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REGULATION AND TECHNOLOGICAL OPTIONS: The Case of Occupational Exposure To Formaldehyde

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I. INTRODUCTION

Technological innovation[1] is vital to the long-term economic growth and stability of any society. By creating jobs, spawning investment opportunities and enhancing productivity, technological innovation raises the standard of living for society as a whole.[2] While some countries have developed formal industrial policies to influence directly the nature and direction of technological development, the United States, with its market economy, has traditionally relied on intervention policies that only indirectly influence technological innovation.[3] With mounting national concern over declining productivity growth and increasing foreign competition, United States government intervention has become more intense over the past 15 years.[4]

At the same time, serious concern about the adverse effects of technological progress on the general environment and on human health has emerged. This social concern has resulted in a plethora of government regulations through legislation relating to air and

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1. Technological innovation is the first commercially successful application of a new technical idea. Previous studies of innovation have used various definitions, ranging from invention on the one hand to widespread adoption of technology on the other. Definitions used herein draw on a history of several years' work at MIT, beginning with a five-country study, CENTER FOR POLICY ALTERNATIVES, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, NATIONAL SUPPORT FOR SCIENCE AND TECHNOLOGY: AN EXAMINATION OF THE FOREIGN EXPERIENCE (1975).

2. *See, e.g.*, Landau, *Technology, Economics, and Public Policy*, in TECHNOLOGY AND ECONOMIC POLICY (R. Landau & D. Jorgenson ed. 1986).

3. For a critique of past *laissez faire* approaches and suggestions for a more interventionist role for government, see TECHNOLOGICAL INNOVATION FOR A DYNAMIC ECONOMY (C. Hill & J. Utterback ed. 1979).

4. *See* Rothwell, *Government Innovation Policy: Some Past Problems and Recent Trends*, 22 TECH FORECASTING AND SOCIAL CHANGE 3 (1982); Abernathy & Chakravarthy, *Government Intervention and Innovation in Industry: A Policy Framework*, 20 SLOAN MGMT. REV. 3 (Spring 1979); OFFICE OF TECHNOLOGY ASSESSMENT, PUB. NO. OTA-R-73, A CONTRACTOR'S REPORT: GOVERNMENT INVOLVEMENT IN THE INNOVATION PROCESS (1978).

water quality,[5] toxic substances,[6] workplace health and safety,[7] hazardous wastes,[8] pesticides,[9] and consumer product safety.[10]

Regulation has always been one of several policy tools used in the United States to influence industrial development and economic growth. Traditionally, regulation has been used to correct market imperfections that might affect the free functioning of the market, *e.g.* regulation of monopolies.[11] Broadly considered, environmental, health and safety regulation is a relatively new form of government intervention which is more social than economic in its purpose. Yet this latter type of regulation can have a significant effect on the operation of United States industry.[12]

This Article reviews the historical impact of environmental, health and safety regulation on innovation and considers the relevance of this history for the regulation of formaldehyde.[13] Using an existing conceptual framework, technological responses are predicted to environmental regulation that (1) bans the chemical through an EPA authority, (2) reduces use of the chemical through an EPA authority or (3) limits worker exposure to the chemical by means of OSHA regulation. This analysis focuses on the use of formaldehyde by the textile and apparel industries. Direct economic costs, other systemic changes important for industry and labor, and health consequences that would result from the most likely responses are discussed. The analysis is based on a model of innovation that has been applied to regulation-induced

5. Clean Air Act (CAA), 42 U.S.C. §§ 7401-7642 (1982); Federal Water Pollution Control Act (FWPCA), 33 U.S.C. §§ 1251-1376 (1982).

6. Toxic Substances Control Act (TSCA), 15 U.S.C. §§ 2601-2629 (1982).

7. Occupational Safety and Health Act (OSHA), 29 U.S.C. §§ 651-678 (1982).

8. Resource Conservation and Recovery Act (RCRA), 42 U.S.C. §§ 6901-6987 (1982).

9. Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), 7 U.S.C. §§ 136-136y (1982).

10. Consumer Product Safety Act (CPSA), 15 U.S.C. §§ 2051-2083 (1982).

11. *See* W. JONES, REGULATED INDUSTRIES (1976).

12. *See* Hoerger, Beamer & Manson, *The Cumulative Impact of Health, Environmental, and Safety Concerns on the Chemical Industry During the Seventies*, 46 LAW & CONTEMP. PROBS. 59-107 (Summer 1983). Observations of the authors suggest that perhaps 10 - 20% of chemical industry research and development [hereinafter R&D] is motivated primarily by health, environmental and safety concerns, diverting scientific and technical manpower from traditional chemical R&D with attendant negative impacts on innovation. The article argues that regulatory concepts of the past, such as generic regulations and technology-forcing standards, should be discarded in favor of less public involvement in decision making, greater control of regulatory decisions by scientists and greater pre-regulation analysis.

13. Formaldehyde presents an ideal substance for study. It was a substance intensely scrutinized for possible regulation during the Carter Administration, but the first Reagan Administration abandoned the regulatory effort. *See* Ashford, Ryan & Caldart, *Law and Science Policy in Federal Regulation of Formaldehyde*, 222 SCI. 894 (1983). Formaldehyde was only recently regulated under the OSH Act. *See infra* notes 151-54 and accompanying text. This Article comments on the limitations of this half-hearted action by the federal government and argues that more stringent regulation is preferable. *See infra* notes 170-85 and accompanying text.

technological change and on an analysis of the likely market behavior of the various actors involved in formaldehyde production and use. This Article concludes that effective environmental regulation depends, in large measure, on technological innovation and that OSHA's current regulations limiting worker exposure to formaldehyde are least effective in stimulating innovation and consequently are inadequate for protecting worker health.

II. THE PROCESS OF INNOVATION

Innovation has been variously defined as, and is often confused with, the related concepts of invention and diffusion. Properly defined, innovation is the first commercially successful application of a new product or technology in the marketplace.[14] Thus, innovation is more than either a technical discovery (invention) or a widespread adoption of the commercially successful product (diffusion). Rather, it is the result of a process that involves and is influenced by a variety of factors.[15]

An innovation can be characterized by its type, its significance or by the activity from which it evolves.[16] Innovation can be process-oriented or product-oriented. It can be modest and incremental or radical and revolutionary in nature. Innovation can be the result of an industry's main business activities or can evolve from its efforts to comply with health, safety or environmental demands. Regulation can affect any of these characteristics.

A variety of theoretical models attempt to explain the process of innovation. The simplest model is sequential and linear in nature and describes the innovation process in discrete steps: basic research, applied research, invention, prototype development, commercialization and diffusion.[17] While this model identifies activities that *can* contribute to innovation, the model erroneously suggests that each step is necessary and follows sequentially from the preceding step. However, innovation can and often does occur in the absence of one or more discrete steps. For instance, innovation may occur without basic research, research and development, or prototype development by the innovator.[18] As one commentator

14. *See, e.g.*, Ashford & Heaton, *Regulation and Technological Innovation in the Chemical Industry*, 46 LAW & CONTEMP. PROBS. 109, 110 (Summer 1983).

15. *See generally* TECHNOLOGICAL INNOVATION FOR A DYNAMIC ECONOMY, *supra* note 3.

16. Kurz, *The Impact of Regulation on Innovation. Theoretical Foundations: Draft Discussion Paper* Institute for Applied Economic Research, Tübingen, West Germany at 6 (1987). (To be published in R. KURZ, REGULATION, DYNAMIC COMPETITION AND INNOVATION (1989)).

17. Ashford & Heaton, *supra* note 14, at 111.

18. *Id.* at 127-36. The observation that innovation often occurs without R&D has important implications for the argument that, even though regulation may divert resources from main business R&D, innovation is not necessarily adversely affected.

noted, innovation is an "inherently untidy" process.[19]

The inadequacy of the linear or sequential models spurred the development of more complex models. The chain-linked model emphasizes the key roles of trial and error and feedback.[20] The network model focuses on the interdependency among industries for innovation.[21]

The Abernathy-Utterback dynamic market-phase model[22] ("A-U model") focuses on the differences in the nature of innovation across various industries over time. The model, encapsulated in the following diagram (see Figure 1), refers to a narrow product line or specific process as the unit of analysis. This unit is described as a "productive segment."[23] The A-U model suggests that initially the productive segment creates a market niche by selling a new product. Because the technology is new and often superior to existing technology, it requires refinement. Thus a high degree of product innovation occurs as technology improves and more firms enter the market. In this fluid phase, the firm does not attempt to make process changes. Improvements in process generally become important later when the product is fairly well-defined and firms need to compete more on the basis of price than on the basis of product performance. During this transition stage, process innovation increases, only to subside when the productive segment becomes mature and rigid. In this last stage, little product or process innovation typically occurs un-

19. Sahal, *Invention, Innovation, and Economic Evolution*, 23 TECH. FORECASTING AND SOC. CHANGE 213, 214 (1983).

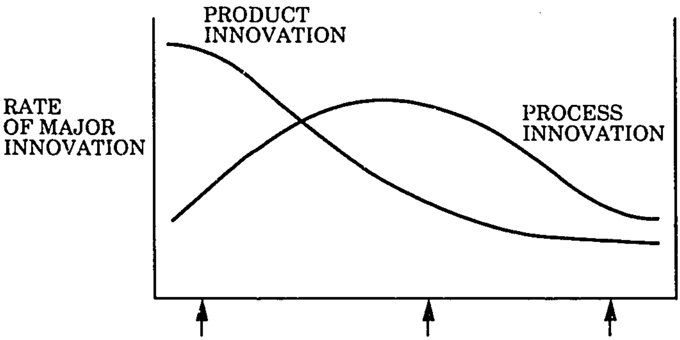
20. Unlike the sequential model which emphasizes the importance of basic and applied research, the chain link model suggests that design and redesign (engineering) are the essential components of innovation. Positing that most innovation is done with existing knowledge, the model emphasizes the importance of feedback throughout the innovation process. *See* Kurz, *supra* note 16, at 9-10.

21. The network model assumes that innovation is not isolated in one industry, but depends on innovation in other industries, especially those downstream and upstream. For example, an innovation in one industry may stimulate another industry to produce a substitute product; a commercially unsuccessful innovation in one industry could stimulate commercial success in another. *Id.* at 11-13.

22. Unlike the previous models, the Abernathy-Utterback model describes the evolution of both product and process innovation over time as an industry matures. Firms have different propensities to innovate at various times in their evolutionary development. This important observation has implications for predicting the effect of regulation on technological responses of the firm. *See, e.g.*, Abernathy & Utterback, *Patterns of Industrial Innovation*, TECH. REV.(June-July 1978), at 41. *See also* Ashford & Heaton, *supra* note 14; Kurz, *supra* note 16 and accompanying text.

23. The term "productive segment" corresponds to a single product line within a firm. Specifically with respect to the textile and apparel industries, the productive segments of interest are respectively the production of permanent-press cloth using formaldehyde-based resins and their conversion into clothing with permanent-press characteristics. In the chemical industry, the productive segment of interest is the manufacture of formaldehyde-based resins for use in the textile and apparel industries. *See generally* Ashford & Heaton, *supra* note 14, at 112.

Figure 1
A Model for the Dynamics of Innovation in Industry



Stage of Development	Fluid	Transition	Rigid
Predominant type of innovation	Frequent major changes in products	Major process changes required by rising volume	Incremental for product and process, with cumulative improvement in productivity and quality
Competitive emphasis on	Functional product performance	Product variation	Cost reduction
Innovation stimulated by	Information on users' needs and users' technical inputs	Opportunities created by expanding internal technical capability	Pressure to reduce cost and improve quality
Product line	Diverse, often including custom designs	Includes at least one product design stable enough to have significant production volume	Mostly undifferentiated standard products
Production processes	Flexible and inefficient; major changes easily accommodated	Becoming more rigid, with changes occurring in major steps	Efficient, capital-intensive, and rigid; cost of change is high
Equipment	General-purpose, requiring highly skilled labor	Some subprocesses automated, creating "islands of automation"	Special-purpose, mostly automatic with labor tasks mainly monitoring and controlling
Materials	Inputs are limited to generally-available materials	Specialized materials may be demanded from some suppliers	Specialized materials will be demanded; if not available, vertical integration will be extensive
Plant	Small-scale, located near user or source of technology	General-purpose with specialized sections	Large-scale, highly specific to particular products

Source: Abernathy & Utterback, *Patterns of Industrial Innovation*, TECH REV., June-July 1978, at 2-9.

less the status quo of the industrial segment is somehow perturbed. Environmental regulation is one form of perturbation.

This Article utilizes the A-U model to analyze the impact of formaldehyde regulation on innovation in the textile and apparel industries. This follows earlier work by one of the authors analyzing technological change in the chemical industry induced by regulation.[24]

III. THE IMPACT OF REGULATION ON INNOVATION

A. The Nature of Regulation

Regulation is an often complex stimulus that restricts or redirects the activities of the regulated entity. A lengthy process, it begins with the perception or recognition of a need for change and can be broadly categorized as economic[25] (*e.g.*, restrictions on market entry and exit, wage and price controls), social[26] (*e.g.*, income redistribution and social insurance programs) or environmental[27] (protection of public health, safety and the environment). Environmental regulations attempt to control different aspects of the development and production process, including research and development (R&D), production, marketing and consumer use.[28] Environmental regulations change over time and are "technology-forcing"[29] to different degrees.[30]

Most environmental regulation affects product quality or the process of production through the development and promulgation of standards. It is important to distinguish performance stand-

24. Ashford & Heaton, *supra* note 14; Ashford, Ayers & Stone, *Using Regulation to Change the Market for Innovation*, 9 HARV. ENVTL. L. REV. 419 (1985).

25. *See generally* S. BREYER, REGULATION AND ITS REFORM (1982).

26. *See generally* BRUDA, INCOME REDISTRIBUTION THEORIES AND PROGRESS (1977).

27. *See generally* J. BONIRE & T. MCGARITY, THE LAW OF ENVIRONMENTAL PROTECTION (1984).

28. Consumer use can be influenced both through the regulation of product safety and by the imposition of labeling requirements. Most of the environmental protection acts passed between 1948 and 1977 relied upon direct regulation through the imposition of standards. *See* S. HADDEN, READ THE LABEL (1986).

29. "Technology-forcing" refers to the tendency of a regulation to force industry to develop or adopt new technology. Regulations may force development or adoption of new technology through the use of different types of restrictions. The degree of technology-forcing ranges from pure "health-based" mandates, such as that in the ambient air quality standards of the CAA, to a technology diffusion standard, such as "best available technology" under the CWA. However, in the absence of political resolve that the benefits of pollution control outweigh the social and economic disruption of technology-forcing, the capacity of both types of standards to force technological changes will be sharply limited. For a discussion of this issue and comparison of statutes, *see* La Pierre, *Technology-Forcing and Federal Environmental Protection Statutes*, 62 IOWA L. REV. 771 (1977).

30. Ashford & Heaton, *supra* note 14, at 153.

ards from specification standards.[31] Performance standards set a mandatory level of performance and allow the regulated entity considerable flexibility in designing or selecting methods to achieve compliance.[32] Specification standards, on the other hand, define both the particular level of performance and the particular method of compliance to be used in achieving the performance level.[33] For example, the specification standard may dictate the use of specific engineering controls rather than individual respiratory protection to reduce exposure to an airborne toxic substance in the workplace.

B. Federal Environmental Regulation

Since the mid-1960's, the federal government has established several new regulatory agencies intended either wholly or in part to maintain the quality of the environment. These include the Environmental Protection Agency (EPA),[34] the Occupational Safety and Health Administration (OSHA)[35] and the Consumer Product Safety Commission (CPSC).[36] By adopting regulations to fulfill their respective statutory mandates, each of these agencies places different demands on industry. Some of these demands affect all industries and others affect only specific industrial sectors. This Article considers two of these environmental statutes, the Occupational Safety and Health Act (OSH Act) and the Toxic Substances Control Act (TSCA) and explores the impact they are likely to have on innovation or other technological changes associated with formaldehyde use in permanent-press textiles.

The OSH Act was passed in 1970 "to assure so far as possible every working man and woman in the Nation safe and healthful working conditions."[37] Administered by OSHA within the Depart-

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31. Ashford, Heaton & Priest, *Environmental, Health, and Safety Regulation and Technological Innovation*, in TECHNOLOGICAL INNOVATION FOR A DYNAMIC ECONOMY at 193 (C. Hill & J. Utterback eds. 1979).

32. It is often asserted that performance standards spur compliance innovation more than specification standards. However, comparisons between the two kinds of standards are also confounded by the different stringencies of the standards. *Id.*

33. If the specification standard imposes substantial costs on the industry, innovation may be encouraged in compliance technology. However, this would require that the industry obtain a waiver from the standard method of compliance. *See* Ashford, Ayers & Stone, *supra* note 24, at 443-62.

34. The EPA was created as an executive branch agency by Executive Order in 1970.

35. OSHA was created in the Department of Labor by the Occupational Safety and Health Act, *supra* note 7.

36. An independent commission, the CPSC is authorized to regulate the production or sale of consumer products that may contain hazardous substances under the Federal Hazardous Substances Act, 15 U.S.C. §§ 1261-1276 (1982) and the Consumer Product Safety Act 15 U.S.C. §§ 2051-2081 (1982).

37. 29 U.S.C. § 651(b) (1982).

ment of Labor, the Act gives broad authority to the Secretary to promulgate both health and safety standards. In promulgating standards that deal with toxic substances, the Secretary is instructed to "set the standard which most adequately assures, to the extent feasible, on the basis of the best available evidence, that no employee will suffer material impairment of health or functional capacity even if such employee has regular exposure to the hazard . . . for the period of his working life."[38]

The TSCA was enacted in 1976 "to regulate chemical substances and mixtures which present an unreasonable risk of injury to health or the environment and to take action with respect to chemical substances and mixtures which are imminent hazards . . . ."[39] Under this statute, the EPA Administrator is given broad authority to prohibit or limit the manufacturing, processing, distribution, use and disposal of any chemical substance or mixture that, in any way, presents an "unreasonable risk of injury to health or the environment."[40] The Act further provides for the promulgation of testing,[41] pre-manufacture notification,[42] and reporting requirements.[43]

Technological change *per se* is not the goal of either the TSCA or the OSH Act, but may represent a means by which the purposes of the Acts are achieved. Prior to the passage of the TSCA, neither Congress nor the agency administrators indicated any concern for the impact of their regulations on innovation.[44] Significantly, the declared policy of the TSCA was, in part, "not to impede unduly or create unnecessary barriers to technological innovation . . . ."[45] The possibility that regulation could actually stimulate innovation seems not to have been considered. However, in reality, regulation can have both positive and negative impacts on innovation.

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38. 29 U.S.C. § 651(b)(5) (1982). Thus, for toxic substances like the carcinogen formaldehyde, the statute suggests that where there is no safe level, OSHA is required to set the lowest level feasible. However, as a result of Industrial Union Dep't v. American Petroleum Inst., 448 U.S. 607 (1980) (OSHA benzene standard), OSHA may regulate only "significant risks." OSHA has judged this latter requirement to be satisfied at a permissible exposure limit of 1 ppm for formaldehyde. *See infra* notes 151-54 and accompanying text. However, the apparel industry seems to have been able to protect the vast majority of its workers at an existing exposure level of well below 0.5 ppm. This suggests that, for the apparel industry at least, OSHA did not set the lowest feasible level, and there appear to be significant health effects remaining. *See infra* notes 178-80 and note 186 and accompanying text.

39. 15 U.S.C. § 2601(b)(2) (1982).

40. *Id.* § 2605(a).

41. *Id.* § 2603.

42. *Id.* § 2604.

43. *Id.* § 2607.

44. Stewart, *Regulation, Innovation, and Administrative Law: A Conceptual Framework*, 69 CALIF. L. REV. 1259, 1288 (1981).

45. 15 U.S.C. § 2601 (1982).

C. *The Impact of Regulation on Innovation*

An industry's perception of the need to change either a product or a process may precede any regulatory action. Public concern, an increase in tort suits (especially when liability is imposed), adverse publicity or comment in the press, and pressure from environmental or labor groups may all provide stimuli for change. Indeed, these factors may simultaneously stimulate both the industry and the regulatory agency. This pre-regulatory period is important because it alerts the industry to the need for change and allows time for the industry to change its product or process or to develop compliance technologies.[46] Analyses of the impact of regulation on technological innovation seldom consider this complex pre-regulatory baseline. Yet it is important to recognize and differentiate these stimuli because industry often begins to respond technologically in anticipation of regulation, sometimes long before publication of the regulation in the Federal Register. OSHA regulation of formaldehyde follows this pattern.

The literature on the impact of regulation on innovation is contradictory, sometimes ideological and certainly far from complete.[47] Most authors conclude that environmental and safety regulation has had an adverse impact on innovation, except for compliance technology development.[48] Those reaching this conclusion typically argue along the following lines:

1. Compliance with environmental, health and safety regulation is costly. It reduces not only the profitability of an industry, but also the ability of the firm to undertake innovative endeavors and to expand its research and development. The estimated private sector compliance cost of all such regulation in 1979 was $98 billion.[49]
2. Regulation increases the uncertainty of would-be-innovators. Such uncertainty derives from vague or changing regulations, conflicting or inconsistent regulations and the uncertain commercial success of a regulated product.[50]

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46. *See* Ashford & Heaton, *supra* note 14, at 120.

47. *Compare*, Ashford & Heaton, *supra* note 14 *and* Ashford, Heaton & Priest, *supra* note 31 *with* Kurz, *supra* note 16 *and* Rothwell, *Some Indirect Impacts of Government Regulation on Industrial Innovation in the United States*, 19 TECH. FORECASTING AND SOC. CHANGE 57 (1981).

48. *See generally* FEDERAL REGULATION AND CHEMICAL INNOVATION (C. Hill ed. 1979).

49. *See* Rothwell, *supra* note 47. This assertion rests on two crucial assumptions: (1) R&D is an important ingredient for innovation and (2) compliance costs divert efforts from R&D. *But cf.* Ashford, Heaton & Priest, *supra* note 31, at 177-78.

50. Rothwell, *supra* note 47, at 62. This follows from the increased risk of commercial failure if future regulations impose demands on product characteristics.

3. Regulation delays the introduction of new products into the market.[51]
4. Regulation diverts resources from main business innovation activities into compliance-related activities.[52]
5. Regulation handicaps small firms.[53] Yet, data suggest that smaller organizations introduce a disproportionate share of commercially-oriented innovations into the marketplace[54] and keep the competitive spirit alive.

In addition to these direct effects, regulation may reduce incentives to innovate. For instance, industry has little incentive to develop innovations that go beyond the performance level indicated in the regulation.[55] Moreover, because the regulated industries participate in the regulatory process, they may cause the standard to be set at levels achievable with existing on-the-shelf technology.[56] Rather than stimulating innovation, this will result at most in technological diffusion. If the applicable standards are of the specification type, innovation may be further discouraged because specifying the method of compliance severely restricts the possibility that the regulated entity will respond by developing new technology.[57] In this regard, however, the distinction between specification and performance standards may not be clear cut. Indeed, if a performance standard simply mandates a per-

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51. Ashford, Heaton & Priest, *supra* note 31, at 172-75.

52. Eads, *Chemicals as a Regulated Industry: Implications for Research and Product Development*, in FEDERAL REGULATION AND CHEMICAL INNOVATION at 1-20 (C. Hill ed. 1979). *See also* Rothwell, *supra* note 47, at 74. Both financial and managerial attention may be diverted to comply with regulation.

53. Diamond, *The Differential Impact of Government Regulation on Small Versus Large Business: A Review of an Inadequate Information Base*, 5 JOINT ECONOMIC COMMITTEE OF THE U.S. CONGRESS: SPECIAL STUDY ON ECONOMIC CHANGE 270 (1980).

54. Researchers have documented the desire for independence, the creative drive and the need for recognized achievement in small firms. In fact, small firms produce about twice as many significant innovations per employee as large firms produce. ISSUE ALERT: INNOVATION IN SMALL FIRMS, OFFICE OF ADVOCACY, U.S. SMALL BUSINESS ADMINISTRATION (1986); Roberts, *Entrepreneurship and Technology*, RESEARCH MANAGEMENT (1978).

55. *See* Kurz, *supra* note 16, at 43.

56. There is a strong correlation between the type of regulation and the nature of the regulatory response, *e.g.*, product regulation generally leads to product response, while pollutant and component regulation generally lead to process response. For the hazardous materials surveyed, the actual standard resulting from the regulatory process appears in most cases to be based largely on considerations of technological feasibility. The agencies consistently use substantial industry input in drafting the regulations, resulting in standards that can be easily satisfied with on-the-shelf technology. For example, the final rule on lead-in-paint was modified substantially on the basis of the hearing comments. *See* Ashford & Heaton, *The Effects of Health and Environmental Regulation on Technological Change in the Chemical Industry: Theory and Evidence*, in FEDERAL REGULATION AND CHEMICAL INNOVATION (C. Hill ed., 1979).

57. *But cf.* Ashford, Ayers & Stone, *supra* note 33.

missible level of exposure that can be met by existing technology, it becomes little more than a specification standard. Finally, regulations requiring the submission of confidential, proprietary information to the regulatory agency may discourage innovation because such disclosure may provide outsider access to commercially important information.[58]

That regulation generally has an adverse impact on innovation is not, however, a universally accepted idea. Another group of authors has extolled the positive effects that environmental, health and safety regulation can have on innovation. These views[59] may be summarized as follows:

1. Regulation can reduce commercial risk through intensified premarket testing requirements.[60]
2. Redirection of research and development may actually increase innovation. A study of the impact of regulation on innovation in five foreign countries found that main business innovations were more likely to be commercially successful when environmental regulations were present as an element of the planning process than when the regulations were absent.[61]
3. Regulation can create the need for new compliance technology.[62]
4. Compliance-related technological change has often led to product improvements far beyond the scope of the compliance[63]
5. Regulation creates opportunities for technological

58. If the information is not protected by patent, trade secrets could be divulged. The reduction in trade secret protection is seen as penalizing technological innovation because it decreases the legal protection (and hence the rewards) available to new technologies. Whether such fears are real or imagined, they may produce a chilling effect on innovation.

59. *See* Ashford, Heaton & Priest, *supra* note 31, at 167-90.

60. Because standards both provide a definite statement of legal requirements and encourage the development of safer products, they may limit highly unpredictable products liability suits. *Id.* at 175.

61. Allen, Utterback, Sirbu, Ashford & Holloman, *Government Influence on the Process of Innovation in Europe and Japan*, 7 RES. POL. 124 (1978).The study found that, in general, the proportion of successful and unsuccessful projects was statistically the same regardless of whether or not the government was involved. However, where there were regulatory constraints of various kinds (primarily in the form of environmental and product safety requirements in industrial chemical and auto industries), the project was more often successful. *Id.* at 148.

62. The need to create new compliance technologies, and the dynamic relationships between the regulated and pollution control industries, have restructured the innovative effort in many industries. In fact, between 1974 and 1983, the expenditures in the pollution control industry will total about $44 billion. Leung & Klein, *The Environmental Control Industry* 104 (submitted to COUNCIL ON ENVIRONMENTAL QUALITY) (1975).

63. Ashford, Heaton & Priest, *supra* note 31, at 186.

change. One study reported that 33% of the firms surveyed indicated they had made process improvements in response to regulation.[64] Another study found that process improvements were made even in unregulated areas when regulation occurs.[65]

6. If regulation spurs the affected industry to add technical experts in order to achieve compliance, the creativity pool of that industry will increase, with concomitant increase in the likelihood of innovation generally.[66]
7. Regulation can create market opportunities for new entrants who offer safer products.[67]

These authors acknowledge the costs that regulation impose on industry, but suggest that regulatory costs are often passed on to the consumer, especially in the areas of pharmaceuticals, essential chemicals and products with no close substitutes.[68] In addition, a large part of the uncertainty surrounding regulation can be attributed to an industry's own efforts to modify or litigate proposed standards.[69] Moreover, it is argued that some uncertainty is healthy because absolute certainty about regulation provides little incentive to surpass mandated performance levels.[70]

Both groups of authors cite empirical evidence to support their conclusions. However, the number of studies is relatively small and those that exist have some methodological difficulties. These difficulties include measuring both the degree of innovation and the intensity of regulation,[71] establishing that regulation causes rather than simply correlates with observed falls in business innovation during periods of regulation,[72] and defining the appropriate time lag between the regulatory stimulus and the technologic response.

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64. J. INVERSTINE, J. KINARD & W. SLAUGHTER, IMPACT OF ENVIRONMENTAL PROTECTION REGULATIONS ON RESEARCH AND DEVELOPMENT IN THE INDUSTRIAL CHEMICAL INDUSTRY, (1976).

65. Ashford, Heaton & Priest, *supra* note 31, at 180.

66. The addition of sophisticated analytical chemistry expertise in order to assess the health and environmental risks of both new and existing products may lead to better understanding of the nature and possible applications of the product. *Id.* at 181.

67. *Id.* at 174. There has been an average decline from 15% to 6.3% in the rate of return for new drugs. SCHWARTZMAN, INNOVATION IN THE PHARMACEUTICAL INDUSTRY (1976). However, the extent to which this decline is related to health and safety regulation is unclear. The decline probably results in large part from the regulatory requirement for proof of efficacy. Ashford, Heaton & Priest, *supra* note 31, at 174.

68. Ashford, Heaton & Priest, *supra* note 31, at 174.

69. *Id.*

70. Regulatory uncertainty is often necessary and beneficial, as it allows some degree of administrative flexibility. *Id.* at 164.

71. *See* Kurz, *supra* note 16, at 14-17, 21.

72. *See* Ashford, Heaton & Priest, *supra* note 31, at 171.

On balance, there is evidence and agreement that environmental regulation can both impede and stimulate innovation. The impact of a regulation on innovation is a function of the type and stringency of the regulation, as well as of the developmental stage of the productive segment.[73] (See Figure 1.) Thus, both the government and the regulated industry can affect the impact of regulation on innovation. The government *could* design environmental regulations to increase the probability of an innovative technological response. Industry *could* respond to environmental regulations in innovative ways. The following section presents examples of how selected industrial sectors have responded to recent environmental regulations.[74] These examples are relevant for predicting technological response in the case of formaldehyde.

D. *Examples of the Impact of Regulation on Innovation*

1. *PCB's*

Polychlorinated biphenyls (PCB's) are compounds widely used to provide coolant insulation in electrical transformers and capacitors.[75] PCB's are biologically stable substances that persist in the environment and in human tissue and are known to cause a variety of adverse health effects.[76] In 1979, the EPA, under the TSCA, banned both commercial distribution and manufacture of PCB's beginning January 1, 1980.[77] However, three years prior to the EPA manufacturing ban, Monsanto, the sole United States supplier of PCB's, announced that it was pulling out of the PCB market.[78] As early as 1970, Monsanto attempted to manufacture

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73. Ashford & Heaton, *supra* note 14, at 113 (Figure 1).

74. *See generally* Ashford, Ayers & Stone, *supra* note 24.

75. *See* TOXICOLOGY: THE BASIC SCIENCE OF POISONS at 647 (J. Doull, C. Klassen & M. Amdur 2 ed. 1980).

76. *See generally* ENVIRONMENTAL AND OCCUPATIONAL MEDICINE at 596 (W. Rom ed. 1983). The most notable adverse health effect of PCB exposure surfaced in Japan in 1968. The ingestion of PCB-contaminated rice oil caused an epidemic of a severe form of acne called chloracne. Affected individuals also had anemia, as well as gastrointestinal and neurological problems. In addition, there was evidence of low-birthweight babies and retarded growth in children in the exposed population. The PCB's used in the United States differ in isomer distribution and the presence of contaminants. The largest survey of United States PCB workers revealed evidence of skin changes (40%), impaired pulmonary function (14%), and limited evidence of liver abnormalities. Animal studies have demonstrated that the incidence of liver neoplasms increases and that PCB's are secreted in human breast milk. *Id.* at 597.

77. TSCA §§ 6(e)(2)(A), (e)(3)(A), 15 U.S.C. §§ 2605(e)(2)(A), (e)(3)(A). Section 6(e)(3)(A) generally prohibits the manufacture of PCB's beginning January 1, 1979, and the processing and commercial distribution of PCB's beginning July 1, 1979. Section 6(e)(2)(A) prohibits the use of PCB's, other than within totally enclosed areas, beginning January 1, 1978. EPA regulations implementing section 6 appear at 40 C.F.R. § 761 (1984).

78. Ashford, Hattis, Heaton, Jaffe, Owen & Priest, *Environmental / Safety Regulation and Technological Change in the U.S. Chemical Industry*, CPA NO. 79-6 (Mar. 1979) (Report to the National Science Foundation) [hereinafter CPA Chemical Industry Study]. Results of this study were published in FEDERAL REGULATION AND CHEMICAL INNOVATION, *supra* note 48.

a more biodegradable form and restricted the sale of PCB's to manufacturers of closed electrical systems.[79] This action prompted an innovation in capacitor design which reduced PCB use by sixty-six percent.[80]

The PCB industry first became aware of the possibility of environmental regulation[81] of PCB's in the late 1960's when the federal government began regulatory surveillance of the substance.[82] With Monsanto's withdrawal from the market, PCB users were forced to look for substitute products. Five substitutes were subsequently developed by new entrants to the PCB manufacturing market.[83] These new entrants were the original downstream users of PCB's.[84] This case thus illustrates the importance of the pre-regulatory period and the usefulness of the A-U model of innovation. When faced with the possibility of environmental regulation, the sole supplier of a product in a rigid productive segment attempted some modest process innovation and ultimately withdrew from the PCB market. The new entrants responded to the EPA ban with radical product innovation, developing PCB substitutes for transformers and capacitors.

2. *Vinyl Chloride*

A variety of toxic effects have been associated with vinyl chloride exposure.[85] In 1974, the first cases of angiosarcoma[86] of

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79. CPA Chemical Industry Study, *supra* note 78, at A-14. Monsanto's actions prior to formal regulatory action reveal the often complex nature of public pressure and the role of government intervention in stimulating private action. However, it seems appropriate to attribute Monsanto's actions to the regulatory process.

80. *Id.* at C-18 (citing B. Kerns, Statement Representing Westinghouse Corp., in National Conference on PCB's) (Nov. 19-21, 1975) (EPA-560/6-75-004); Telephone interview with Robert Sawyer, Manager of Manufacturing Support, Westinghouse Distribution Apparatus Division (Apr. 26, 1985).

81. The U.S. Food and Drug Administration began surveillance of PCB's in human and animal food in 1968. *See* Highland, *PCB's in Food*, ENV'T. 12 (Mar. 1976).

82. Ashford, Ayers & Stone, *supra* note 24, at 432.

83. *Id.* at 433. The transformer substitute developed by Monsanto was a type of silicone (polydimethlysiloxane). The four PCB capacitor substitutes were isopropyl naphthalene, butylated monochlorodiphenyl oxide, di-isononyl phthalate ester, and a mixture of di-octyl phthalate ester with trichlorobenzene.

84. *Id.* General Electric (a transformer manufacturer and silicon producer) and Dow Corning (a silicon producer) independently developed the transformer substitute. The capacitor substitutes were developed by capacitor firms or by chemical firms in conjunction with capacitor firms.

85. *See generally* Rom, *supra* note 76, at 579-88. (The earliest references in the literature to liver disease or findings suggestive of acroosteolysis (AOL) in vinyl chloride monomer workers date from 1949. The liver findings included "hepatitis-like changes." The AOL, described in more detail in the 1960's, typically includes symptoms of Raynaud's phenomenon. More recent findings include pulmonary function decrements, chromosomal aberrations and possible genetic and reproductive effects.)

86. Hepatic angiosarcoma is a rare form of liver cancer.

the liver among polyvinyl chloride (PVC) workers were reported.[87] OSHA quickly promulgated a vinyl chloride standard reducing permissible workplace exposure levels to 1 part per million (ppm).[88] Two years later, EPA issued vinyl chloride emission standards under the Clean Air Act.[89]

Manufacturers of the vinyl chloride monomer (VCM) and PVC questioned the technological and economic feasibility of complying with both the OSHA and EPA regulations.[90] Nevertheless, in response to these regulations, the PVC industry made a number of important, though incremental, process innovations.[91] The industry automated and closed their reactor cleaning systems and developed new technology to reduce the handling of resin.[92] They also used on-the-shelf technology to reduce leaks in their manufacturing systems.[93] The VCM industry, less severely affected by these regulations than was the PVC industry, complied by improving equipment maintenance in order to lower emissions and by installing incinerators to destroy unwanted monomer.[94] The PVC fabricators were affected by the OSHA regulation only and responded by upgrading ventilation, automating some materials handling tasks and incrementally changing parts of the fabrication process to reduce exposure to residual VCM.[95] Because the innovations undertaken by the PVC polymerization industry in response to OSHA and EPA regulation eliminated most of the environmental hazard before the product was delivered to the fabricators, the necessary compliance efforts of the fabricators were much less substantial.

In sum, although the vinyl chloride industry resisted environmental regulation, the resultant innovations both improved production processes and provided a safer environment for the worker.[96]

3. *Cotton Dust*

Byssinosis, also called brown lung, is a progressive and

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87. The authors described three cases of angiosarcoma of the liver among PVC polymerization workers at the B.F. Goodrich plant in Louisville, KY. Creech & Johnson, *Angiosarcoma of Liver in the Manufacture of Polyvinyl Chloride*, 16 J. OCCUP. MED. 150 (1974). Subsequent studies identified additional cases. *See* Rom, *supra* note 76, at 579-88.

88. 29 C.F.R. § 1910.1017(c) (1984).

89. 42 U.S.C. § 7412 (1982).

90. CPA Chemical Industry Study, *supra* note 78, at A-26 to A-28.

91. *Id.* at C-2 to C-9.

92. *Id.*

93. *Id.* at C-9.

94. *Id.*

95. *Id.* at C-3.

96. Ashford, Hattis, Heaton, Katz, Priest & Zolt, *Evaluating Chemical Regulations: Trade-off Analysis and Impact Assessment for Environmental Decision-making*, NTIS No. PB81-195067, at A-113-14.

debilitating respiratory disease that has left many cotton textile workers totally and permanently disabled.[97] As a result, OSHA initiated efforts to reduce workplace exposure to cotton dust in 1974.[98] However, the mature American textile industry stubbornly resisted all regulatory efforts and pursued its claims to the Supreme Court. In *American Textile Manufacturers Institute Inc. v. Donovan*, the Court upheld the OSHA standard.[99] The final cotton dust standard, issued in 1984, established different exposure limits for various segments of the cotton textile industry as well as for non-textile industries.[100]

In order to comply with these standards, the affected industry utilized largely existing technology to modernize its equipment and manufacturing processes.[101] Although little real innovation occurred, broad diffusion of state-of-the-art textile technology resulted.[102] Some observers suggest that these regulation-induced changes have resulted in a net benefit to the cotton textile industry.[103] Indeed, it is apparent that the OSHA cotton dust standard prompted, or at least accelerated, the modernization of the American textile industry.

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97. Byssinosis is a serious and important occupational chronic bronchitis that begins with chest tightness and can progress to severe pulmonary impairment. *See generally* Rom, *supra* note 76, at 207-14.

98. 39 Fed. Reg. 44,769 (1974) (advance notice of proposed rulemaking soliciting comments).

99. Without arguing the technological feasibility of the OSHA standard, the textile industry contended that OSHA had exceeded its statutory authority by failing to conduct a cost-benefit analysis and by failing to determine that the standard's benefits justified the costs of compliance. By a vote of 5 to 3, the Supreme Court held that cost-benefit analysis was not required by the OSH Act. Instead, it found that § 6(b)(5) of the Act required "feasibility analysis." defining "feasible" as "capable of being done, executed, or effected." American Textile Mfrs. Inst., Inc. v. Donovan, 452 U.S. 490, 508-09 (1981). The Court ruled that § 6(b)5 of the OSH Act "directs the Secretary to issue the standard that 'most adequately assures . . . that no employee will suffer material impairment of health,' limited only by the extent to which this is 'capable of being done.' In effect . . . Congress itself defined the basic relationship between costs and benefits, by placing the 'benefit' of worker health above all other considerations save those making attainment of this 'benefit' unachievable. Any standard based on a balancing of costs and benefits by the Secretary that strikes a different balance than that struck by Congress would be inconsistent with the command set forth in § 6(b)(5)." *Id.* at 509.

100. Different exposure limits, however, were set such that equivalent levels of risk were provided across the industry. This reflects the varying nature and composition of cotton dust in different operations. Occupational Safety and Health Standards Subpart Z-Toxic and Hazardous Substances, 29 C.F.R. § 1910.1043(c) (1984).

101. R. RUTTENBERG, COMPLIANCE WITH THE OSHA COTTON RULE: THE ROLE OF PRODUCTIVITY-IMPROVING TECHNOLOGY (Mar. 1983) (submitted under contract to the Office of Technology Assessment).

102. *See* Ashford, Ayers & Stone, *supra* note 24, at 442.

103. *See* RUTTENBERG, *supra* note 101. *See also* AMALGAMATED CLOTHING AND TEXTILE WORKERS UNION, DEPARTMENT OF OCCUPATIONAL SAFETY AND HEALTH, THE ECONOMIC IMPACT OF THE OSHA COTTON DUST STANDARD (Mar. 1983) (unpublished report).

IV. FORMALDEHYDE

Formaldehyde (HCHO) is a ubiquitous, toxic chemical that deserves to join the ranks of regulated substances. A major industrial chemical, formaldehyde ranks 24th in production volume in the United States.[104] Approximately 5.7 billion pounds of 37% formaldehyde (by weight) was manufactured in 1985.[105] Used primarily as an intermediary in the manufacture of a variety of resins, formaldehyde is also popularly used as a preservative, germicide and fungicide in a wide variety of consumer products, including cosmetics, disinfectants, pharmaceuticals and agricultural products.[106] Approximately 59% of all formaldehyde produced is consumed in the manufacture of urea, phenolic or melamine resins which are widely used in textile finishing, plywood and particle board manufacturing, adhesives and sealants, paper treating and coating and insulation materials.[107] Toxic effects of formaldehyde result from exposure during manufacturing operations involving use of any formaldehyde-based product.

A. *The Hazard*

The irritant effects of formaldehyde have been well known for many years.[108] Eye, nose and throat irritation occur at concentrations as low as 0.1 ppm.[109] At higher concentrations, formaldehyde can cause coughing, dyspnea and pulmonary edema.[110] Formaldehyde is also a potent skin irritant and sensitizer. Dermal sensitization has been caused by many products that contain formaldehyde, including textiles, paper, cleaning agents and nail hardeners.[111] Household products containing 1% formaldehyde

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104. Occupational Exposure to Formaldehyde Final Rule, 52 Fed. Reg. 46,168, 46,172 (1987) (to be codified at 29 C.F.R. § 1910 and 1926) [hereinafter OSHA Final Rule].

105. *Id.*

106. *Id.*

107. *Id.*

108. This section summarizes the health effect data presented in OSHA's Notice of Proposed Rulemaking for Exposure to Formaldehyde, 50 Fed. Reg. 50,412, 50,414 (1985) (to be codified at 29 C.F.R. § 1910), *reprinted in* 15 THE OCCUPATIONAL SAFETY AND HEALTH REP. 605, (1985) [hereinafter OSHA NPR]..

109. One investigation of eight textile plants in England where formaldehyde was used to treat fabrics found complaints of mucous membrane irritation, tearing and wheezing in approximately 15% of the employees. Formaldehyde concentrations ranged from 0 to 2.7 ppm, with an average of 0.68 ppm in the plants. *See* SHIPKOVITZ, as cited in OSHA NPR, *supra* note 108, at 50,425.

110. *See* OSHA Final Rule, *supra* note 104, at 46,173.

111. Dermal sensitization is a well-known phenomenon. In patch testing results done of atopic individuals seeking medical assistance at allergy clinics, formaldehyde is among the top ten sensitizers. Sensitization is not readily reversible, so, once sensitized, an individual must usually avoid all contact with formaldehyde. *See* OSHA Final Rule, *supra* note 104, at 46,173-77, and OSHA NPR, *supra* note 108, at 50,427-30.

are considered strong sensitizers under the Federal Hazardous Substances Act,[112] and, as such, must bear a cautionary label.[113] However, it is the potential carcinogenic effect of formaldehyde that has prompted recent regulatory activity.[114]

In 1979, the Chemical Industry Institute of Toxicology (CIIT) reported the results of a 24-month inhalation animal bioassay.[115] Both neoplastic and non-neoplastic lesions of the nasal cavity were found. Researchers at New York University corroborated the results of this study two years later.[116] Several earlier epidemiologic studies demonstrated increased risk of death from brain cancer and leukemia in humans.[117] One prospective study of British chemical factory workers revealed a statistically significant excess mortality from lung cancer and chronic bronchitis.[118]

In 1980, the Federal Panel on Formaldehyde, composed of scientists from eight federal agencies, including OSHA, concluded that it was "prudent to regard formaldehyde as posing a carcinogenic risk to humans."[119] In 1981, the United Auto Workers (UAW) and 13 other unions petitioned OSHA either to issue an Emergency Temporary Standard (ETS) or to initiate permanent rulemaking.[120] This action marks the beginning of the regulatory furor over formaldehyde. Table 1 summarizes the major events. OSHA estimates that approximately 2.1 million workers are exposed to formaldehyde in a variety of industries and that about 200,000 workers are exposed to levels above 0.5 ppm.[121] Nearly half of these workers exposed are in the apparel industry.[122]

B. *The Use of Formaldehyde in the Textile and Apparel Industries*

The textile industry has produced fabrics treated with formaldehyde-based resins for over 50 years. These resins impart three

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112. 15 U.S.C. §§ 1261-1276 (1983).

113. 16 C.F.R. § 1500.13.

114. OSHA NPR, *supra* note 108, at 50,430-47.

115. *Id.* at 50,414-15, 50,433-34.

116. *Id.* at 50,434.

117. *Id.* at 50,446. These studies involved professional groups who preserve human tissues with solutions containing formaldehyde and other chemicals. Such risks have not been detected among industrial workers.

118. *Id.* at 50,441-42.

119. *Id.* at 50,415.

120. *Id.*

121. OSHA's Final Rule provides estimates of the number of affected establishments and employees, by SIC Code and industry. OSHA Final Rule, *supra* note 104 at 46,239; *but cf. infra* notes 177-180 and accompanying text for criticism of this estimate.

122. OSHA estimates that, of the 2.16 million workers exposed to formaldehyde, 941,000 are in the apparel industry. OSHA Final Rule, *supra* note 104, at 46,239.

Table 1.
History of Regulatory Action Regarding Formaldehyde

1979	CIIT study implicates formaldehyde as an animal carcinogen.
1980	Federal Panel on Formaldehyde concludes that it is prudent to regard formaldehyde as a carcinogenic risk to humans.
1981	NYU study corroborates CIIT findings.
1981	UAW petitions OSHA for an Emergency Temporary Standard (ETS). OSHA denies request on 1/19/82.
1981	EPA Office of Toxic Substances determines that formaldehyde might be a candidate for action under section 4(f) of the TSCA. EPA ultimately concludes that the available scientific information is insufficient to trigger section 4(f), and drops it as a priority for consideration.
1982	CPSC bans use of urea-formaldehyde foam insulation (UFFI) in residences and schools. Overturned in 1983 when Fifth Circuit Court of Appeals finds that CPSC failed to support its ban with substantial evidence.
1984	District court in Washington, DC remands UAW petition for an ETS to OSHA for reconsideration, or for initiation of permanent rulemaking.
1985	HUD issues regulations covering formaldehyde emissions from pressed wood products in manufactured homes and requires that plywood and particle board emit 0.2 ppm and 0.3 ppm respectively.
1985	OSHA again denies UAW petition for ETS, but indicates continuing consideration of need for a permanent standard.
1985	OSHA issues notice of proposed rulemaking in which it indicates that it will reduce the permissible exposure limit to either 1.5 or 1.0 ppm.
1987	An EPA study indicates that formaldehyde is "a probable human carcinogen," and the agency indicates that it will consider regulatory action.
1987	OSHA promulgates final formaldehyde standard, limiting workplace exposure level to 1.0 ppm.

important characteristics to textiles: durable-press, shrinkage control and wrinkle resistance.[123] Early in its development, formaldehyde-based resins could not be used on cotton textiles because of resulting fabric deterioration. Their use on cotton textiles became a commercial success in the early 1950's. Since that time, consumer demand for cotton and cotton-blend apparel has increased.[124] Approximately 62% of all apparel manufactured in the United States uses cotton or cotton-blend textiles and about 80% of these are treated with resins containing formaldehyde.[125] Most of this fabric is treated by the textile and finishing mills and virtually all of the apparel manufacturing plants handle such fabrics during any given year.[126] The National Cotton Council's consumer preference surveys suggested that cotton fiber can clearly capture an even larger share of the retail apparel market, but only if the textile retains its durable-press characteristics.[127] The Council noted that there were no commercially available alternatives to using formaldehyde-based resins for obtaining these characteristics and that "the net result of any regulation lowering formaldehyde levels in apparel manufacture, of course, would be reduced competitiveness of domestically manufactured apparel with a corresponding adverse effect on an already critical textile and apparel trade situation."[128]

V. REGULATORY OPTIONS AND POSSIBLE TECHNOLOGICAL RESPONSES

Worker exposure to formaldehyde can be affected by actions under the TSCA,[129] which is administered by the EPA Office of Toxic Substances, or by regulations under the OSH Act.[130]

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123. American Textile Manufacturers Institute, Inc., Comments on the Environmental Protection Agency's Regulatory Investigation of Formaldehyde, Docket Control No. OPTS 62033, 5 (1984) [hereinafter ATMI].

124. Cotton consumption by United States apparel manufacturers and cotton's share of the retail apparel market increased steadily during the 1980's. *See* Comments of the National Cotton Council of America to OSHA's Request for Information on Occupational Exposure to Formaldehyde, 50 Fed. Reg. 1547 (March 1, 1985) [hereinafter NCC].

125. *Id.*

126. *Id.* at 3.

127. *Id.* and appendices.

128. *See* Comments of the NCC to EPA's Advance Notice of Proposed Rulemaking-Formaldehyde: Determination of Significant Risk, at 8 July 23, 1984 (in response to 49 Fed. Reg. 21,870 (May 23, 1984)).

129. 15 U.S.C. §§ 2601-2629.

130. 29 U.S.C. §§ 651-678.

A. Regulation Under EPA

When EPA received the results of the Federal Panel on Formaldehyde's deliberations in 1981,[131] officials in the Office of Toxic Substances determined that the evidence was sufficient to require EPA to consider regulating under section 4(f) of the TSCA.[132] Ultimately, the agency did not act.[133] Had it opted to regulate formaldehyde under the TSCA, at least two options were available. The agency could ban the use of the product, as it did with PCB's a decade earlier, or it could reduce the allowable concentration of formaldehyde in resin. Under either EPA action, it is likely that significant product innovation would occur.

1. A Ban

Consumer surveys conducted by the textile and apparel industries clearly indicate a preference for cotton-blend, durable-press clothing.[134] Moreover, the cotton and cotton-blend textile and apparel manufacturers will not voluntarily give up their share of the market to synthetic fabric manufacturers. A ban would create the demand for a substitute product. Textile and apparel manufacturers, as downstream users of formaldehyde resins, would likely turn to the suppliers for help. With sufficient notice, their suppliers could respond.

In the late 1970's, in anticipation of future regulation and with pressure from a major apparel manufacturer, the existing chemical suppliers developed resins containing lower concentrations of formaldehyde,[135] which are now used but are reported to provide

131. *Report of the Federal Panel on Formaldehyde*, 43 ENVTL. HEALTH PERSP. 139 (1982), [hereinafter Federal Panel Report]. The panel was composed of top scientists of the federal government and was directed to evaluate all available information on the effects of exposure to formaldehyde.

132. Under section 4f of the TSCA, if the EPA Administrator is presented with information "which indicates . . . that there may be a reasonable basis to conclude that a chemical substance or mixture presents or will present a significant risk of serious or widespread harm to human beings from cancer, gene mutations, or birth defects, the Administrator shall . . . initiate appropriate action . . . to prevent or reduce to a sufficient extent such risk or publish in the Federal Register a finding that such risk is not unreasonable." 15 U.S.C. § 2603(f)(2).

133. For an interesting historical account, *see* Ashford, Ryan & Caldart, *A Hard Look at Federal Regulation of Formaldehyde: A Departure from Reasoned Decisionmaking*, 7 HARV. ENVTL. L. REV. 297 (1983).

134. *See* NCC Comments on OSHA's Advance Notice of Proposed Rulemaking–Occupational Exposure to Formaldehyde, August 15, 1985 (in response to 50 Fed. Reg. 15,179 (April 17, 1985)).

135. Levi Strauss, conscious of likely future regulation and citing concern for its workers, instituted a policy that it would not accept fabric from its suppliers with more than 500 micrograms of formaldehyde per gram of cloth. Formerly, upwards of 2000 micrograms/gram was used. Personal communication with Larry Elliott, Supervisory Industrial Hygienist, Hazard Evaluation Technical Assistance, National Institute for Occupational Safety and Health, Cincinnati, OH and Beth Andrews, Textile Chemist, Southern Regional Research Center, Agricultural Research Service, United States Department of Agriculture (USDA), New

somewhat inferior durable-press characteristics to textiles.[136] Non-formaldehyde substitutes[137] also have been developed by existing suppliers, but none have been acceptable for use in treating fabric because they are considered more expensive to use and considerably less effective.[138] The American Textile Manufacturers Institute (ATMI) has said that "[m]andating nonformaldehyde treatments would be unrealistic, is not necessary and would force consumers back to the drudgery of ironing."[139]

To date, the existing suppliers have not developed a commercially successful non-formaldehyde substitute, even during a protracted, visible and emotionally charged pre-regulatory period. This is not surprising, given their stage of technological evolution in the market. This sector has been supplying formaldehyde for a half century, is relatively mature and is therefore unlikely to respond with significant product innovation without outside assistance.[140] A substitute product is likely to be developed now that the United States Department of Agriculture (USDA) is working with industry[141] to provide the necessary technical ingredients for innovation.

Unless existing suppliers are able to respond with a new product, new entrants would have every incentive to enter the marketplace. However, unless the need for a new product was fairly certain, extensive innovation might be considered too large

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Orleans, LA (March 7, 1988); *See also* Comments of the American Apparel Manufacturers Association on OSHA's Advanced Notice of Proposed Rulemaking–Occupational Exposure to Formaldehyde, at 5, August 13, 1985 (in response to 50 Fed. Reg. 151,799 (April 17, 1985)) [hereinafter AAMA]. In what has been called a "marriage between the chemical industry and the textile industry", with assistance from the USDA, a resin imparting 200-250 micrograms of free formaldehyde per gram of cloth is now routinely available to the apparel industry. L. Elliott & B. Andrews, *supra*. The low formaldehyde content resins were apparently "easy to develop." (Andrews *supra*). For a technical description of the modified resins and their formaldehyde release on textiles, see Kottes, Andrews & Reinhardt, *Formaldehyde Release From Cellulose Textiles Treated for Smooth-Drying Properties with Formaldehyde and Its Amide Derivatives*, in WOOD AND CELLULOSICS: INDUSTRIAL UTILIZATION, BIOTECHNOLOGY, STRUCTURE AND PROPERTIES at 417 (Kennedy, Phillips & Williams ed. 1987).

136. *See* NCC Comments, *supra* note 134.

137. These agents have included sulfones, epoxides, and glyoxal and other amides, but have focused on dihydroxyethyleneurea and N,N'-dimethyldihydroxy-ethyleneurea. *See* NCC Comments, *supra* note 134, at 5 and NCC *supra* note 124, at 5-6.

138. *Id.* at 5 and ATMI, *supra* note 123, at 3.

139. ATMI, *supra* note 123, at 22.

140. As a result of a joint research effort between the industry and the United States Department of Agriculture, a new product is in development. (Andrews *supra* note 135).

141. Note that both the lower formaldehyde-containing resin and the new product in development involved the technical assistance of the USDA. The industry is unlikely to have been able to develop new technology by itself. Note also that the formaldehyde in the lower formaldehyde-containing resins is not low enough to provide a safe workplace without the use of general ventilation as well. The reduction of allowable formaldehyde that EPA would adopt would require further dramatic modifications of the existing resins. *See infra* note 145 and accompanying text.

a commercial risk.[142] If new entrants could successfully develop a substitute product that did not present an unreasonable risk to human health and the environment, their commercial risk would be small. In that event, the entire cotton textile and apparel industries would be waiting in the wings.[143]

2. *Reduction of allowable concentration*

EPA could elect to require reductions in the concentration of formaldehyde in resins used to treat textiles. Existing suppliers have already developed lower formaldehyde-containing resins for use in the textile industry.[144] EPA regulation could stimulate further innovation by the existing suppliers who could retain their place in the market by developing resins with even lower levels of formaldehyde.[145] It is unlikely that this scenario would attract new entrants to the market, as the existing suppliers would have a competitive advantage in terms of existing manufacturing plant and human resource experience.

Both options available under EPA regulation would result in technological innovation, with the ban creating much more radical innovation than the reduction. A total ban would also eliminate all formaldehyde exposure and its associated morbidity and mortality.

B. Regulation Under OSHA

After reviewing the results of the CIIT animal bioassay in 1979, OSHA joined the Federal Panel on Formaldehyde. The agency also joined the National Institute for Occupational Safety and Health (NIOSH) in the preparation of a Current Intelligence Bulletin on Formaldehyde which listed formaldehyde as a potential occupational carcinogen.[146] In 1981, a new Secretary of Labor withdrew the agency's sponsorship of this publication and later stated that he found the CIIT data unpersuasive.[147] That same

142. If the existing suppliers are able to develop a new product with government technical assistance, new entrants would not likely undertake the commercial risk.

143. According to the ATMI, "an immense and captive market awaits the developer of a substitute treatment for permanent-press." *Supra* note 123, at 20.

144. *See* NCC Comments of August 15, 1985, *supra* note 134, at 4-5; *see also supra* notes 135, 141.

145. EPA has limited authority under the TSCA to regulate the workplace directly. It can affect workplace health by limiting the nature and amount of industrial products used. Therefore, it could regulate the amount of formaldehyde in resins whose emissions would result in very low ambient concentrations of formaldehyde *in the absence of ventilation*. Thus an EPA limitation on formaldehyde content could be much lower than the current industry practice of 200-250 micrograms per gram of cloth. *See supra* note 141.

146. *See* Ashford, Ryan & Caldart, *supra* note 133, at 299.

147. *Id.* at 299, 347-58.

year, the UAW petitioned OSHA to issue an emergency temporary standard (ETS) and the regulatory dance began.[148]

1. Regulation

Unlike EPA, OSHA's regulatory options do not include a ban. The agency can set permissible exposure limits (PEL's)[149] and short-term exposure limits (STEL's).[150] Moreover, OSHA can require exposure monitoring, medical surveillance, medical removal and worker training. After five years of litigation,[151] OSHA finally published a comprehensive health standard for formaldehyde on December 4, 1987, which became effective on February 22, 1988.[152] The standard, which regulates formaldehyde as a human carcinogen, lowers the PEL from 3 ppm to 1 ppm as an eight hour time-weighted average (TWA); sets an STEL of 2 ppm for any 15 minute period; and sets requirements for exposure monitoring, personal protective equipment, medical surveillance, hazard communication and worker training.[153] Exposure monitoring, medical surveillance and worker training are triggered by any exposure at or above an action level of a TWA of 0.5 ppm or STEL of 2.0 ppm.[154]

By setting a performance standard, OSHA essentially regulates the manufacturing process. Unless waivers or exemptions are given, the standard demands compliance from all employers who expose workers to the regulated substance above a certain action level, in this case 0.5 ppm.

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148. *Id.* at 348.

149. A PEL is expressed as an eight hour time-weighted average of allowable exposure. For example, a PEL of 2 ppm could be satisfied by four hours exposure to 3 ppm and four hours exposure to 1 ppm.

150. An STEL is expressed as a maximum allowable level over a short period of time, *e.g.*, an exposure not to exceed 2 ppm for longer that fifteen minutes.

151. The UAW filed suit to compel OSHA to promulgate an ETS on August 25, 1982. Ashford, Ryan & Caldart, *supra* note 133, at 348.

152. *See* OSHA Final Rule, *supra* note 104, at 46,168.

153. *Id.*

154. The standard requires periodic exposure monitoring every six months after initial monitoring as long as the exposure is at or above the action level of 0.5 ppm in an eight hour TWA or the STEL of 2 ppm. *See* OSHA Final Rule, *supra* note 104, at 46,255-59. Medical surveillance includes the administration of an annual medical and occupational disease questionnaire for all workers exposed at or above the action level or the STEL, and medical testing if the responsible physician reviewing the questionnaires feels that further testing is warranted. In addition, all persons exposed to formaldehyde (at any level) are eligible to receive nonroutine screening if the employer suspects that they have signs or symptoms relating to their exposure to formaldehyde. All medical examinations and the administration of the questionnaire must be conducted at no expense to the worker. *See* OSHA Final Rule, *supra* note 104, at 46,276-82. Worker training is required at least annually for all workers exposed at or above the action level or STEL. *See* OSHA Final Rule, *supra* note 104, at 46,286-87.

2. *Responses*

Both textile and apparel manufacturers could use general or source ventilation[155] to reduce exposure. Alternatively, they could attempt to automate or enclose the processes that result in the exposure. This response would involve process innovation. Theoretically, the industries could rely on employee use of personal respiratory protective equipment to reduce exposure, but the standard specifies that this option is allowable only when engineering controls and work practices cannot achieve the PEL.

Both the textile and apparel industries are convinced that the American public wants clothing with permanent-press characteristics. They have also stated that there are no acceptable substitutes for formaldehyde at the moment.[156] The apparel industry apparently successfully pressured the formaldehyde manufacturers to come up with a lower formaldehyde-containing product.[157] However, the modified resin must be used in combination with general ventilation in order to achieve compliance with the OSHA PEL of 1.0 ppm and to ensure that few workers in both the textile and apparel industries are exposed above the action level of 0.5 ppm.[158]

The installation of source ventilation in the apparel industry would be a significant innovation, but it is not now necessary, given the use of lower formaldehyde-containing resins.

C. *Choice of Technological Options for Analysis*

Table 2 ranks the technological responses expected under each of the regulatory options analyzed in this paper. As suggested, without outside assistance to existing resin suppliers, an EPA ban would likely result in the development of a substitute product by new entrants (chemical suppliers) into the market. Existing formaldehyde resin suppliers have not yet come up with an acceptable non-formaldehyde substitute, but with the assistance of the USDA they are developing a new product.[159] New or existing textile manufacturers will not quickly develop a new textile or textile-blend to replace a demonstrated consumer preference for cotton and cotton-blend fabric.

If, on the other hand, EPA lowered the permissible formal-

155. The installation of source ventilation in the apparel industry would be a significant innovation, but it is not likely to occur. In most apparel plants, the sources of formaldehyde release are diffuse, as treated fabric is stacked around many machine operators. General on-the-shelf ventilation technology is the engineering control of choice.

156. *But cf. supra* notes 140 and 141.

157. *See supra* notes 135 and 141.

158. *See infra* notes 170-186 and accompanying text.

159. *See supra* notes 140 and 141.

Table 2.
Likely Technological Responses to Different Types of Formaldehyde Regulation

EPA-IMPOSED BAN
New resin by new market entrant
Development of acceptable non-formaldehyde resins by existing suppliers
New textile or textile blend
EPA-IMPOSED REDUCTION IN HCHO CONTENT IN RESIN
Existing suppliers provide altered resin–incremental innovation
New market entrant provides altered resin
Possibility that reduction is so difficult to achieve that the response is the same as with a ban (see above)
OSHA-IMPOSED STANDARD
Use of existing ventilation technology
Improvement in low formaldehyde-containing resins by existing suppliers
New market entrant with altered resin

dehyde content in resin used to treat textiles, the existing resin suppliers could be expected to attempt further incremental changes in their technology to retain their market share with the textile industry. New firms would enter the market only if the existing suppliers were slow to respond. If the EPA's permissible formaldehyde concentration in resin were so low that neither existing suppliers nor new entrants could come up with an acceptable formaldehyde-containing resin, the results would be essentially the same as if EPA had imposed a ban.

The technological response to the new OSHA standard has been the use of largely in-place ventilation technology and the development of modified resins. Prior to and in anticipation of the regulation, the existing resin suppliers have made improvements in their low concentration formaldehyde-resin such that many of the exposure levels in the textile and apparel industries fell below the action level of 0.5 ppm.[160] Except for the possible but unlikely development of entirely new types of textiles, three clear technological responses emerge for further analysis of economic costs and health benefits: (1) the development of a new product, (2) the further lowering of formaldehyde content in resins used for treating textiles or (3) the use of largely in-place ventilation technology in combination with existing modified resins.

160. *See supra* note 135; *infra* note 178 and accompanying text.

VI. ANALYSIS

This section explains the types of direct economic costs and benefits to be expected by industry under the three technological compliance scenarios considered above. Precise cost and health benefit data have not been calculated by the authors, but are given when available from the literature.

A. *A New Product*

1. *Economic Consequences*

The existing chemical suppliers would bear the major economic cost of developing a non-formaldehyde resin for treatment of textiles. Approximately two percent of the 5.7 billion pounds of formaldehyde produced in the United States are used in the textile industry.[161] At approximately eight cents per pound (1980 price),[162] the existing suppliers could lose their $9 million annual market unless they develop a successful new product.[163] The additional manufacturing cost of this new product, including development costs, is unknown. The developer of the new product would pass most of the cost on to the textile industry.[164] This would increase the latter's manufacturing cost to some extent, although resin is a minor cost item and is only one of several production factors. This additional cost might be offset by the lower costs of compliance with OSHA regulations for formaldehyde exposure (*i.e.*, ventilation and medical surveillance would no longer be required) and by the benefits of any improvement in textile quality that might result.

The apparel industry would bear little of the adverse economic consequences of a ban which resulted in a new product. It is unlikely that the textile industry would pass much of its additional costs on to the beleaguered apparel manufacturers. But it *is* likely that any benefits of improved textile quality would also accrue to the apparel industry.

In the unlikely event that new entrants were unable to make available a substitute product within a reasonable time and if the EPA ban affected only resin and not cloth, the apparel industry would be forced to shift to foreign textile suppliers. In order to save their market, the textile industry might increase off-shore

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161. *See* OSHA Final Rule, *supra* note 104, at 46,172.

162. Ashford, Hattis, Mitchell, McCleary-Jones, Gorelick, *Control of Occupational Exposures to Formaldehyde: A Case Study of Methodology for Assessing Health & Economic Impacts of OSHA Health Standards*, CENTER FOR POLICY ALTERNATIVES 81-117 (1981).

163. *See supra* note 141.

164. If the existing joint research effort between the chemical industry and the textile industry, assisted by the USDA, succeeds, the cost is shared. *See supra* note 141.

production, purchasing formaldehyde-containing resins from foreign suppliers. In the more likely event that the ban extended to cloth, the apparel industry could lose a significant part of its market to foreign producers of finished products.

How would any of these economic consequences affect labor? Some employees of the existing formaldehyde resin manufacturers would lose their jobs. Other individuals would gain employment in the new entrant firms or in association with new product lines.[165] Workers in the textile and apparel industries should not encounter significant adverse economic consequences in terms of wage reduction or job loss, unless the industries elected to move to off-shore production.

A ban on formaldehyde would also result in economic benefits associated with reduced formaldehyde-related morbidity and mortality. These benefits are discussed below.

2. *Health Consequences*

A formaldehyde ban would virtually eliminate all health effects associated with formaldehyde exposure. It is likely, however, that formaldehyde-related cancers would continue to occur for a number of years after the ban, due to long latency periods. It is estimated that workplace formaldehyde exposure at levels of 3 ppm result in an excess cancer risk that ranges from 43.4 to 620 per 100,000 based on the most likely estimate, with upper confidence levels ranging from 600 to 1,819 cases per 100,000.[166] Exact risk estimates of sensory irritation have not been calculated, although one estimate has been made that 31% to 94% of workers will experience discomfort even when exposure levels are as low as 0.5 to 1.0 ppm.[167] Although recognized as a serious problem, no reliable estimates of skin diseases associated with formaldehyde exposure are available. Nor has the risk of associated respiratory disorders been quantified. Thus, the overall health benefits of a formaldehyde ban, although substantial, are difficult to determine.

The major health benefits would accrue to workers in the apparel industry. Almost every one of its 960,000 production employees are exposed to formaldehyde on a daily basis. Although exposure levels are relatively low in this industry, the workers will suffer significantly fewer adverse health outcomes than are currently caused by their work with formaldehyde-impregnated textiles. For all industries involved, improvements in worker health status would result in savings related to reductions in

165. The number of newly created jobs is likely to be less than the number lost due to automation or less labor-intensive production processes in the new firms.

166. *See* OSHA Final Rule, *supra* note 104, at 46,223.

167. *Id.* at 46,224.

health care costs, workers' compensation costs, employee absence, and turnover rates. The latter savings would result in productivity increases with an associated increase in revenues. Chemical suppliers would also see reduced tort liability.

Of course, while unlikely, it is possible that the new substitute product would itself prove to be hazardous. This would pose health risks to workers in the new firms, as well as to workers in the textile and apparel industries. New economic and human costs would ensue. It is not possible to predict these costs for the purposes of the present analysis.

B. Additional Reduction of Formaldehyde Concentration in Resins

1. Economic Consequences

While it is possible that new suppliers would enter the market, resulting in consequences similar to those discussed above, it is more likely that the existing chemical suppliers would be willing to incur the costs of further reducing the formaldehyde in their product to meet an EPA regulation. This R&D cost could be passed on to the textile industry. It is also possible that the innovation ultimately could be cost-saving, as in the case of vinyl chloride regulation, and could increase the profit margin of the industry. Similarly, the improved resin could be useful in other applications, providing additional economic advantage to the industry.

The textile industry would probably bear the economic burden of this regulatory option, although the magnitude of this burden is unknown. With little possibility for new suppliers to enter the market and offer lower formaldehyde-containing resin competitively, the textile industry would be obliged to purchase the improved resin from the existing suppliers and to absorb the expected price increase.[168] The textile industry would be hesitant to pass this cost on to the apparel industry, for fear of losing its own market to foreign textile suppliers. This regulatory option, limiting the use of formaldehyde, could result in some restructuring of the textile industry over time as marginal firms might be unable to compete. The economic costs to the apparel industry would be minimal.

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168. It was apparently easy to develop a lower formaldehyde-containing resin in anticipation of the OSHA regulation. *See supra* note 135. Whether a further, dramatic reduction would follow as readily is unknown. Radically different technical modification of the resin (*i.e.*, major rather than minor innovation) might be necessary to reduce the amount of free formaldehyde below that in the present commercial product which yields 200-250 micrograms of formaldehyde per gram of cloth. Continuing assistance by the USDA would go a long way in keeping commercial development costs, and hence price increases, at a minimum.

Any economic disadvantage to labor would likely be limited to workers in the textile industry. The increased cost of a necessary production factor could result in some downward pressure on wages and some local unemployment as marginal firms leave the market.

2. *Health Consequences*

Because formaldehyde would not be eliminated under this regulatory option, some adverse health effects associated with formaldehyde would continue to occur. Only if the regulation resulted in ambient exposures lower than 0.1 ppm would a large proportion of irritant and respiratory effects disappear.[169] A cancer risk would remain, although it would likely be reduced in magnitude.

C. *Use of Existing Ventilation Technology In Combination with Existing Modified Resins*

1. *Economic Consequences*

The distribution of the economic burdens of complying with the new OSHA formaldehyde standard is significantly different from the distribution that would occur under the two options described above. To comply with the new PEL, the affected industries will use existing ventilation in combination with existing modified resins.

There is considerable disagreement about the extent of this compliance cost in the apparel industry. While OSHA and the Amalgamated Clothing and Textile Workers Union (ACTWU) estimate that the cost of engineering controls in this industry will be essentially zero because the firms are already at or below the PEL,[170] the American Apparel Manufacturers Association

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169. *See* OSHA Final Rule, *supra* note 104, at 46,173. Even at airborne concentrations as low as 0.1 ppm, however, formaldehyde can irritate the eyes, nose and throat. As concentrations increase, the severity of the irritation increases.

170. In its Final Rule, OSHA estimates that the textile finishing industry and the apparel industry will incur *no* costs relating to engineering controls in order to achieve the standard's PEL and STEL. *See* OSHA Final Rule, *supra* note 104, at 46,240. In its comments on occupational exposure to formaldehyde, the ACTWU asserted that "with currently available technology, apparel manufacturers are now able to comply with a new permissible exposure limit of either 1.0 ppm or 0.5 ppm without any capital costs whatsoever." Comments of the ACTWU, AFL-CIO before the Occupational Safety and Health Administration on the Advanced Notice of Proposed Rulemaking (ANPR) for a Standard to Regulate Formaldehyde at 3 (1985). *See also infra* note 177.

(AAMA) claims otherwise.[171] In an interesting turn of events, the AAMA implies higher exposure levels in the plants than estimated by either OSHA or the union.[172] In contrast, OSHA concludes than no workers in the apparel industry are exposed to levels greater than 1.0 ppm and that most are exposed to levels below 0.5 ppm.[173]

For the textile industry, OSHA estimates zero compliance costs for engineering controls. (The firms are already in compliance with the PEL.) Interestingly, in their comments on EPA's regulatory investigation of formaldehyde, the American Textile Manufacturers Institute (ATMI) presents no information on their own sector's ability to comply with a reduced PEL, but does offer opinions on the apparel industry's inability to install ventilation technology. "Ventilation of the workplace . . . has immense costs in the case of the apparel industry . . . . While . . . ventilation is technologically feasible, there is serious question as to whether it is economically viable . . . . The data suggest that the apparel industry would likely respond by increasing off-shore production."[174]

The new OSHA regulation is a comprehensive health standard that does more than set a PEL and STEL. It also requires exposure monitoring, medical surveillance and worker training triggered by an action level of 0.5 ppm.[175] OSHA has estimated the annual costs for the apparel industry of complying with these requirements to be $6.6 million,[176] among the highest of any affected industry. However, the ACTWU insists[177] that this calculation depends on OSHA's erroneous estimate of 117,663 as the number of apparel industry workers exposed to formaldehyde between 0.5 ppm and 1.0 ppm.[178] The union argued that the number of apparel workers exposed to formaldehyde between 0.5 ppm and 1 ppm is closer to 17,000, approximately two percent of the

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171. In its comments to OSHA, the AAMA acknowledged that the entire industry could comply with a 1.5 ppm standard because of technical advances in the formaldehyde-containing finishes applied to fabric. However, using figures generated by an Arthur D. Little study, the AAMA estimates that a 33% reduction, from 1.5 ppm to 1.0 ppm, could require $399 million in capital investment, and additional operating costs of $15.6 million per year. The AAMA also suggests that this reduction could result in the loss of 135,000 jobs. *See* AAMA, *supra* note 135.

172. *Id.*

173. *See* OSHA Final Rule, *supra* note 104, at 46,239.

174. *See* ATMI Comments, *supra* note 123, at 24-25.

175. *Supra* note 154.

176. *See* OSHA Final Rule, *supra* note 104, at 46,240.

177. Private communication with Eric Frumin, Director of Occupational Safety and Health for the American Clothing and Textile Workers Union (March 7, 1988). *See also* Testimony [Docket Number H-225A (April 14, 1986) pp. 9-13]; Post-hearing Statement of the ACTWU, AFL-CIO on the Proposed OSHA Standard for Formaldehyde (August 15, 1986).

178. *See* OSHA Final Rule, *supra* note 104, at 46,239.

total number of exposed workers in the textile industry.[179] An industrial hygienist from NIOSH agreed with the union's position that the 117,663 figure was a gross overestimate.[180] Calculations based on the lower estimate of workers exposed above the action level would reduce the OSHA compliance cost estimate to approximately $700,000 per year, which the apparel industry could absorb.

The textile industry will find compliance with all aspects of the standard easier to achieve. The industry will lose its market only in the unlikely event that the foreign apparel industry penetrates the United States market significantly or that the relocation of segments of the apparel industry significantly affects the market for American textiles. In these situations, the textile industry can also anticipate economic loss.

The formaldehyde resin suppliers will have little difficulty meeting the PEL through ventilation technology, which, in fact, is largely in place. The total cost of engineering controls for resin manufacturers will be a mere $401,747.[181] Even with the additional costs of exposure monitoring, medical surveillance and worker training, total compliance costs for the resin manufacturers will be 0.07% of profits.[182]

2. *Health Consequences*

The new standard reduces workplace exposure to formaldehyde by two-thirds. This reduction will have a positive effect on worker health, although it will not eliminate formaldehyde-related disease and symptoms. The OSHA record contains numerous objections to the new PEL, with frequent calls for a more stringent level based on health considerations.[183] Indeed, many of formaldehyde's irritant effects occur with exposures well below the action level of 0.5 ppm. The agency heard testimony from NIOSH and from a number of affected unions urging a more stringent PEL, but concluded that "adopting a 0.5 ppm TWA PEL rather than a 1 ppm TWA would reduce the risk of acute health effects, although it would do little to further reduce the risk of cancer . . . ."[184] OSHA estimates that the new PEL will result in a 6- to 471-fold reduction in cancer risk for a worker whose exposure is decreased from an average of 3 ppm to an average of 1 ppm.[185] The agency relies on other provisions of the standard to reduce the more acute health hazards.

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179. *See* Frumin, *supra* note 177.
180. *See* Elliott, *supra* note 135 and Elliott, *infra* note 186.
181. *See* OSHA Final Rule, *supra* note 104, at 46,240
182. *Id.* at 46,241.
183. *Id.* at 46,244, 46,249.
184. *Id.* at 46,252.
185. *Id.* at 46,223

The standard may have some unintended health benefits as well. Although physical examinations and ancillary procedures are limited to individuals who exhibit symptoms of, or have complaints consistent with, formaldehyde-related illness, such medical screening may detect other incipient health problems in time for effective intervention. The value of this spill-over effect is unknown. At any rate, the health benefits of the standard, while distributed across all industries, will be greatest for workers in those industries with the highest pre-regulatory exposure levels (resin manufacture) and in industries where a large number are exposed routinely (apparel). The positive economic consequences of reductions in morbidity and mortality associated with formaldehyde exposure will be felt in those industries as well.

VII. SUMMARY AND CONCLUSIONS

Formaldehyde has been an important chemical for a wide variety of United States industries for many years. Its acute health effects have been well known; its chronic respiratory and carcinogenic effects have been recognized only relatively recently. The government has several regulatory options when it seeks to control exposure to hazardous substances. Each will evoke different technological responses from the affected industries. The resulting level of health protection depends in large measure on the nature of the response. This Article examined three regulatory options for controlling exposure to formaldehyde–two possible options under EPA's TSCA authority and the one which actually occurred under OSHA. Each would result in some level of protection, but the distribution of the costs and benefits of each regulatory option would differ significantly.

A ban on the product would encourage product innovation and permit the market to operate in an efficient manner by internalizing *all* of the social costs of production. The small number of resin suppliers would suffer economic loss if new suppliers entered the market; the textile and apparel industries would not be severely affected and could even enjoy some economic benefit. In addition, the workers in these industries would be fully protected from the hazardous product. Alternatively, EPA action that reduced the allowable concentration of formaldehyde in resin would encourage product or process innovation in the chemical industry, which might or might not lead to an abandonment of formaldehyde-based resins. Such action would place the economic burden on the textile industry and, as compared to a ban, provide fewer health benefits to the workers in all related industries.

The OSHA standard will do little, if anything, to encourage significant innovation, although significant resin modification has already occurred. Currently, almost all of the workers in the apparel industry are exposed below the action level of 0.5 ppm.[186] Workers in the apparel and textile industries will enjoy some additional health benefits from the standard, but will not be fully protected from adverse health effects of formaldehyde exposure. For the apparel industry, at least, OSHA did not set the lowest feasible level.[187] The most stringent regulatory option–an EPA ban–could result in lower economic costs, a more efficient market and greater health benefits. Admittedly, this is not what some critics of regulation would predict. Innovation, rather than diffusion of technology, is the crucial factor in arriving at a new and dynamic market efficiency.

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186. *See supra notes 177-180 and accompanying text. See also* Elliott, Stayner, Blade, Halperin & Keenlyside, *Characterization in Garment Manufacturing Plants: A Composite Summary of Three In-Depth Industrial Hygiene Surveys* (Jan. 1987) (unpublished manuscript, National Institute for Occupational Safety and Health).

187. *See supra* note 38.