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Pollution Prevention: Factors Behind Toxic Release Reduction in the U.S. Paper Industry*

John P. Tiefenbacher & William D. Solecki**

Introduction

During the 1980s, U.S. industries increasingly used pollution prevention (P2) programs because reducing emissions decreased production and disposal costs, and improved relationships with local residents and environmental groups.[1] P2 programs have helped U.S. manufacturers significantly reduce reported emissions. For example, U.S. manufacturing facilities from 1987 to 1992 achieved a 34% reduction in the quantity of environmental releases reported to the Toxic Release Inventory (TRI).[2]

Many studies have examined the progress of P2 programs and impediments to continued success at specific facilities, and for the nation as a whole.[3] This paper focuses on a largely unexamined aspect of P2: geographic factors that affect industrial pollution release

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1 For further discussion, *see* Louis Theodore & Young C. McGuinn, **Pollution Prevention** (1992); Nelson Leonard Nemerow, **Zero Pollution for Industry: Waste Minimization Through Industrial Complexities** (1995); James R. Aldrich, **Pollution Prevention Economics: Financial Impacts on Business and Industry** (1996).

2 Office of Pollution Prevention and Toxics, *1991 Toxics Release Inventory* (EPA 1993).

3 *See e.g.*, Ann B. Graham, *The Results of PPR's 1993 Survey Industry's Pollution Prevention Practices*, Poll. Prev. Rev., Autumn 1993; *see also* Kingley E. Haynes, Samuel Ratrick & James Cummings-Saxon, *Toward a Pollution Abatement Monitoring Policy: Measurements, Model Mechanics, and Data Requirements*, 16 Envtl. Profn'l. 293 (1994); Raymond J. Burby, *Coercive Versus Cooperative Pollution Control: Comparative Study of State Programs to Reduce Erosion and Sedimentation Pollution in Urban Areas,* 19 Envtl. Mgmt. 359 (1995) and Monica Becker & Nicholas Ashford, *Exploiting Opportunities for Pollution Prevention in EPA Enforcement Agreements*, 29 Envtl. Sci. & Tech. 220 (1995).

reduction. The objective is to examine the spatial characteristics associated with the pollution reduction progress made in a single industry. The paper industry is used to test a series of hypotheses regarding the relationship between the level of pollution reduction at paper production facilities and the internal (within the facilities and their corporate organizations) and external (outside the firm) contexts in which facilities operate. Specifically, we seek to understand how and why successful pollution reduction varies from one place to another. Are there internal and external factors that are determinants of pollution reduction behavior at industrial facilities? Existing data on the level of P2 in the paper industry indicate that significant release reduction has been made since the late 1980s.[4] Whether reduction has been industry-wide, or whether certain facilities have been more successful than others has not yet been determined. Furthermore, the factors that achieve reductions have not yet been discerned.

The current research develops and tests numerous assertions about release reduction developed from the ideas put forward in the geographic literature that deals with hazards, particularly the hazards-in-context framework. The hazards-in-context framework enables conceptualization of risk and hazardous events as resulting, at least partially, from the social, economic, and political contexts present at particular locales. Examination of hazards in their contexts has proven effective in providing explanatory details that assist in mitigation of risks.

In this research, three basic assertions describing internal and external conditions that might effect pollution reduction are put forth and tested. The internal factors pertain to each facility and its parent company. It is proposed that the fiscal and political character of the manufacturing facility and its parent company are associated with the amount of release reduction. The external factors describe the socio-economic and political elements of the local community and state in which each facility operates. Two assertions regarding external conditions are made. These are (1) that the socio-economic character of the community in which the facility is located is associated with the amount of release reduction, and (2) that the political context or level

4 *See* EPA (1993), *supra* note 2.

of environmental protection maintained by the state in which the facility is located is associated with the amount of release reduction.

To better understand the role of internal and external factors on a facility's reduction of toxic releases, this study attempts to minimize the complexities generated by multiple-industry and multiple-chemical assessments. This study focuses solely on the paper industry and on the releases of only two chemicals: chlorine and chloroform. We chose these two substances because they are ubiquitous within the industry, are traditionally released to the environment as part of the paper-bleaching process, are used in similar ways in the vast majority of facilities, and present human and/or ecosystem health threats.

The TRI for five years (1988, 1989, 1990, 1991 and 1992) provide the basic data for this study. Although the analysis of TRI data presents problems associated with self-reported and rarely verified data, the data show the changing nature of environmental toxic emissions from American facilities. These changes are generally products of the technological advances made in the paper industry itself, but these have been enhanced recently by the establishment of a toxic emissions reduction program.

Thirty-three states reported having paper facilities that emitted TRI threshold amounts of toxics to the environment during the period 1988 to 1992. In 1988, 155 of the 188 U.S. paper manufacturing facilities submitting information to the TRI program reported release of at least one TRI substance. By 1992, that number climbed to 175 facilities.

Nationally, the total quantity of all toxic releases from paper facilities declined during the study period by 22% from more than 33,997,000 pounds in 1988 to approximately 26,480,000 pounds in 1992. Reduction was not achieved evenly at all facilities nor did it occur in all states. In fact, the traditional paper production regions had uneven success in reducing toxic emissions. Twenty of the 30 states reporting releases of chemicals in 1988 had reduced the quantities released in their states by 1992. The greatest absolute reduction was in Alabama where over four million fewer pounds of chemicals were released to the environment, despite an increase in annual reports filed. The next greatest reductions were in Oregon and Washington. Thirteen other states, however, reported greater emissions in 1992 than in 1988. The greatest increase was in North Carolina, with more than two million additional pounds, nearly two and one-half times its 1988 levels. The next greatest increases were in Ohio and Pennsylvania.

In early 1991 the U.S. Environmental Protection Agency (EPA) initiated the 33/50 Program (as recommended in the 1990 Pollution Prevention Act), a voluntary toxic chemical release reduction program for 17 chemicals which pose serious health and environmental concerns, are high volume industrial chemicals with substantial releases, and can be reduced through P2. Chloroform is a 33/50 Program chemical, whereas chlorine is not. Participating corporations were asked to develop facility-specific reduction plans in order to meet a national goal of 33% reduction by 1992 and a 50% reduction by the year 1995 (using 1988 production as the base year). Furthermore, the EPA would provide technical and other forms of assistance (e.g., data) in order to help facilities meet reduction goals. The program did not involve grants or other monies provided directly to the firms or facilities.

The P2 results achieved by both the 33/50 Program facilities and non-participating paper production facilities are analyzed in this paper to assess the role of facility, corporate, county, and state characteristics in reducing toxic emissions. Releases within the paper industry are descriptively analyzed and several hypotheses specific to chlorine and chloroform releases from paper facilities are tested using univariate and multivariate statistical techniques.

A Conceptual Model of Pollution Reduction

Geographers often have asked why some places are more hazardous or polluted and why some people (or groups of people) suffer disproportionately frequent or disproportionately severe losses.[5] Several characteristics are most commonly identified as the best explanatory factors: the nature of the hazard (i.e., the action or condition which can cause death, injury or damage), the risk of the hazard (i.e., the probability that a hazard will occur), and the vulnerability of the affected population (i.e., the likelihood that an individual or group will be exposed to and adversely affected by a

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5 *See* Michael J. Watts & Hans G. Bohle, *The Space of Vulnerability: The Causal Structure of Hunger*, 17 Progress in Hum. Geog. 43 (1993); *see also* Susan Cutter, Living with Risk (1993) and Piers Blaikie et al., At Risk: Natural Hazards, People's Vulnerability, and Disasters (1994).

hazard). This study focuses on the reasons behind changes in the extent and frequency of toxic releases over time.

In hazards research, natural and technological hazards are most typically presented as events which result from physical properties of the environment, the engineering process, or social, cultural and political factors. Some places are more likely to experience such events because of physical environmental conditions or technological problems. The risk facing a locale can be defined by the frequency and intensity of the events. Interrelations of hazards as a series of events produce the hazardousness of a place as exemplified in Hewitt and Burton's study of all natural disasters occurring in and around London, Ontario.[6] Although this initial analysis did not progress beyond description, it established the notion that hazards could be considered part of the process that forms the character of a locale.

Scholars have also focused attention on the differing relative impacts of hazardous events. Some communities or groups respond differently to hazards and are more prone to exposure or are more vulnerable than others.[7] While some define vulnerability qualitatively and others quantitatively, implicit or explicit in the research is the view that the nature and impact of the hazard is dependent on the context in which it occurs. This "hazards-in-context" approach was proposed and discussed by many researchers since the early 1980s.[8] They argued

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6 *See* Kenneth Hewitt & Ian Burton, The Hazardousness of Place: A Regional Ecology of Damaging Events (1971).

7 *See e.g.,* Carlo Pelanda, *Disaster and Sociosystemic Vulnerability,* Disaster Research Center, Preliminary Paper #68 (U. of Del. 1981); *see also* Peter Timmerman, *Vulnerability, Resilience and the Collapse of Society,* Institute for Envtl. Studies Monograph 1, (U. of Toronto 1981) 1; Paul Susman, Phil O'Keefe & Ben Wisner, *Global Disasters, A Radical Interpretation*, Interpretations of Calamity, 263, 280 (Kenneth Hewitt ed., 1983); Diana M. Liverman, Vulnerability to Global Environmental Change, Understanding Global Environmental Change, The Contributions of Risk Analysis and Management, 27 (Roger E. Kasperson et al, eds., 1990); Cutter, *supra* note 5; Blaikie et al., *supra* note 5; and Roger Kasperson, *Global Environmental Hazards: Political Issues in Societal Responses,* Reordering the World: Geopolitical Perspectives on the 21st Century, 141 (George J. Demko & William B. Wood eds., 1994).

8 *See e.g.,* Kenneth Hewitt, Interpretations of Calamity (1983); *see also* Nothing to Fear: Risks and Hazards in American Society (Kirby Andrew ed, 1990); *see also* James K. Mitchell, *Why Do Geographers Study Hazards,* Geography in America (Gary L. Gaile & Cort J. Willmott eds., 1989); *see also* Risa I. Palm, Natural Hazards — An Integrative Framework for Research and Planning (1990); *see also* Michael Watts, *On the Poverty of Theory: Natural Hazards Research in Context,*

that broader political, economic, and social structures play a role in the development and impact of hazards and risk. In this setting, hazards are understood as more than discrete events. Their occurrence and impacts are the result not only of the likelihood or magnitude of a particular event, but also of the larger societal setting, including such things as the patterns of investment and disinvestment, the changing role of government, and the achievements of community and workplace safety struggles. The hazards-in-context framework has emerged as a way to integrate conceptions of risk and hazard with theories of organizational behavior, economic development, political economy, and the state, resulting in an improved understanding of hazard causality.

The hazards-in-context approach is also useful for identifying social processes that lead to the development of high-risk and low-risk regions. Much of the work in this field has focused on chronic natural hazards such as droughts and desertification and, to a lesser extent, acute events such as earthquakes and extreme storms.[9] The hazards-in-context approach has been applied fruitfully to acute and chronic technological hazards. For example, extensive research has been done recently on the processes that result in specific places and populations suffering a disproportionately large share of technological hazards, including polluted water supplies, hazardous waste sites, and acute and chronic toxic airborne emissions. Researchers argue, for example, that the spatial variation of environmental degradation and exposure to environmental pollutants are an expression of uneven development, economic dependency and/or environmental racism.[10]

Given that argument, it can be asserted that the reduction of toxic releases is at least partially a product of the economic, political, and

Interpretations of Calamity, 231 (Kenneth Hewitt ed. 1983); *see also* Watts & Bohle, *supra* note 5; *see also* Anders Wijksman & Lloyd Timberlake, Natural Disasters, Acts of God or Acts of Man (1984).

9 *See* Hewitt, *supra* note 8; *see also* Sallie A. Marston, *Natural Hazards Research: Towards a Political Economy Perspective,* 2 Political Geog. Qtly. 339 (1983); *see also* Wijksman & Timberlake, *supra* note 8; *see also* Piers Blaikie & Harold Brookfield, Land Degradation and Society (1987); *see also* Robert Geipel, Disaster and Reconstruction: The Friuli (Italy) Earthquakes of 1976 (1982); *see also* James K. Mitchell, Neal Devine & Kathleen Jagger, *A Contextual Model of Natural Hazard,* 79 Geog'l. Rev. 391 (1990).

10 *See* Robert D. Bullard, Dumping in Dixie: Race, Class and Environmental Quality (1990); *see also* Race and the Incidence of Environmental Hazards (Bunyan Bryant & Paul Mohai eds., 1992); *see also Race, Waste, and Class: New Perspectives on Environmental Justice,* 28 Antipode, Special Issue (1996).

social contexts in which the manufacturing process takes place. More specifically, one can define four primary factors associated with the rate of release reduction: (1) engineering conditions and production process changes (e.g., changes in bleaching methods and technological developments in pulpmaking); (2) industrial organization and market conditions (e.g., corporate structure, price competition); (3) the context of community or place (e.g., level of poverty, underdevelopment, unemployment, or reliance on single industries); and (4) state functions (e.g., regulations, policies, and institutions). These factors generate the hypotheses tested in this study and are discussed in more detail below.

Facility Conditions and Corporate Behavior

Historically, many U.S. corporations began to reduce hazardous waste primarily for expected economic benefits.[11] Studies of more recent attempts at waste reduction point to other primary incentives, such as the promotion of good corporate-public relationships and the hope of foregoing more stringent regulation. These, too, however, were ultimately tied to profits. Over the last several decades attempts have been made to sensitize corporations to the wide range of social concerns that result from their operations. During the mid-1980s, U.S. industry increasingly recognized that public concern over environmental issues, particularly pollution, would not fade. Industry became acutely concerned about public opinion after the publication of 1986 chemical release data. A report stated that all U.S. industries released (and transferred) over 22.5 billion pounds of toxic chemicals during that year.[12] Industry recognized the need to be more proactive (particularly after the Act required them to report environmental releases) and to initiate environmental programs that the public perceived as meaningful.[13] This approach was designed to promote a good neighbor image and demonstrate facilities' concern for local quality of life.

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11 *See* Craig Colten, *Historical Development of Waste Minimization*, 11 Envtl. Prof. 94 (1989).

12 Office of Pollution Prevention, *Toxics Release Inventory: A National Perspective*, (EPA 1989).

13 *See* Reid Miner & Jay Unwin, *Progress in Reducing Water Use and Wastewater Loads in the U.S. Paper Industry*, 74 Tappi J. 127 (1991).

Organizational theorists in an explanation of the greening of industry, state that industry and individual facility representatives are increasingly driven by external forces to make their manufacturing plants less environmentally degrading and less polluting.[14] A related claim is that corporate policy shifts have occurred because of a firm's greater "visibility" to the media and public, and because of increasing environmental awareness among industry leaders.[15] Larger corporate parent companies with numerous facilities tend to be more visible, hence are under greater scrutiny and might be more responsive to local environmental concerns. Larger corporations, therefore, should, because of their visibility and financial wherewithal, be expected to be more likely to initiate efforts to reduce environmental degradation and the pollution that their facilities emit. In order to quantify the effects that facility and corporate size have on P2 programs at individual facilities, two variables were created. Each facility is classified by the size of the workforce at the facility and were deemed either large (more than 500 workers) or small (fewer than 500 workers). Larger facilities are expected to be more prominent and visible in a community. Similarly, large corporations receive more attention based upon their economic and international prominence. The 170 facilities emitting chlorine, chloroform, or both chemicals over the study period were owned by about 65 corporations. These companies ranged from major international corporate owners (like DuPont, International Paper, and Kimberly-Clark Corp.) to smaller corporations with local and/or regional importance (like Appleton Papers, Mississippi Chemical, and Wausau Paper Mills Co.). International Paper alone owned 15 paper plants around the U.S. during the study period. Most of the remaining paper mills discussed here were parts of smaller corporations with fewer

[14] *See e.g.*, Thomas N. Gladwin, *The Meaning of Greening: A Plea for Organization Theory*, Environmental Strategies for Industry: International Perspectives on Research Needs and Policy Implications, 37 (Kurt Fischer and Johan Schot eds., 1993).

[15] *See* Matthew J. Coleman, *The Paper Industry and the Environment*, 73 Tappi J. 105 (1990); *see also* Robert W. Hanley, *Setting the Scene for Environmental Compliance in the Last Decade of the Twentieth Century*, 73 Tappi J. 155 (1990); *see also* Judith Lichtenberg & Douglas MacLean, *The Role of the Media in Risk Communication*, Communicating Risks to the Public, 157 (Roger E. Kasperson & Pieter M. Stallen eds., 1991); *see also* Ortwin Renn & Debra Levine, *Credibility and Trust in Risk Communication*, Communicating Risks to the Public, 175 (Roger E. Kasperson & Pieter M. Stallen eds., 1991).

facilities to manage. Corporate owners of paper facilities were classified as large if they were listed in the top quartile of the Fortune 500 and small if not in that group.

Another measure of industrial facility responsiveness can be discerned by a plant's participation in voluntary programs designed to enable P2 activities. By March 1992, for instance, 139 paper industry companies had been approached by the EPA and were invited to participate in the 33/50 Program. Slightly more than 25% (35 out of 139) were participating in the Program, twice the average for all industrial codes.[16] The Program began to achieve results by 1992. The EPA began investigating the reduction performance of participating firms and non-participating firms and found that between 1988 and 1991 participating firms reported a nearly 36% decrease in releases, compared to only a 20% decline reported by nonparticipants. They also compared the rates for Program chemicals and non-Program chemicals. In the first year after formal announcement of the 33/50 Program, the releases of the 17 Program chemicals were reduced by 21%, substantially greater than the reductions for all other chemicals, which were reduced by only 8%.[17] Corporate participation in the 33/50 Program is included as a dichotomous variable.

Place, Space, and Pollution Reduction: Economics and Community Dependence

Links between economic dependency, poverty, and exposure to environmental hazards in the U.S. are relatively well documented.[18] Communities that are dependent on one particular economic activity (such as chemical manufacturing or fishing) become vulnerable to the hazards associated with that activity (such as losses due to global shifts in capital production strategies, depletion of the resource base, or the contamination of the local physical environment).

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16 *See* Office of Pollution Prevention and Toxics, *EPA's 33/50 Program Second Progress Report Reducing Risks Through Voluntary Action* (EPA 1992), T5-792A.

17 *See* EPA (1993), *supra* note 2.

18 *See* Bryant & Mohai, *supra* note 10; *see also* Communities in Economic Crisis (John Gaventa, Barbara Ellen Smith & Alex Willingham eds., 1990); *see also Rural Sociological Society Task Force on Persistent Rural Poverty*, Persistent Poverty in Rural America (1993).

Economic dependency also dampens local environmental activism. Others have suggested that in communities in which a substantial percentage of local income and revenue is derived from a single large facility local residents will be less likely to oppose environmental pollution from the facility.[19] The general concern is that the facility might be relocated if pressure came to bear on the facility or its parent company.[20] Separate case studies have suggested that a pervasive "mill town" atmosphere is a primary reason that strong environmental coalitions do not develop in communities dominated by one large polluting facility with few alternative employment opportunities.[21] Dependency also develops in counties with higher poverty and unemployment rates. For instance, half of the paper manufacturing facilities evaluated in this study were located in counties with more than 9.7% (approximately the U.S. average in 1989) of the population in poverty; higher rates of unemployment should be expected to suppress community activism further. The more economically dependent on a facility a community is, the less likely it is that local residents will pressure the facility to make significant toxic release reductions. Although paper mills are commonly perceived to be rural industries, the majority of paper manufacturing employment is located in metropolitan areas. Therefore, the assertions put forth are potentially important external factors guiding facility management practices.

Four variables represent measures of a county's lack of economic diversity, employment opportunities and the perceived risks associated with community demands of increased local industrial environmental protection. These variables include: the rurality of the county (part of a metropolitan statistical area), the overall amount (number of manufacturing employees living in county) and importance of

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[19] *See* Louise Fortmann & Jonathan Kusel, *New Voices, Old Beliefs: Forest Environmentalism Among New and Long-Standing Rural Residents*, 55 Rural Soc. 214 (1990); *see also* Gary E. Machlis & Jo Ellen Force, *Community Stability and Timber-Dependent Communities*, 53 Rural Soc. 220 (1988).

[20] *See* Richard Feiock et al., *Environmental Regulation and Economic Development: The Movement of Chemical Production Among States*, 43 West. Pol. Q. 561 (1990).

[21] *See* William D. Solecki, *Paternalism, Pollution and Protest in a Company Town*, 15 Pol. Geog. 5 (1996); *see also* Conner Bailey, Charles E. Faupel & James H. Gundlach, *Environmental Politics in Alabama's Blackbelt*, Confronting Environmental Racism: Voices from the Grassroots, 107 (Robert D. Bullard ed., 1993).

manufacturing employment in the county (relative ranking of manufacturing sector of employment), and the level of poverty in the county (percentage of families). The percentage of a county's workforce employed in the paper industry would be the best measure of the dependence upon that industry. The U.S. census, however, avoids reporting any data that might describe any single facility. This precludes the use of facility-specific variables.

Politics of Pollution Control

Another factor associated with the success of facility emissions reduction programs is the strength of state environmental policies. With the New Federalism of the 1980s and the 1990s and the continued decline of the federal government as a policy initiator, states and localities have more actively initiated environmental policies themselves. This phenomenon has resulted in wide spatial differences in environmental protection programs and enforcement throughout the U.S. One argument is that the New Federalism during the Reagan era allowed for development of two types of states:[22] active states that adapt federal mandates to their own priorities, and captive states that have been overwhelmed by federal cutbacks and have not been able to respond because of state budget constraints. Some states, for example, have begun to take the lead in toxics protection while others have fallen behind.[23] The policies of active states are expected to be more successful tools for protecting the local environment.[24]

As some states have become more active in initiating environmental policies, substantial policy and enforcement differences have emerged among states with large potentially hazardous facilities (such as paper mills). Based on this premise, environmental pollution reduction and

22 *See* Cristy A. Jensen, Richard Krolak & Anne C. Cowden, *Implementing Title III: Assessing Opportunities for State Activism*, 10 Pub. Budg. & Fin. 54 (1990).

23 *See* Virginia D. McConnell & Robert M. Schwab, *The Impacts of Environmental Regulation on Industry Location Decisions: The Motor Vehicle Industry*, 61 Land Econ. 67 (1990).

24 *See* Jensen, Krolak & Cowden, *supra* note 22; *see also* Charles E. Davis & James P. Lester, *Federalism and Environmental Policy*, Environmental Politics and Policy, 57 (James P. Lester ed., 1989); *see also* Michael R. Greenberg, Frank J. Popper & Bernadette M. West, *The Fiscal Pit and the Federalist Pendulum: Explaining Differences Between US States in Protecting Health and the Environment*, 11 Environmentalist 95 (1991); *see also* James P. Lester, *A New Federalism? Environmental Policy in the States*, Environmental Policy in the 1990s, 59 (Norman J. Vig & Michael E. Kraft eds., 1990).

better compliance should be found in states with stronger environmental legislation and enforcement records. For example, as of the end of 1990, 21 states had established a P2 policy and/or goal through legislation, and a larger set of states have initiated programs to encourage P2 in general.[25]

In our study, political action is measured in three ways; two of which pertain directly to state-level pollution reduction efforts. These two measurements focus one whether a state has pollution reduction assistance programs and how many P2 laws have been enacted in each state. It should be noted that while presence and number of laws does not indicate program effectiveness, presence does indicate state-level government recognition and interest in pollution control. The third measure is a relative ranking of the overall environmental initiative taken by each state based upon the State Policy Initiatives rankings portion of the Green Index.[26] The Green Index is a ranking of states based on 256 indicators of their environmental health. These include, among others, indicators of air quality, water quality, energy use and production, transportation efficiency, community health, and toxic chemical waste production. A subset of the indicators is used to compare the environmental activity or strength of state policy initiatives using 73 indicators.

Chlorine and Chloroform in Paper-making and Human Health

The move toward less use of and reliance upon chlorine (particularly organochlorines) in paper-grade bleached kraft pulp mills began in the mid-1980s in response to heightened concerns generated by the 1985 discovery of dioxin in paper mill effluents.[27] Dioxins and furan compounds are believed by many to be the most toxic synthetic compounds on earth. Researchers determined the source of these materials to be the elemental chlorine and chlorine compounds (i.e. halogens) used to bleach the pulp.[28] Technological developments have

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[25] *See* Office of Pollution Prevention, *Pollution Prevention 1991, Progress on Reducing Industrial Pollutants,* (EPA 1991), EPA 21P-3003.

[26] *See* Bob Hall & Mary Lee Kerr, 1991-1992 Green Index, A State-by-State Guide to the Nation's Environmental Health (1991).

[27] *See* Thomas J. McDonough, *Recent Advances in Bleached Chemical Pulp Manufacturing Technology,* 78 Tappi J. 55 (1995).

led to attempts to remove adsorbable organic halogens (AOX): reduced-chlorine and non-chlorine bleaching processes that employ oxygen compounds (like chlorine dioxide and nitrogen dioxide), peroxide, and ozone; adjustments in the timing, sequencing of steps, and manner of bleaching the pulp; biological treatment; and effluent-free facilities.[29]

Since 1990, the new processes, called elemental chlorine-free (ECF) and totally chlorine-free (TCF), have been adopted widely by the paper industry. ECF paper production worldwide grew from 3.5 million metric tons in 1990 to over 23 million metric tons in 1994. TCF increased from zero in 1990 to over 4 million metric tons in 1994. The use of ECF technology has grown worldwide, but in general, the adoption of TCF has been limited to Europe. This is primarily because producers doubt the demand for and marketability of the more expensive paper product generated by TCF processes.[30]

Chlorine, chloroform, and their byproducts, the AOXs, have been classified as extremely hazardous substances by the EPA and studies have identified links to human health impacts.[31] Sub-lethal exposures to chloroform can cause cancer, birth defects, liver, kidney, eye and nervous system damage.[32] Dioxins, a family of 75 AOX compounds,

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28 *See* Terry L. Pulliam, *Pulp Bleaching: Low and No Chlorine Methods,* Papermaker, July 1993, at 18.

29 *See* Pulliam, *supra* note 28; *see also* McDonough, *supra* note 27; *see also* Charles E. Swann, *The Case for ClO2: Pollution Prevention Chemistry At Its Best,* in Papermaker at 36 (January 1994); Nic Soteland et al., *Reducing Discharges from Sulfite Pulp Bleach Plant,* 74 Tappi J. 119 (1991); *see also* Andrei L. Barkovskii & Peter Adriaens, *Microbial Dechlorination of Historically Present and Freshly Spiked Chlorinated Dioxins and Diversity of Dioxin-Dechlorinating Populations,* 62 Appd. & Envtl. Micro. 4556 (1996); *see also* Hendrik Ballerstedt, *Reductive Dechlorination of 1,2,3,4-Tetrachlorodibenzo-p-dioxin and Its Products by Anaerobic Mixed Cultures from Saale River Sediment,* 31 Envtl. Sci. & Tech. 1749 (1997); *see also* Subhash Chandra *The Effluent-Free Kraft Pulp Mill: Myth or Reality?,* in Papermaker at 40 (November 1993); *see also* Ronald T. Klinker, *Zero Discharge: Hennepin Paper Aims to Eliminate Effluent,* in Papermaker at 28 (April 1994); *see also* Jerome A. Koncel & Jackie Cox, *A Hot Topic: New Pulp Bleaching Processes Continue to Crop Up on the Horizon,* in Papermaker at 26 (October 1994); *see also* Jean-Claude Patel, *Zero Discharge: Recycling Mills Can Lower Water Discharge Without Sacrificing Quality,* in Papermaker at 36 (January 1995).

30 *See* McDonough, *supra* note 27.

31 *See* Appendix D — list of extremely hazardous substances, threshold planning quantities, and reportable quantitites. 51 Fed. Reg. 41,582 (EPA 1986); *see also* R.D. Morris et al., *Chlorination, Chlorination By-Products, and Cancer: A Meta-Analysis,* 82 Am. J. Pub. Health 955 (1992); *see also* John Tibbetts, *What's in the Water: The Disinfectant Dilemma,* 103 Envtl. Health Perspectives 30 (1995).

and furans, a closely related group that is structurally similar to and almost as toxic as dioxins, are byproducts of the bleaching process that raise the greatest concerns about human and environmental health.[33] Both compounds persist in the environment and bioaccumulate in organisms.[34] Furthermore, dioxins are known to be extremely toxic to animals in controlled experiments causing deaths, cancers, birth defects, and fetal deaths.[35] The evidence for effects on non-laboratory animals and on humans is controversial. Little consensus has been achieved and the risk remains a controversy, however the EPA has recently labeled dioxin a "known" carcinogen.[36] Evidence is building against chlorine compounds that mimic the human endocrine system including the hormones estrogen and testosterone.[37]

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32 *See* Material Safety Data Sheet — Chloroform (EPA 1989).

33 *See* Janet Raloff, *Those Old Dioxin Blues,* 151 Sci. News 306 (1997).

34 *See* Vic Peck & Ralph Daley, *Toward a "Greener" Pulp and Paper Industry: The Search for Milleffluent Contaminants and Pollution Prevention Technology,* 28 Envtl. Sci. & Tech. 524 (1994).

35 *See* Kathryn Harrison & George Hoberg, *Setting the Environmental Agenda in Canada and the United States: The Cases of Dioxin and Radon,* 24 Can. J. Pol. Sci. 3 (1991).

36 *See* Harrison, *supra* note 36; *see also* Peck, *supra* note 35; *see also Is It Science? EPA's Dioxin Reassessment Stirs Debate,* 7 J. NIH Res.: Life Sci. Res. 34 (1995); *see also Dioxins Exhibit Multiple Toxic Pathways,* 31 Envtl. Sci. & Tech. 18A (1997); *see also EPA Dioxin Risk Methods Challenged,* 31 Envtl. Sci. & Tech. 130A (1997); *see also Dioxin Labeled a "Known" Carcinogen,* 31 Envtl. Sci. & Tech. 18A (1997); *see also* Harold J. Geyer et al., *Considerations on Genetic and Environmental Factors That Contribute to Resistance of Sensitivity of Mammals Including Humans to Toxicity of 2,3,7,8-Tetrachlorodibenzo-Dioxin (TCDD) and Related Compounds. Part 1: Genetic Factors Affecting the Toxicity of TCDD,* 36 Ecotoxicology & Envtl. Safety, 213 (1997).

37 *See* John Ashby et al., *The Challenge Posed by Endochrine-Disrupting Chemicals,* 105 Envtl. Health Perspectives 164 (1997); *see also* William H. James, *Reproductive Effects of Male Dioxin Exposure,* 105 Envtl. Health Perspectives 162 (1997); *see also* William H. James, *The Sex Ratio of Offspring Sired by Men Exposed to Wood Preservatives Contaminated by Dioxin,* 23 Scandinavian J. Work, Env. & Health. 69 (1997); *see also* A. Mayani, S. Barel & M. Almagor, *Dioxin Concentrations in Women with Endometriosis,* 12 Hum. Reproduction 373 (1997); *see also* Katherine I. Nodland, Mark Wormke & Stephen Safe, *Inhibition of Estrogen-Induced Activity by 2,3,7,8-Tetrachlorobenzo-P-Dioxin (TCDD) in the MCF-7 Human Breast Cancer and Other Cell Lines Transfected with Itellogenin A2 Gene Promoter Constructs,* 338 Archives of Biochemistry & Biophysics 67 (1997); *see also* J.T. Sanderson, D.M. Janz & J.P. Giesy, *Effects of Embryonic and Adult Exposure to 2,3,7,8-Tetrachlorodibenzo-P-Dioxin on Hepatic Microsomal Testosterone Hydroxylase Activities in Great Blue Herons (Ardea Herodias)* 16 Envtl. Toxicology & Chemistry 1304 (1997).

Methods and Data

The research hypotheses in this study focus on the association between the level of pollution reduction and the internal and external contextual factors of each facility. The internal factors include the engineering of, operation of, and economic considerations of the facility and its corporate owner/manager. The external factors include the socio-economic (community and county) and political (state-level) contexts of the facilities. It is argued that engineering of a facility's infrastructure and/or process to achieve pollution reduction is partially represented by participation in the 33/50 Program because the program was created to foster problem-solving and transfer of technology to participant corporations and facilities to reduce environmental pollution. Because of the proprietary nature of each facility's operations, facility-engineering data were considered to be beyond the scope of this paper. Hypotheses relating to the other three factors were tested.

Hypotheses from the literature related to the character of the facility and the parent company include: (A1) larger paper manufacturing facilities (those with more than 500 employees) will have greater reductions than the smaller facilities; (A2) parent companies participating in the 33/50 Program will have greater reductions than non-participating firms; and (A3) larger parent companies (those with greater sales) will have greater reductions than smaller parent companies. Hypotheses derived from the local economics and dependency literature include: (B1) facilities in counties with greater numbers of manufacturing employees will have greater reduction than those in counties with fewer employees; (B2) greater reductions will be achieved by facilities in counties in which manufacturing is among the top three employment sectors; (B3) facilities in counties with higher poverty rates will achieve less reduction than facilities in counties with lower poverty rates; and (B4) facilities in urban counties will have greater reductions of pollution emissions. Hypotheses derived from the state environmental policy literature are that facilities in states with (C1) P2 assistance programs and (C2) P2 laws will have greater reductions than facilities in states without such policies; and (C3) facilities in states with strong environmental records overall will have greater reduction than facilities in states with weaker records.

Table 1[38]
Variables Used in the Analysis

Name	*Description*	*Expected Association with Pollution Reduction*	*Variable Type*	*Source*
Facility and Parent Company				
33/50 Program Chemical	Whether or not the chemical released was an EPA's 33/50 Program chemical	+	Nominal	a
Facility Size	Whether or not the facility employed more than 500 people	+	Nominal	b
33/50 Program Firm	Whether or not the parent company was a member of the EPA's 33/50 Program as of February 1992	+	Nominal	b
Fortune 500 Firm	Whether or not the parent company was listed among the top quartile of the companies on Fortune magazine 1991 *Fortune 500 List* (the list is ordered by volume of sales)	+	Nominal	c
Local Economics				
Manufacturing Employment	Number of manufacturing employees in the county in which the facility is located	+	Ratio	d
Manufacturing Rank	Rank order number of manufacturing employees in the county in which the facility is located (0 - 0 to 5,000 employees; 1 - 5,000 to 10,000 employees; 2 - 10,000 to 30,000 employees; 3 -more than 30,000 employees)	+	Ordinal	c
Poverty Level	Percentage of families living below the poverty rate in the county in which the facility is located	-	Ratio	f
Metropolitan County	Whether the county is metropolitan county, as defined by the U.S. Census Bureau	+	Nominal	f
State Policy				
P2 Assistance	Presence of grants/award/financial assistance to firms given by the state in which the facility is located	+	Nominal	g
P2 Laws	Number of state-level pollution prevention laws	+	Ratio	g
State Environmentalism	Rank of state in regards to state policy initiatives	+	Ordinal	h

38 Sources: (a) Office of Pollution Prevention and Toxics, EPA'S 33/50 Program Second Progress Report Reducing Risks Through Voluntary Action, T5-792A (EPA 1992); (b) e.g., Census of Manufacturers 1987, County Business Patterns, Ward's Business Directory of U.S. Private and Public Companies, Dun & Bradstreet Reference Book of Corporate Managements, 1988 Lockwood-Post's Directory of Pulp, Paper and Allied Trades, and 1992 Industry Update & Mill Guide; (c) Fortune 500 Largest U.S. Industrial Corporation, Fortune, Apr. 20, 1992, at 220; (d) U.S. Department of Commerce, Census Bureau, 1990 County Business Patterns (1990); (e) *Id.* (calculated by author); (f) U.S. Dept. Commerce, Census Bureau, City and County Data Book, (1994); (g) Office of Pollution Prevention, Progress on Reducing Industrial Pollutants, (1991); and (h) Bob Hall & Mary Lee Kerr, 1991-1992 Green Index, A State-by-State Guide to the Nation's Environmental Health (1991).

Data on chronic releases were gathered from the TRI. These data describe the planned chronic legal releases from each reporting facility. Because of widely recognized inconsistencies present in the first year of data (1987), the data record covers the years 1988–1992. The analysis will focus on the total volume of releases of chlorine and chloroform to the environment. The dependent variables used in these analyses included the absolute quantity of toxic chemical release reduction achieved at each paper manufacturing facility. Data on the socio-economic and political variables were gathered from a wide range of sources. These included state and federal government documents and censuses, business reports, and NGO publications (Table 1). Because of the varying quality of the data, it was decided that a data reduction procedure should be performed to make the variables all dichotomous, thereby reducing their skew.

After an initial examination of the data for all chemical releases in the paper industry, several statistical procedures were performed to determine the factors associated with reduction in chlorine and chloroform pollution levels. A total of 1009 release reports were examined for the five-year period to establish an industry-wide trend regarding chlorine and chloroform pollution (Tables 2 & 3). The results indicate that there were significant reductions for both chemicals, particularly for chlorine. Given the non-parametric nature of the data, further analysis was performed using Spearman's correlations, Mann-Whitney U-tests, and principal components analyses.

Table 2[39]

Number of Environmental Toxic Release Inventory Reports

Chemical	*1988*	*1989*	*1990*	*1991*	*1992*
Chlorine	120	128	131	125	123
Chloroform	66	76	80	80	80
Total	186	204	211	205	203

39 Authors derived from EPA's 1987-1992 Toxic Release Inventory (CD-ROM 1994). Chloroform is a 33/50 Program chemical.

Table 3[40]

Volume of Chlorine and Chloroform Environmental Toxic Release Inventory Reports

Chemical	*1988*	*1989*	*1990*	*1991*	*1992*	*Percentage Change (1988-92)*
Chlorine	13,418,424	7,577,420	4,580,639	3,604,486	2,579,072	-80.8
	(111,820.2)	(59,198.6)	(34,966.7)	(28,835.9)	(20,968.1)	(-81.2)
Chloroform[1]	14,911,949	14,731,664	14,438,953	13,327,843	12,403,661	-16.8
	(225,938.6)	(193,837.7)	(180,486.9)	(166,598.0)	(155,045.8)	(-31.4)

Results

Factors Associated with Release Reduction of Chlorine

Spearman's correlation statistics and Mann-Whitney U tests only partially support the hypotheses that pertain to environmental releases of chlorine (Tables 4 & 5).[41] Among the comparisons of ranks of facilities based on chlorine release reduction and the independent variables, the only significant correlation is that between manufacturing rank and rank of release reduction (Table 4). This translates into a slight tendency for mills in counties with lower percentages of manufacturing employees to make greater reductions in chlorine releases (rs = .14, ps = .1). This was also supported by the results of the Mann-Whitney U test (p = .1). County poverty levels were associated with greater amounts of release reduction (Table 5). Counties with higher poverty levels had significantly greater average reductions of chlorine releases than counties experiencing lower rates (p = .05).

As expected, however, larger facilities were more likely to have significantly greater reductions of chlorine releases (p = .1). There appears to be little relationship between the strength of a state's initiative toward environmental protection and reduction success.

40 *Id.* (Total volume average per release report all measures in pounds).

41 In Tables 4-6, * incidates significance at the 0.1 level; ** at the 0.01 level.

Table 4
Spearman's Correlation for Ranked Changes of Quantities of Chemicals Released, and the Facilities and Their Contexts, 1988–92

Variable	*Rank of Changes in Amount of Chlorine Releases (number of facilities)*	*Rank of Changes is Amount of Chloroform Releases (number of facilities)*
Facility Size	.01	-.32**
	(134)	(82)
Fortune 500 Firm	-.02	-.11
	(140)	(83)
33/50 Program Firm	-.02	-.21
	(140)	(83)
Metropolitan County	.04	.03
	(140)	(84)
Poverty Level Rank	.08	-.16
	(140)	(84)
Manufacturing Employment Rank	.14*	.01
	(141)	(84)
P2 Laws Rank	-.10	.04
	(141)	(84)
P2 Assistance	.03	.19
	(141)	(84)
State Environmentalism Rank	-.02	-.12
	(141)	(84)

Table 5
Mann-Whitney U-Test Results of Chlorine Release Changes,1988–92: Significance of Difference between Mean Ranks of Groups Defined by Possession of Variable Characteristic

Variable	*Mean Rank Group 1*	*Mean Rank Group 2*
Facility Size	64.13	52.68*
Fortune 500 Firm	65.36	62.93
33/50 Program Firm	66.13	63.31
Metropolitan County	68.88	71.99
Poverty Level	78.27	63.57**
Manufacturing Rank	62.91	75.31*
P2 Laws	69.22	61.94
P2 Assistance	69.28	72.03
State Environmentalism	72.07	70.00

For Facility Size, Fortune 500 Firm, 33/50 Program Firm, Metropolitan County, and P2 Assistance, Group 1 releases do not hold that property, and Group 2 releases do hold that property. For Poverty Level, Manufacturing Rank, P2 Laws, and State Environmentalism, nominal variables were constructed from the original ratio or ordinal variables defined as: Poverty level: Group 1 = 0% to 9.7% and Group 2 = 9.7% to 39.3%. Manufacturing rank: Group 1 = facilities in counties where manufacturing didn't rank first, second or third in employment in county and Group 2 = facilities in counties where manufacturing was among the three most important employment sectors. P2 laws: Group 1 = facilities in states with no laws and Group 2 = facilities in states with 1, 2, 3, 4 or 8 laws. State environmentalism: Group 1 = facilities in states that ranked in the top 12 on the Green Index and Group 2 were in states that did not. Again, * incidates significance at the 0.1 level; **at the 0.01 level.

Factors Associated with Release Reduction of Chloroform

A similar set of analyses performed on the data describing chloroform releases produced statistically significant evidence to support two of the stated hypotheses regarding internal factors and pollution reduction. Both the Spearman's correlation (Table 4) and the U-test (Table 6) confirm the hypothesis that larger facilities should achieve larger amounts of pollution reduction ($rs = -.32$, $ps = .01$ and $p = .01$, respectively). As expected, 33/50 Program firms also achieved much greater average reductions than did non-Program firms ($p = .01$). Non-Program firms in fact, on average, increased their chloroform output by nearly 30,000 pounds. One hypothesis regarding an external contextual factor, however, was refuted by the analysis of the chloroform release data. Unexpectedly, facilities in states without P2 laws were somewhat more likely to have achieved significantly greater decreases in chloroform releases ($p = .1$) (Table 6).

Unlike the analysis of ranked chlorine release changes, the ranked chloroform release analysis supports the associated absolute changes of chloroform emissions. Spearman's correlations and U-tests show the greatest reductions are most likely at large facilities and those that were taking part in the 33/50 Program.

The Spatial Setting of Toxic Release Reduction

To untangle these somewhat contradictory results, we decided to use principal components analysis to help identify the internal and external characteristics of facilities most strongly associated with the reduction of releases of chlorine and chloroform. Two separate analyses were employed. The same variables were included in both.

The principal components analysis of ranked chlorine release changes from 1988 to 1992 produced five factors. The third through fifth factors are most pertinent to the questions posed here. About 10% of the total variation explained by the five factors generated was accounted for by the fourth factor, which we'll call the "release factor."

This component best identifies either small facilities, located in states without P2 assistance programs, which have reduced a large percentage of their chlorine releases over the four-year study period, or large facilities, located in states with P2 assistance programs, which have not effectively reduced their releases (0.65) during the period. Examples of the large facilities are found in Pennsylvania, Minnesota, and Wisconsin. International Paper, Potlatch, and James River own these plants, respectively. Smaller facilities are found in Maine, Virginia and Washington and are owned by James River, American Tobacco, and Simpson Paper, respectively. Additionally, component five explains about 10% of the variation. This component represents both the large urban facilities that reduced their chlorine releases (-0.39) and the small rural ones that didn't. For example, Monroe County, Alabama's Parsons & Whitmore plant, Nez Perce County, Idaho's Potlatch plant, Haywood County, North Carolina's Champion Paper plant, and Marlboro County, South Carolina's Willamette Paper plant are of the latter variety. The third factor represents about 14% of the variation. This component is weaker on the relationship to release changes (0.28), but represents the urban facilities in industrial counties in the "green" states that have achieved reductions in releases. Facilities that loaded strongly on this factor are found in Oregon, Wisconsin and Florida. Conversely, this also highlights those facilities in rural, non-industrial counties in less environmentally active states.

Table 6
Mann-Whitney U-Test Results of Chloroform Release Changes 1988–92
Significance of Difference between Mean Ranks of Groups
Defined by Possession of Variable Characteristic

Variable	*Mean Rank Group 1*	*Mean Rank Group 2*
Facility Size	51.00	32.94**
Fortune 500 Firm	45.32	37.08
33/50 Program Firm	54.40	36.63**
Metropolitan County	41.78	43.19
Poverty Level	46.26	38.74
Manufacturing Rank	42.09	42.76
P2 Laws	41.67	43.04
P2 Assistance	36.97	46.26*
State Environmentalism	45.38	39.62

Table 7
Principal Components Analysis of the Chlorine Releases, 1988 and 1992
(e xplains 72.4% of the total variation)

	Factor 1	*Factor 2*	*Factor 3*	*Factor 4*	*Factor 5*
Release Change Rank	0.08	-0.07	0.28	0.65	-0.39
Facility Size	-0.04	0.07	0.04	0.51	0.77
Fortune 500 Firm	0.09	0.50	0.04	0.10	-0.03
33/50 Program Firm	0.11	0.49	0.02	0.05	-0.13
Metropolitan County	0.25	-0.11	0.41	-0.23	0.31
Poverty Level Rank	-0.37	0.12	0.01	-0.05	0.20
Manufacturing Employment Rank	0.35	-0.01	0.31	-0.10	0.10
P2 Laws	0.23	0.01	-0.42	-0.10	0.24
P2 Assistance	0.06	0.20	-0.19	0.43	-0.04
State Environmentalism Rank	0.29	0.01	-0.43	0.10	-0.03
Proportion of Explanation	20.6	17.7	13.5	10.3	10.3
Eigen Value	2.06	1.77	1.35	1.03	1.03

The principal components analysis of ranked chloroform release changes, 1988–92, produced four factors. The second and fourth factors are most important. About 13% of the total variation explained by the four factors was accounted for by the fourth, the best "release factor" generated by this analysis. Facilities identified by this factor are large, urban, less wealthy (not Fortune 500), and located in industrial counties that reduced their chloroform releases during the study period. Facilities that characterize this factor are Consolidated Paper's Wood County, Wisconsin plant and Simpson Paper Company's Oregon plant. Champion International's Haywood County, North Carolina facility and Georgia-Pacific's Washington County, Maine plant are two examples of smaller, rural operations owned by Fortune 500 firms that didn't reduce their chloroform output as effectively.

The second factor might be called the "33/50 Factor" as it represents Program facilities that have reduced their chloroform releases. Smaller companies operate these facilities in counties with lower poverty rates. Wisconsin is home to four plants that fit these criteria. Pope & Talbot, Fort Howard Paper, Wausau Paper Mills and Kimberley-Clark operate mills in Eau Claire, Brown, Marathon, and Winnebago counties, respectively. All are non-Fortune 500 companies and all are urban and generally affluent counties. On the other hand, this component also identifies non-Program, Fortune 500 companies in counties with higher poverty rates. For example, James River

Corporation and International Paper own plants in the parishes of West Feliciana and Morehouse in central and northern Louisiana.

Table 8
Principal Components Analysis of the Chloroform Releases, 1988 and 1992
(explains 66.7% of the total variation)

	Factor 1	*Factor 2*	*Factor 3*	*Factor 4*
Release Change Rank	-0.06	-0.27	0.17	-0.42
Facility Size	0.02	0.11	0.11	0.63
Fortune 500 Firm	0.18	0.35	0.13	-0.29
33/50 Program Firm	0.18	0.38	0.15	-0.11
Metropolitan County	0.18	-0.13	0.43	0.22
Poverty Level Rank	-0.27	0.27	-0.05	0.07
Manufacturing Employment Rank	0.24	-0.01	0.44	0.21
P2 Laws	0.29	-0.15	-0.35	0.02
P2 Assistance	-0.14	-0.23	0.22	0.11
State Environmentalism Rank	0.37	-0.10	-0.29	0.01
Proportion of Explanation	21.1	18.9	14.0	12.8
Eigen Value	2.11	1.89	1.40	1.28

Discussion and Conclusion

Examination of the spatial patterns of pollution reduction using the hazards-in-context approach shows that there is spatial variation of recent P2 success and that this spatial variation is to some degree related to the external political and socio-economic contextual characteristics. Facility management seems to be guided as much or more by the spatial context of the facility than by practices of the parent company. Contrary to expectations (hypotheses numbered A1, A3, and C1) smaller facilities owned by non-Fortune 500 companies in states without P2 assistance programs seem to be more actively reducing pollution than are the facilities located in places with inverse the characteristics, whether owned by the same corporations or not. Cost reduction and industry-wide competition may be the motivations for pollution reduction in such settings. Based upon the success of the federal 33/50 Program effort to reduce chloroform releases to the environment, one could conclude that P2 programs are helpful tools for overcoming the spatial factors that affect pollution reduction.

The evaluation of the non-Program chemical, chlorine, strengthens such a conclusion. The pattern of emissions reduction for chlorine was quite different from that of chloroform. In the absence of a federal program designed to achieve chlorine release reduction, it appears that external political forces, measured by the enactment of state P2 assistance programs (C1) and laws (C2), are not important elements of chlorine reduction. Surprisingly, reductions were only once associated with strong state environmental records (C3). But as expected, the external economic characteristics (B2, B3 and B4) of the counties in which the facilities were located were often associated with release reductions. Lower poverty rates and higher manufacturing prominence in the local economy were associated with greater reductions.

It must be mentioned that the support or refutation of the hypotheses developed from the literature might be partially explained either by complications caused by technological changes that were not accounted for in this study or by the internal operations of each facility and/or corporation. Some facilities may have been slow to adopt chlorine pollution reduction technology that passed through the U.S. paper industry prior to the study. They might also have been responding to pressures arising from concern about dioxin and other chlorine-based environmental contaminants.

The possibility of problems caused by "snapshot" research illustrates the difficulty in doing policy analyses of this type. Innovation diffusion theory points to three types of actors and times at which individuals will act: true innovators, the main group that accepts innovation quickly, and the laggards. It is somewhat difficult to know which group we've tracked with the data employed. While somewhat constrained by data availability (the earliest data are for 1988), it could be possible in subsequent research to identify the innovative facilities and firms through surveys to determine when they began their P2 activities.

Though internal factors might be paramount, there is an important external context to the adoption of chlorine reduction strategies. A regional component to this trend seemed to be apparent. For example, significant reductions might have already occurred in other paper mills outside of the South by 1988 (the first year in the study period), and in turn, the southern mills were lagging behind the rest of the nation. Unfortunately, this cannot be easily confirmed because of the lack of data on chemical emissions before the initiation of 1987 Right-to-Know legislation. Almost all facilities in non-southern states, similar in size and composition to those in southern states which experienced the dramatic chlorine release reductions, started the study period (1988) with relatively low chlorine emissions and ended the study period (1992) with similar emission levels. Furthermore, the emission levels for both southern and non-southern facilities were roughly comparable, ranging from 5,000 to 50,000 lbs.

This regional component to the pollution reduction process further illustrates the fact that large corporations could behave differently depending upon the socio-economic and environmental regulation contexts in which their facilities are located. For example, corporate facilities in more environmentally progressive states such of Maine, New York, Wisconsin, Michigan, and Oregon, might have achieved the bulk of chlorine emission reduction in the years before 1988 while other facilities within the same company, yet located in environmentally less-aggressive states, lagged behind. In this way, corporate environmental strategies, like other components of corporate strategy, can be seen as flexible — operating at the global level yet able to respond to local conditions, adopting a "global" posture.

The flexibility of corporate behavior could be further illustrated by the actions of 33/50 Program firms regarding Program and non-Program materials. Program-participating companies made more significant chloroform (a Program material) emission reductions than chlorine (a non-Program material) emission reductions. Firms participating in the 33/50 Program were no more likely to reduce chlorine releases than were non-participating companies. The hope that a pollution reduction "habit" would emerge among those companies participating in pollution prevention programs (like 33/50) does not hold true, at least during the short period reflected in this study.

The other internal corporation and facility characteristics examined in the study, however, were found to be counter-intuitively related to pollution reduction. For example, the wealth of the parent company was inversely related to chloroform pollution reduction, but not chlorine. The larger, higher income corporations typically owned and operated many facilities and had wide variation in reduction at their various sites. Facility size was related to greater release reductions (in terms of pounds), but was not related to greater percentage reductions.

These issues need to be examined in more depth. A fuller history of chlorine reduction within the paper industry and its spatial manifestations needs to be developed. This analysis could confirm the above-speculated lag-effect. A more detailed examination of corporate and facility flexibility of adaptation of P2 policies and goals to local and state-level policy and societal settings needs to be constructed. This second issue might generate a second round of hypotheses on the nature and success of P2 programs.

A third area of pursuit regards methodology. An approach must be developed to acquire (or at least to account for) facility-specific paper production data to which facility-specific emission data can be related. Until production levels are reliably measured, it will be impossible to be certain that changes in contaminant production are not caused by changes in production. Lacking such data, conclusions drawn from studies like this must assume that production levels were consistent over short periods of study.

Finally, the examination of the issue of technological development, technology transfer, and P2 engineering within facilities is complex and presents difficult practical problems. Until the engineering component of pollution reduction is accounted for, it will be impossible to fully determine the relative importance of these other internal and external factors in accounting for environmentally protective behavior. Extending the hypotheses and findings of this research to other industries, such as to the organic chemical industry or to the electroplating industry, will improve our understanding of industrial pollution behavior. It will further clarify the most important components of the industrial process so that management can more effectively mitigate environmental hazards.