generated 2.34 percent in 1995, rising to 3.14 percent in 1999.

If we exclude chemical manufacturers the spatial pattern of toxic chemical generation is more diffuse reflecting the broader manufacturing base of Texas (Figure 2). Again, the Gulf Coast area dominates with 34 percent of "non chemical industry" toxic chemical generation, but the largest single concentration is in the Dallas-Fort Worth area. In addition, a number of counties in both East and Central Texas (including paper industry concentrations in Jasper, Angelina, and Cass, primary metals in Milam, and plastics in Bell) and the metropolitan areas of Tyler (petroleum), Austin and San Antonio emerged with contained concentrations between one and 5 percent in 1999.

Toxic Chemical Releases in Texas

The most immediate issue surrounding toxic chemicals is the associated releases to the environment. As with generation, releases are highly skewed with the chemical industry accounting for over 75 percent of total releases throughout the study period (Table 3). Also important are the petroleum refining, the multi-SIC group, paper, food and primary and fabricated metals sectors. Unlike toxic chemical generation, however, most of the top 10 sectors examined recorded relatively substantial decreases in releases since 1995. Only the primary metals, stone, clay and glass, and petroleum refining industry (during 1997 and 1998) recorded consistent increases in toxic chemical releases during the latter half of the 1990s.

As was the case with toxic chemical generation, the top 25 releasers in the chemical sector account for approximately 80 percent of total releases in both 1995 and 1999. Of the top 25 releasers in 1995, 18 reduced their releases by 1999. This totaled to 71,177,995 lbs. or 31 percent of total releases by the chemical sector in 1995. The other 7 increased their volume of releases by 10,923,196 lbs. or 4.7 percent of the 1995 total. Two hundred and fifty nine chemical firms reported releases to the TRI in both periods and among these, 53 percent experienced a reduction in releases, 45 percent increased their level of releases and 2 percent remained the same.

More important than the absolute and relative level of releases, however, is the ratio of releases to generation. This is particularly important for our understanding of the chemical sector, which dominates patterns of

	1995 toxic chemical generation		Relative % Shift from 1995 base			
Industry Group	Total pounds	% of total	1996	1997	1998	1999
Chemical	230,898,508	76.8	-13.80	-18.24	-16.48	-17.52
Petroleum Refining	22,186,169	7.4	-0.55	0.36	7.55	-6.76
Multi-Sic code industry	9,993,893	3.3	-44.23	-34.49	-50.17	-52.35
Paper	8,604,330	2.9	-2.80	2.80	-2.26	-12.71
Food	8,515,462	2.8	-16.56	-14.56	-15.42	-43.63
Primary Metals	6,145,600	2.0	5.15	51.67	51.34	23.83
Fabricated metal	6,127,544	2.0	-14.99	-9.99	-14.58	-0.54
Rubber and Misc. plastic	5,454,539	1.8	-16.43	-8.65	-3.08	-3.90
Stone, Clay and Glass	2,021,834	0.7	36.59	62.51	106.86	143.10
Electronic Equipment	722,588	0.2	-13.07	-24.67	-10.25	-0.27

Source: United States Environmental Protection Agency 2001.

Table 3. Shifts in Toxic Chemical Releases for Top 10 Industries, Based on "1995 Core Chemicals – Original Industries," 1995-1999.

hazardous waste generation/releases because of the huge volume of chemicals used by the industry. From this perspective the chemical industry fares much better (Table 4). Along with the primary metals and electronic equipment sectors, the chemical industry has one of the lowest ratios of releases to total toxic chemical generation. In addition, together with the stone, clay and glass sector, the chemical sector is the only top-ten sector to have consistently recorded a decrease in the ratio of releases to total toxic chemical generation. In contrast, the 1999 ratio of four of the sectors (multi SIC-code, paper, primary metals and fabricated metals) was greater than in 1995—despite some fluctuation in the intervening years, while the remaining four also recorded increases during some years.

While this presents a more positive image for the chemical industry, we should expect such efficiency within this sector given the massive volume of chemicals used. High ratios of losses to generation would be extremely cost prohibitive and environmentally disastrous for the industry. On the other hand, in industrial sectors where the overall volume, and hence cost, of toxic chemicals is much less, far less attention is likely to be paid to production/release ratios. Moreover, since the overall volume of releases is much lower in those sectors there is much less public awareness and consequent pressure to reduce releases.

Within the chemical sector, 259 firms reported generation and releases to TRI in1995 and 1999. There is a weak positive, but statistically significant ($p=.000$, $r_s=.299$) relationship between trends in releases and generation. Thirty-five percent of firms represent the ideal situation with declines in both releases and total generation, while another 19 percent reported declines in releases but increases in total generation. The remaining 46 percent of firms represent non-sustainable positions, with 31 percent increasing both their releases and total generation and the final 15 percent of firms, representing the worst situation, where releases were increasing while total generation was decreasing.

The geography of onsite releases is similar to that of toxic chemical generation although there are some differences (Figure 3). Particularly, releases are somewhat less concentrated in the four Gulf Coast metropoli-

Industry Group	1995	1996	1997	1998	1999
Chemicals	7.05	5.89	5.52	5.68	4.53
Petroleum Refining	19.37	11.18	19.28	22.19	16.47
Multi-Sic code industry	5.09	4.11	32.06	4.90	22.74
Paper	10.10	12.63	11.68	12.28	11.49
Food	49.07	48.16	50.88	50.62	47.68
Primary Metals	6.81	5.47	7.20	7.09	7.64
Fabricated metal	16.86	7.31	16.54	13.82	18.21
Rubber and Misc. plastic	34.95	29.52	25.86	27.37	32.47
Stone, Clay and Glass	18.87	7.61	10.33	10.10	10.95
Electronic Equipment	3.60	1.54	2.64	3.44	2.53

Source: United States Environmental Protection Agency 2001.

Table 4. Ratio of Toxic Chemical Releases to Generation, "1995 Core Chemicals" Original Industries, 1995-1999.

tan areas. In 1995, the four Gulf Coast metropolitan areas (Houston-Galveston-Brazoria, Beaumont-Port Arthur, Victoria—including Calhoun, and Corpus Christi) accounted for 83 percent of releases, declining to 79 percent by 1999. Again, this attests to the record of the chemical industry in achieving large reductions in releases without reducing overall levels of toxic chemical generation. In addition, a number of rural counties in East Texas, (paper industry in Cass), Central Texas (primary metals industry in Milam), and the Panhandle (chemical industry in Hutchinson) accounted for between 1 and 4 percent of total onsite releases in 1999. The proportion of total releases was also a little higher than total generation in the Dallas-Fort Worth area, increasing from 3.14 to 4.14 during the latter half of the 1990s.

Removing the chemical industry from the release totals results in a more dispersed spatial pattern, though again the Gulf Coast cities of Houston-Galveston-Brazoria (27 percent of releases) and Beaumont-Port Arthur (10 percent) account for the largest concentrations in 1995 (Figure 4), followed by the Dallas-Fort Worth region (15 percent) and Corpus Christi with 6 percent in 1999. Again, a number of rural counties in East Texas where the paper industry is concentrated – Jasper, San Augustine, Angelina, Cass, the food industry concentration in Titus, the primary metal concentrations in Milam and plastics and stone, clay and glass in Bell, and a variety of concentrations in the Panhandle (Hutchinson—multi-SIC code, Moore—petroleum, Potter—primary metals and Hale—food), and the city of Lubbock, have release proportions of between 1 and 4 percent.

Toxic Chemical Management Strategies in Texas

For manufacturing industries as a whole, most toxic chemicals generated during the production process are managed onsite: increasing from 83 to 88 percent between 1995 and 1999 (Table 5). Within the top ten sectors, however, there is considerable variation. The 4 highest ranked sectors (chemicals, petroleum refining, multi-SIC code, and paper) manage over three-quarters of their toxic chemicals onsite, although this has declined dramatically for the multi-SIC code sector. This result is to be ex-

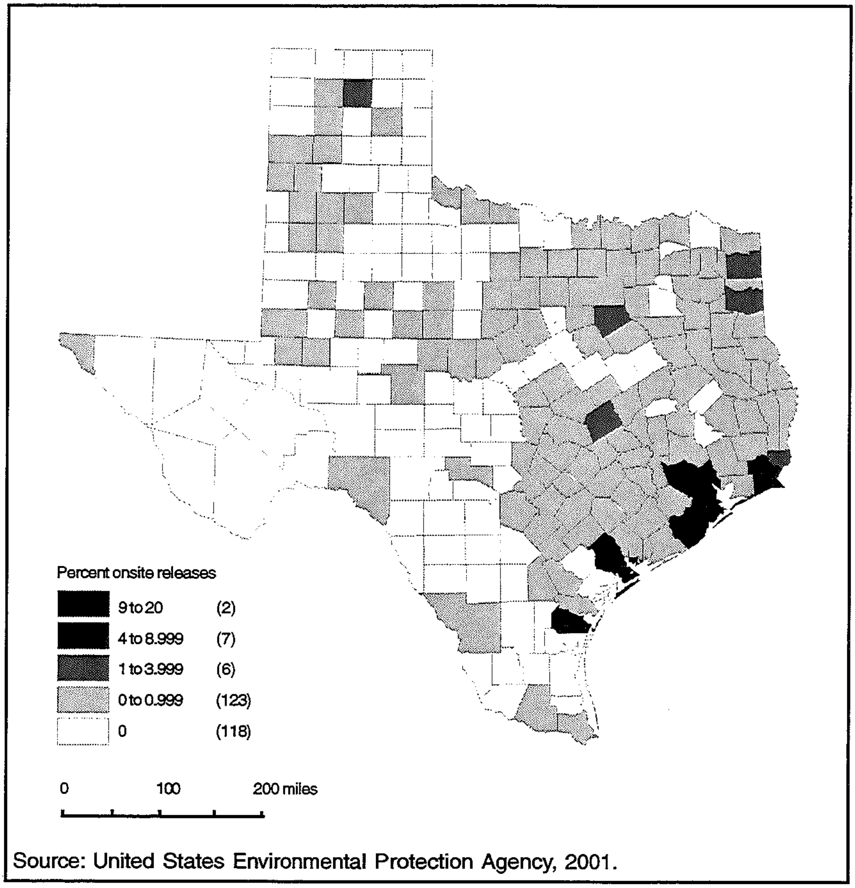
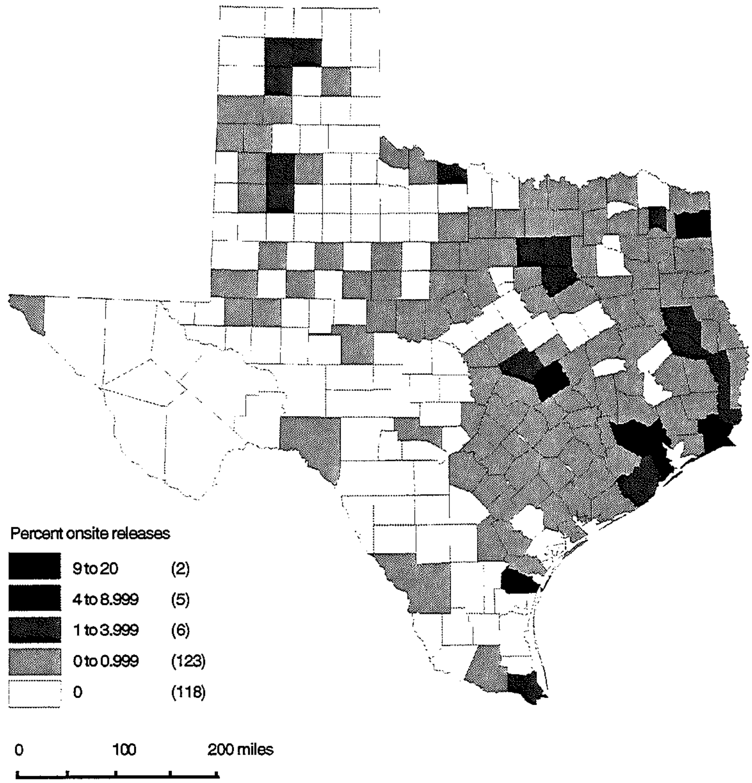


Figure 3. Onsite Releases of Toxic Chemicals, Texas, 1999.

pected given the high liability costs associated with transporting large volumes of toxic chemicals over space. Among the lower ranked sectors (primary metals, fabricated metals, and electronic equipment sectors), where onsite capacity to manage toxic chemicals is much less likely to be present, less than 30 percent of their toxic chemicals were managed onsite in 1995. This proportion increased substantially during the following four years principally due to increases in the amount of recycling. The food industry handled 46 percent of its toxic chemicals onsite in 1995 – decreasing to 40 percent by 1999.



Source: United States Environmental Protection Agency, 2001.

Figure 4. Non-"Chemical Industry" Manufacturer Onsite Releases of Toxic Chemicals, Texas, 1999

Onsite treatment, followed by onsite recycling and energy recovery, is the dominant strategy for Texas manufacturers and has become more important since 1995, increasing its proportion from 45 percent to 53 percent with consequent decreases in the amount of toxic chemicals recycled and burned for energy recovery. Again, within the various industrial sectors examined, there is some variation in the use of the three strategies. For the chemical, petroleum refining and paper industries, treatment continues to be the most important strategy although reliance on treatment has declined in the petroleum refining sector since 1995 and recycling has become more important.

Among the smaller generating sectors – the food, fabricated metals, and electronic equipment sectors, treatment was the principal strategy in 1995, although this decreased significantly by 1999 with substantial increases in onsite recycling. The manufacturing processes of the rubber and miscellaneous plastics and stone, clay and glass industries allow them to burn the vast majority of their toxic chemicals for energy recovery (reducing total energy costs in the process) and this strategy has become more important since 1995. Finally, the primary metals industry recycled almost all of its toxic chemicals in 1995 but has increased the use of treatment strategies since 1995.

Within Texas manufacturing only 9 percent of toxic chemicals were managed offsite in 1995, this proportion decreased to 6 percent by 1999 (Table 6). Of the top ten industries generating toxic chemicals, only 3 (primary metals, fabricated metals and electronic equipment) manage large proportions of their toxic chemical generation offsite. In these three sectors the amounts managed offsite have decreased since 1995. The most important offsite management strategy for manufacturing as a whole is recycling followed by approximately equal proportions treated or burned for energy recovery. In the case of the three industrial sectors where offsite management strategies are dominant, 95 percent of the chemicals were recycled in the primary metals and fabricated metals industries and 73 percent in the electronic equipment sector.

Conclusion

We return to our overarching question. Have Texas manufacturers made progress toward a more sustainable model of industrial production? If we define sustainable industrial development as source reduction, the short answer is "no." The majority of industrial sectors increased their toxic chemical generation during the latter half of the 1990s and for many of the largest generating sectors (particularly chemicals) the increases occurred at the same time as decreased employment and value added. On the other

	Onsite management strategies, 1995				Shifts in onsite management to 1999			
	% of total generation	% of toxic chemical managed by			% of total generation	Relative % shift in strategy		
		Recycling	Energy Recovery	Treatment		Recycling	Energy Recovery	Treatment
Chemicals	86.89	28.08	25.56	46.35	90.84	-2.70	-5.18	7.89
Petroleum Refining	79.04	11.28	32.98	55.75	81.65	7.52	-0.69	-6.84
Multi-Sic code industry	83.08	83.74	3.06	13.20	46.18	-29.23	-3.60	32.29
Paper	79.77	10.25	14.34	75.41	87.47	5.49	-5.67	0.18
Food	45.92	7.60	0	92.40	39.96	32.31	0	-32.31
Primary Metals	23.26	94.51	0.16	5.34	43.67	-10.37	3.10	7.27
Fabricated metal	17.28	13.61	8.54	77.85	22.52	20.31	-3.69	-16.63
Rubber & misc. plastic	62.79	12.39	82.97	4.64	61.14	2.11	6.53	-4.42
Stone, Clay and Glass	75.32	8.57	87.70	3.72	87.71	-7.2	9.34	-2.13
Electronic Equipment	29.38	1.63	0.64	97.73	45.99	50.01	-0.64	-49.37
All Manufacturing	83.26	30.39	24.33	45.28	88.10	-4.71	-3.30	8.01

Source: United States Environmental Protection Agency 2001.

Table 5. Nature of Onsite Management Strategies for Toxic Chemicals in 1995 and 1999.

hand, if we define sustainable industrial development as reducing immediate environmental impact, the answer is more positive. Most sectors recorded substantial reductions in releases and for the chemical industry the ratio of releases to generation continues to decline although this is not the case for many of the other smaller sectors.

In many ways these results are predictable. Since releases are a more immediate and visible concern this is where the majority of public, policy, and political attention is focused. A combination of EPA and state regulations, increased costs for disposal, public awareness and some genuine environmental concern is moving both the chemical industry and other manufacturers to pay greater attention to the environmental impacts of their economic activity. Or it may be more pragmatic. After all, compliance with environmental regulations allows firms, and especially large generators, to argue that they are doing all they can, have adopted plans and strategies for source and release reduction, and have embraced the best science to "clean-up" industries that are an essential part of our contemporary industrial structure.

Actual source reduction gets very little attention, partly because it is often much more costly and partly because it requires a major shift in thinking. Most products are not made or designed with environmental concerns at the core. To do so would require a major philosophical shift in the nature of capitalism: from the pursuit of profit alone to the pursuit of profit within the constraints of environmental stewardship. In addition, it would require major shifts in production processes across a variety of industrial sectors. And, while considerable technological advances in design have emerged within the field of Industrial Ecology, the linkage between design, firm motivation and enhanced profitability in the market-place have yet to be worked out (O'Rourke et al. 1996; Allenby 1999). Finally, the development of a set of new cost structures that would integrate environmental impact into production costs and profit margins within a free-market-based society that eschews government regulation would seem a daunting task.

And there is little pressure to do so. While source reduction has been

	Onsite management strategies, 1995				Shifts in onsite management to 1999			
	% of total generation	% of toxic chemical managed by			% of total generation	Relative % shift in strategy		
		Recycling Recovery	Energy	Treatment		Recycling Recovery	Energy	Treatment
Chemicals	5.98	21.62	43.36	35.01	4.52	2.18	-2.32	0.15
Petroleum Refining	1.58	45.26	2.03	52.71	1.35	-13.46	0.06	13.40
Multi-Sic code industry	11.94	34.37	9.93	55.71	33.77	48.35	-4.58	-43.78
Paper	10.65	0.22	1.51	98.27	0.99	3.99	-1.51	-2.48
Food	4.14	38.74	0	61.26	11.85	-15.61	0	15.61
Primary Metals	71.85	96.04	0.86	3.10	48.59	0.93	-0.18	-0.75
Fabricated metal	65.68	95.59	2.40	2.01	61.01	-0.70	0.79	-0.09
Rubber & misc. plastic	4.47	42.27	39.47	18.26	6.45	23.05	-13.66	-9.39
Stone, Clay and Glass	3.85	68.24	2.16	29.60	0.68	-17.66	1.44	16.22
Electronic Equipment	65.99	72.72	15.19	12.09	51.36	5.84	-8.32	2.47
All Manufacturing	8.75	44.38	27.09	28.52	6.24	1.63	0.92	-2.53

Source: United States Environmental Protection Agency 2001.

Table 6. Nature of Onsite Management Strategies for Toxic Chemicals,1995.

mandated as policy at both the federal and state level, and numerous innovative voluntary measures, information diffusion and partnerships have been developed to move industry in that direction, there is no law that specifically requires firms to reduce the amount of toxic chemicals employed in the production process by measurable indicators[5] (Voorhis 1994; Muzurek 1998; United States Environmental Protection Agency 1998; Fagin et al. 1999; Norberg-Bohm 1999; Portney and Stavins 2000; Texas Center for Policy Studies 2000; Texas Natural Resource Conservation Commission 2000). Nor would such laws necessarily prove successful or feasible. As has been demonstrated time and again with Superfund cleanups, if the technology doesn't exist to clean up a heavily polluted site, binding standards with the weight of law are likely to lead to lengthy and expensive court battles rather than a successful environmental conclusion (Muzurek 1998; Freeze 2000).

Similar realities exist for toxic chemical management. Onsite treatment continues to be the most important strategy, especially for the larger generating sectors. For smaller generators, where onsite technologies and expertise are less likely to be present, offsite management is more common. For large generators onsite treatment continues to dominate management strategy; partly because of liability issues involved in moving toxic chemicals offsite, partly because it is the established method, and partly because technologies to feed the chemicals back into products or the production process have not been fully developed and are likely to incur significant capital costs. And, while treatment is not particularly cost effective, the costs are currently built into the current system and profit can still be made.

On the other hand, significant production process changes are likely to require considerable capital outlays that have yet to demonstrate (or the knowledge has yet to diffuse) their wide-scale cost effectiveness over time – despite numerous individual success stories. Industries are organized around particular production processes and business milieus that have proven to be profitable. As is always the case, there is considerable inherent inertia within industry. Current strategies, while not perfect, represent known successful strategies, whereas new production processes bring with them the possibility of greater uncertainty and perceived (or actual) greater risk.

There are some positive signs, however. Among the smaller generating sectors, the use of onsite recycling has increased and where toxic chemicals are shipped offsite, recycling is the dominant strategy. Even within the chemical sector, approximately one-quarter of the chemicals treated onsite or offsite are recycled. This suggests that a market for certain recycled toxic chemicals has emerged with the potential to increase in size. Mechanisms to increase the profitability of this market segment are now needed. Unfortunately, the potential for independent toxic-chemical recycling industries to capture a greater portion of the toxic chemicals generated during production is likely to be strongest in the smaller sectors where the in-house capacity is less likely to exist. Recycling opportunities within the chemical sector are likely to remain in-house and will have to compete with other treatment strategies and the reality of the current production process.

In conclusion, the good news is that toxic chemical releases have been steadily declining across most manufacturing sectors in Texas. On the other hand, evidence of substantial source reduction is slim. As such, Texas manufacturers are treating the symptoms rather than the cause and this is likely to change in the near future. Yet, awareness of the need to pay greater attention to toxic chemical use is now firmly implanted in manufacturing and may be the first tentative step forward toward a more sustainable model of industrial production within the state.

Notes

[1] Management of toxic chemicals includes chemical treatment to reduce or eliminate toxicity, recycling and incineration for energy recovery.

[2] Under Texas' Waste Reduction Policy Act, burning for energy recovery is considered recycling. This approach has been criticized by environmental groups who argue that using waste as fuel is really a method of disposal and pollution is often created in the burning of the waste (Texas Environmental Almanac 2000).

[3] In 1997 seven new industry groups were added. These include metal

mining, coal mining, electric utilities, commercial hazardous waste treatment, wholesale chemical and allied products, wholesale petroleum bulk terminals and stations and solvent recovery services.

[4] The TRI website contains some data going back to 1988 and 1991 for some categories, but those data are incomplete and not suitable for longitudinal analysis.

[5] An analysis of state and federal policy and trends in toxic chemical production, releases and management is currently underway.

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