EPA 560/4-84-002
May 1984

TOXICS '95: OUTLOOK OF FACTORS AND TRENDS FOR TOXIC CHEMICALS

by

Vary T. Coates
Lisa Heinz
Joseph Coates
Tracie Monk

Contract No. 68-01-6287

Project Officers
Ellen Selonick Berick
George Wirth
Economics and Technology Division
Office of Toxic Substances
Washington, DC 20460

OFFICE OF PESTICIDES AND TOXIC SUBSTANCES
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, DC 20460

PREFACE

The Toxic Substances Control Act is broad legislation covering immense and complex environmental and economic issues. Congress charged the Office of Toxic Substances (OTS) with not unduly impeding technological innovation while fulfilling the primary purpose of the Act, assuring that innovation and commerce in chemicals do not present an unreasonable risk of injury to health or the environment. To do this difficult task well, OTS needs to know more about the likely direction of technological innovation in the chemical industry, and of the environmental and policy issues that it will face in the next decade.

This work was undertaken to assist OTS in identifying the factors and trends that may shape the next decade of toxic substances control. By attempting to anticipate what the next ten years may bring, OTS increases its opportunity to deal effectively with the problems and to use its resources efficiently.

Chapters 1 and 2 of this report may be read as an Executive Summary. Chapters 3-5 are expanded information.

The results of the study may be used by OTS staff to change priorities, or the way in which OTS coordinates with other agencies, or to suggest further research on particular topics. However, the primary point is to assist in the long-term policy and budget planning for the office.

The work reported herein is principally the responsibility of Vary T. Coates, Ph.D., Lisa Heinz, Joseph F. Coates, and Tracie Monk. Additional support was provided by Henry H. Hitchcock. The physical preparation of the document was under the supervision of Beverly Goldberg with the assistance of Bernice Mann, Ann Webber, Diana Clark, Flora Riemer, Maureen Jones, and Elijah Merritt.

At the Office of Toxic Substances, our Project Managers were, first, Ellen Selonick, and later George Wirth. We have all enjoyed their guidance, assistance, and support.

J. F. Coates, Inc., a futures research and policy analysis firm, carried out this project as subcontractor to ICF, Inc., Washington, D.C. We thank Joe Kirk of ICF for his cooperation and support during the project.

This report was produced under Subcontract EPA 22-12, ICF Contract No. 68-01-6287. The opinions, conclusions, findings, and recommendations are those of the authors and do not necessarily reflect the opinions of ICF, Inc., or of the Office of Toxic Substances.

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CHAPTER 1

INTRODUCTION, FINDINGS, AND CONCLUSIONS

Chapters 1 and 2 of this report constitute an EXECUTIVE SUMMARY of the report.

Chapter 1 summarizes this study of the outlook for regulation of chemicals in the environment and highlights findings and conclusions, and the implications for OTS.

Chapter 2 presents alternative scenarios for the future of the U.S. chemical industry and regulatory process.

The Toxic Substances Control Act of 1976 empowered the Federal government to regulate and control the production and use of chemicals that will or may present an unreasonable risk of injury to health or to the environment. Congress also directed that the Environmental Protection Agency which administers this broad mandate through its Office of Toxic Substances (OTS), shall not "unduly impede technological innovation" in the chemical industry, which is recognized as important to the economic life of the nation.

There is no simple or complex formula for determining what constitutes unreasonable risk. Nor is there a ready consensus as to what regulatory strategies might or might not unduly impede technological innovation. These determinations must be made on a case-by-case basis and in a context of uncertainty about the future evolution and behavior of the chemical industry. The industry is, and will continue to be, responding and adapting to complex changes in its economic environment, to increasing competition in world markets, and to continuing advances in science and technology. The industry also responds to pressures that arise from public concerns and public values, and to a broad range of other national policies and objectives.

OTS, to better guide the development and implementation of its program objectives and to develop more cost-effective means of achieving industry compliance with Federal policies, tries to anticipate and understand the forces acting on the chemical industry and their implications for effective control of the risks associated with production and use of chemicals in our society.

As an early step in improving its foresight capability, OTS commissioned this broadly exploratory study to provide a futures perspective on the problems of toxic substances control over the next dozen years -- 1983-1995. This report is to be used by OTS staff in reassessing and evaluating OTS priorities and opportunities for action, the way OTS coordinates with other EPA programs, state governments, agencies in other nations, and other Federal agenices, and EPA needs for further research and analysis of unfolding developments. The twelve-year horizon, while arbitrary, does represent a reasonable futures perspective for addressing toxic chemical concerns because it takes about that long for a new generation of chemicals to be broadly distributed and have significant economic impact.

This study was designed to identify and consider the interactions of trends affecting the nation in general and thus both the chemical industry and public expectations about its role and activities. In particular the study was to consider:

- business and economic trends, including shifts in business strategy and likely changes in international trade patterns;
- scientific and technological trends, including areas where advances in knowledge can be expected that will influence or create public health concerns, and areas ripe for innovation such as alternative chemical feedstocks or waste disposal technologies;
- political trends, covering the general evolution of public attitudes, political responses, and the evolution of institutions, laws, and regulations; and
- broad social, demographic, and lifestyle trends.

Having surveyed this broad range of evolutionary and revolutionary trends and potentialities, the study was to suggest two or three scenarios that would provide alternative futures for the U.S. chemical industry. These scenarios presented in Chapter 2, it should be stressed, are not predictions or forecasts. The scenarios are heuristic. They should stimulate OTS analysts to think constructively and creatively about the forces changing the nature of their responsibilities and about the resulting new problems and opportunities. The reader is invited to construct alternative scenarios from variables presented in this report.

The scope of long-range trends and possible events and developments covered permits only qualitative analysis. The analysis depended on interpretation of information from open literature, especially trade journals and scientific and professional periodicals, and on interviews and discussions with experts and informed observers in industry, unions, government, academies, and public interest groups.

A workshop held one-third of the way through the five-month project was especially valuable. Sixteen people representing major interests affected by toxic chemical regulation -- from major chemical corporations to public interest advocates -- reviewed working papers prepared by the research team. They spent a full day with us in evaluating the first-phase work and advising on how to proceed. Workshop participants are listed in the Appendix. The draft final report was reviewed in a second workshop in December 1983. Those reviewers are also listed in the Appendix. Approximately 36 experts were interviewed, in person or by telephone, during the course of the study. These people are also listed in the Appendix.

The scenarios of alternative futures for the chemical industry in 1995 are presented in Chapter 2. The introduction to the chapter explains how the scenarios were generated. These scenarios depend on the materials presented in Chapters 3, 4, and 5, which identify and discuss long-range trends and their interactions, and the implications for the problem of controlling the risks of toxic chemicals in modern society. Chapter 3 looks at trends in the industry itself, in the business environment and in international trade patterns. Chapter 4 considers social and political trends and identifies some emerging policy issues which, within the next decade, have the potential for involving the industry in controversy and conflict. Chapter 5 reviews impending developments and areas of advancement in basic and applied science, and in industrial innovation, that will affect industry problems and opportunities. For convenience, the findings and conclusions arising from this work are given below.

FINDINGS AND CONCLUSIONS

The Chemical Industry: Strong, Mature

- The chemical industry plays a central role in our economy. It is the fourth largest manufacturing industry in the United States and a big contributor to our balance of payments, with a better than two-to-one ratio of exports to imports.

- The chemical industry after four decades of growth is a maturing industry, facing rising costs of production and increasing competition in international trade. Its largest customers -- the automobile, housing, and steel industries -- are not likely to enjoy again the growth rates of recent decades.

- Some parts of the chemical industry, especially commodity chemicals, are likely to have continuing over-capacity for several years. The work force is likely to remain stable or to shrink.

- Industry strategy for the next decade will emphasize cost-reduction, risk-aversion, risk-spreading (through insurance and through diversification, for example), and the shedding of low profitability products and units.

Product Mix: Movement to Specialties

- There will be a marked movement toward high or value added specialty chemicals and relatively little growth in bulk chemicals production in the United States.
- The United States will continue to be a leader in development of new speciality chemicals and new applications of old chemicals because of its strength in science and technology. Materials sciences, electronic chemicals, and biochemicals will be growth areas.
- Investment in R&D will grow slowly, with a tendency to shift basic research to universities. Large companies, however, are making investments in bioengineering with large-scale commercial applications expected to begin by 1990 or 1995.

Industry Demography: Relatively Stable

- No significant shifts in facilities location are expected although new specialty chemical plants will be built.
- The average plant size is likely to decline. Few or no new world-class facilities are expected to be built in the U.S. except possibly in Alaska.

Feedstock: Impending Change

- Toward the end of the next decade there is likely to be a noticeable movement to new feedstocks for organic chemicals -- primarily coal, with biomass as another strong contender along with biotechnology products.
- One uncertainty for the chemical industry from 1983-1995 is the cost of petroleum and natural gas, as feedstock and energy source.

Issues Confronting the Industry

- One great uncertainty and possibly the largest problem facing the industry is the question of the now unplannable costs of liability and victim compensation.
- At some time in the near future, there will almost certainly be renewed demand for and impetus toward increased testing and regulation of "existing chemicals" -- those in commerce prior to TSCA. This will impose great new uncertainty and increased costs on the industry.
- Related and important problems are:

  -- the rising costs of insurance, and

-- the decisions about improved waste management and disposal, and the emerging technologies of high temperature incineration, recycling, and microbial engineering for waste reduction.

- Genetic screening of workers, labeling, and right-to-know laws will be major workplace issues.

- Multidimensional risk management will be the greatest management challenge from 1983 to 1995; this includes:

  -- new testing, monitoring, and analytical techniques;
  -- new security measures to protect facilities and personnel from terrorists and sabotage.

- There is a strong movement toward the mandatory release of previously closely-held information, illustrated by Section 8e of TSCA, State right-to-know legislation, and the new OSHA hazards communication rule.

<u>The Social Context</u>

- Six long-range demographic trends will be important to the industry:

  -- the political and social dominance of the 35-45 year old age group, characterized by a high level of health and environmental concerns and political activism;
  -- increasing longevity, accompanied by increased concern about the relationships between environmental factors, morbidity, and life expectancy;
  -- prevalence of small, dual-income households, implying both increasing per capita consumption of consumer products and greater independence, mobility, and assertiveness of employees;
  -- decentralization of other industry toward the Sunbelt and toward small cities and suburban areas, with resulting changes in the patterns of industrial users of chemicals, transportation of hazardous products and wastes, and availability of facility and waste disposal sites;
  -- a continuing migration of people toward the Sunbelt and toward smaller communities so that chemical facilities and waste disposal sites will be less readily acceptable in some areas than now;
  -- both the work force and the general population are increasingly well educated; and increasingly mobile -- demands for a safe environment will become more general in all regions.
  -- Women will make up nearly half of the work force by 1995; there will be increasing concern about genetic and reproductive effect of chemicals in the work place.

Public Attitude: Support for Risk Reduction

- Environmental and scientific policy issues are increasingly international in scope. Health effects of chemicals in world trade are likely to bring about recurring international controversies and diplomatic tensions.
- Public support for environmental safety will remain strong and well organized. There is an emerging coalition between environmental interest groups and trade unions that may become a powerful factor.
- Opinion surveys indicate that the public is increasingly intolerant of involuntary risks.

Decisionmaking: Scientific and Public Pressures

- Public decisionmaking will be subject to two strong pressures; the influence of scientific information and advanced analytical techniques, and demand for openness and opportunity for public review.
- The need for greater consistency in regulation will be an increasingly visible issue. Concerns include harmonization of local, state, national, and international regulation; consistency of regulation throughout the lifecycle of substances, across different applications and different industries; and the lack of understanding and data on the relationship between regulation and innovation.
- Congressional reaction to court restrictions on the use of the legislative veto and a more general swing toward greater Congressional assertiveness may lead to a reduction in the discretion and flexibility allowed to regulatory agencies.
- Congress is seeking improved capability for foresight and planning, both for itself and for the Executive Branch.
- Deregulation efforts will be highly scrutinized and increases in regulation may be called for by public interest groups. Not withstanding deregulatory efforts, increased regulation is likely.
- There is growing consensus among scientists and regulators that a more holistic, cross-media, and flexible regulatory strategy is necessary for future progress in environmental quality. This may run counter to Congressional pressures for reduced agency discretion.
- State toxic control programs and laws are increasing, with considerable diversity in approaches likely to develop. State legislatures are handicapped by lack of scientific information and staff support. Waste disposal sites and work place right-to-know laws are the urgent issues in most states.

- State initiatives are likely to be driven by specific local disasters or alarms and by siting and transport controversies. This may bring about extreme remedies in some cases. Differences in state laws will cause problems for industry.
- There are signs that organized crime is an important factor in illegal hazardous waste disposal. Such dumping will be difficult to halt without industry cooperation.

Increased Litigation

- Increasing reliance on court litigation to force attention to public concerns is likely.
- The volume of legal cases of victim compensation will continue to grow. Awards are likely to be unpredictable, but generally increasing in the absence of a legislatively imposed cap, or an alternative form of compensation.
- There are likely to be changes in tort law at the state level to facilitate the acceptance of epidemiological and statistical evidence of cause and effect.
- Environmental mediation and negotiation in lieu of adversarial proceedings will increase but will not significantly reduce the volume of legal proceedings.

Sources of Policy Issues

- Diplomatic pressure on the U.S. to adopt stronger export controls over toxic chemicals and other hazardous products will increase.
- Computers and telecommunications will support public interest groups and public health advocates in working for strengthened regulation of environmental hazards by providing aggregated data bases, networking, and modeling capability.
- The media will continue to be a potent catalyst in public health concerns, and will go to advocacy groups for information if industry refuses to provide it. Proprietary information versus public right to know will be a growing issue.
- Specific incidents of injury or risk to public health will be a recurring stimulus to demand for new control measures. Likely sources of future concern are:
  - -- discovery of the contamination of groundwater especially where this threatens drinking water supplies;
  - -- rail or highway accidents involving toxic chemicals and resulting in death, injuries, or large-scale evacuations;
  - -- a natural disaster, such as a flood or dam collapse, that is found to have spread concentrated toxic waste deposits over a large area.

- Genetic screening of workers, as an industrial health protection strategy, is likely to become a major civil rights and equal opportunities issue.
- The politics of toxic chemicals control will be shaped by the stronger convergence of public health and worker safety issues.

New Knowledge of Health Effects

- Health concerns will increasingly focus on birth defects, reproductive and sexual disorders, aging processes, neurological and neurochemical disorders, and immunology.
- Converging advances in understanding the metabolic transformation of chemicals, in genetics, and in biomedical technologies are paving the way for individual monitoring and neutralization of toxic substances within the body.
- It is becoming increasingly apparent that there is a close link between genetics and environment in causing disease.
- The distinction in environmental and health impacts between "natural" background toxic substances and man-made toxic substances has not yet been addressed by science. However, there is a significant difference in the way the two are perceived by society, and consequently a difference in regulatory priorities.

Improved Analytical Techniques

- Technologies for multidimensional analysis of complex mixtures of chemicals are being developed rapidly. Attention to the synergy and antagonism of chemicals interacting with other chemicals will drive toward life-cycle regulation.
- Linkages of genetics to individual variations in susceptibility to disease and environment pollutants is an early warning system which can help avert and reduce risk. Some see this development optimistically; others see it as encouraging discrimination against populations at unusual risk. This illustrates the many policy compromises that will have to be found in the application of fast-paced human genetic research to environmental problems.
- Modeling of the transport and transformation of chemicals in the environment (and in man) demands an integrated and large-scale approach. This critical area of research could yield invaluable information with coordination of existing computer technologies, databases, and human expertise.

- Biology and biochemistry-based technologies present new opportunities for monitoring and detoxification in industry processes, waste sites, water supplies, and the natural and built environment.

Better Data and Interpretation

- The sensitivity of chemical detection is outstripping our ability to understand and respond to possible but uncertain effects of chemicals at extremely low concentrations. This gap is likely to worsen the policy conflict over acceptable limits for known or suspected toxic substances.

- The need to mesh scientific knowledge and uncertainty with social priorities means that a balance will have to be drawn between standardized methodologies and informed judgment in applying risk analysis to regulation.

- Advances in epidemiology, computerized data collection and management, and improved medical analysis of cause and effect relationships may lead toward separation of the population into groups of high, low, and average risk to different environmental factors (including toxic substances). Regulation will have to deal with the different interests of these micropopulations.

- Systematic epidemiology, integrating multiple sources of information, may gradually become operational and practical. Information generated independently in epidemiology, occupational health statistics, medical records, environmental monitoring, and demographic analysis could eventually be compiled into a national database creating a comprehensive and dynamic picture of exposure to environmental, chemical, occupational stresses in terms of social and genetic factors. Such data is now extremely difficult to reconcile and interpret. Serious issues of privacy and information access will have to be resolved before potential benefits can be fully realized. The networking of the nation through telematics is already making these issues more urgent.

- As toxicity testing methods diversify and expand, the need to assure reliability and comparability of test results grows. This concern applies across different tests on a single substance; to tests across industry, government, and academic labs; and to testing across laboratories from different nations.

- International attention to analysis and regulation of toxic substances is increasing along with pressure for international exchange of data and coordination of testing and standards.
- Computer-based analysis and toxicity testing methodologies, primarily structure-activity relationships, are becoming more sophisticated and widespread due to their low cost and high speed. We will continue to rely on a battery of cellular and animal methodologies, however, to provide the database for computer analysis and investigate chronic and acute whole-organism responses to chemicals.

New Sources of Toxics

- The rapid expansion of biotechnology will create and release large amounts of proteinaceous biological materials and other intermediates and products. Little is known about the long-term health and environmental effects of these materials.
- High-technology materials and products such as composites, plastics, electronic chemicals, photovoltaics, and ceramics, are being developed faster than their health and environmental effects can be assessed. These materials add new opportunity for chronic or accidental exposure to toxic substances during their manufacture, use and environmental dispersal, and final disposal.
- Non-point sources of toxic substances remain a problem for regulation as well as a challenge for monitoring and control. Dispersed chemicals contribute a substantial proportion of the total toxic load on the environment and will be of increasing concern as point sources are better controlled.

IMPLICATIONS FOR EPA's OFFICE OF TOXIC SUBSTANCES

The mission of OTS as stated in the Toxic Substances Control Act (TSCA), is to insure that chemicals do not impose unreasonable risk of injury to the public, or damage to our common environment. OTS is also instructed that the regulatory process should not unduly impede innovation. The perception of risks associated with chemicals is increasing, and the public is less and less willing to consider them reasonable. The chemical industry will be under increasing pressure for better risk management. It is unclear what effect these pressures will have on industry innovation, but it is certain that the next decade will provide broad opportunities for the development of new, highly specialized chemicals and biochemical products. OTS will have to be prepared to stay abreast of rapid changes in the development, manufacture, and use of chemicals.

OTS will have the even more difficult task of staying abreast of rapid developments in science, technology, and human health assessment; most importantly in the physiology of aging and sexual competence, neurological and neurochemical science, and immunology. These developments will stimulate new concern about toxic risks, but will also provide new control capabilities.

Guidelines for Implementation

TSCA created Federal authority to control chemicals, but its equally important thrust is to create mechanisms for informing the public about the risks associated with chemicals. TSCA implies that OTS should:

- support the Administration and Congress in developing public policy related to chemicals,
- as far as practical, act to stabilize expectations and requirements imposed on the chemicals industry, so that it can internalize these requirements and remain strong and productive, and
- foster frankness and openness in relationships between government, the public, and the chemical industry.

Principles for a Safe Toxics Management System

TSCA may well be amended and strengthened in the future. Both the authority and the workload of OTS may increase. Planning should be underway now to prepare for enlargement of OTS's mission. OTS's responsibilities are to support decisionmakers in developing toxic risk policy and to deal openly with the industry and the concerned public. These considerations also should guide the eventual development of an integrated and consistent national toxics management system or process that should have the following characteristics without regard to the jurisdictional boundaries imposed by incremental legislation (TSCA, OSHA, RCRA, CPSA, CERCLA):

- information generated cooperatively by industry and the government, about all chemicals on the market;
- adequate information about chemicals throughout their lifetime of marketing, use, and disposal;
- assurance of safe handling at all times;
- assurance of safe, documented, and monitored waste disposal;
- monitoring of public health and of the environment to detect unanticipated effects and interactions of chemicals;
- the clean up of past mistakes;
- the internalization of the associated costs.

Regulation of chemicals must impose costs on the chemical industry and ultimately on the users of chemicals. In the past, however, American industry has repeatedly shown itself to be sufficiently resilient and resourceful to absorb the costs of rising societal expectations of better health and a cleaner environment, and still remain strong and vigorously competitive in world trade.

Possible Reorganization

Over the next decade, as OTS's workload increases and becomes more complex, the need for close coordination with other agencies will increase. Rationalization of chemicals regulation may require reorganization of agencies that have closely related or overlapping responsibilities. For example, elements of EPA, OSHA, CPSC, FDA, and NIOSH might be combined. In the meantime, more effective sharing of data should help all of these agencies in their assigned tasks.

New Policy Strategies

High conflict political issues, driven by strong economic pressures, complicate regulatory procedures and test the willingness of industry to comply. OTS should be working to help invent regulatory strategies that accomplish national policy objectives without reducing incentives for industry cooperation. If policymakers can draw on OTS expertise, future regulatory strategies may be far less difficult to implement and enforce.

The most important challenge on the horizon for OTS is the great likelihood of a sudden and powerful demand for increased attention to chemicals long on the market and in wide use.

The Changing Chemical Industry

The chemical industry itself will change in significant ways over the next decade. Regulatory strategies must reflect and adapt to these changes. Toward the end of the decade there may be changes in feedstocks or commercialization of biological processing and biochemical products, which will pose new environmental and health questions. EPA (and OTS) are now beginning to prepare for these developments. If they fail to meet this challenge, they will again be forced to react and correct rather than instruct and guide their safe implementation.

OTS is the obvious and most appropriate site for the aggregation and analysis of data about chemicals. To the extent that such data is not collected and collated now in a systematic and accessible way for use by other agencies and by industry, the task will be much more difficult in the future.

Foresight

OTS, charged with a difficult mission in a rapidly changing society, should systematically strive to improve its ability to anticipate change. It needs to be able to anticipate new chemical products and changes in the mix of products, and to relate these to changing market patterns. OTS also needs to understand long-range trends affecting the social context of risks to public health, including changes in the age structure, location, and activities of the population and their social values and political priorities.

Some strategies for better anticipation or foresight could include:

- building a continuing planning and foresight process;
- carrying out studies of the innovation process in the chemicals industry, and of the factors influencing industry decisionmaking;
- using systematic procedures to monitor and interpret advances in the basic and applied sciences and advances in medical science and diagnostic techniques.

OTS clearly must stay abreast of the latest developments in analytical methods, assessment techniques, and instrumentation. This should include developing the capability to use new tools and techniques of judgment theory and decision analysis. Some suggestions for strengthening this capability include:

- development of a in-house Fellows program, bringing in people from universities, research laboratories, hospitals, industry, and environmental interest groups,
- providing sabbaticals and re-training for OTS professionals,
- bringing in recent retirees from industry,
- holding professional seminars and conferences.

Priorities

OTS must have systematic and sensitive techniques for priority setting, so that it can plan and schedule the allocation of its limited resources. Some successful techniques that deserve to be used even more extensively are:

- decision analysis tools,
- advisory panels for priority setting and ranking,
- explicit criteria for selecting critical issues,
- systematic ranking of the inventory of existing chemicals by volume of production, estimated exposure, and suspected risk characteristics.

Regulatory Innovation

OTS should continually pursue the design of innovative regulatory strategies by:

- modeling the effects of past regulation and hypothetical regulation in terms of economic impacts, industry adaptations, and public response,
- attempts to develop improved techniques for economic and social impact assessment,
- exploring the feasibility of regulation focused on objectives rather than on standards or restrictions.

Communication with Stakeholders

It is essential that OTS earn the respect and trust of the concerned public, of the chemical industry, and of the larger scientific community. Some ways of doing this are:

- emphasizing public explanation and discussion of its proposed actions,
- holding seminars on regulatory issues for scientists, industry risk managers and decisionmakers, and public interest representatives,
- encouraging OTS professionals to publish and to play active roles in professional and academic organizations and activities.

Other Leadership Opportunities

OTS should take a leading role in building institutions and creating processes that support and buttress its mission. OTS might, for example, propose and work for:

- a systematic groundwater survey by EPA or another government agency such as the Corps of Engineers,
- more emphasis on environmental epidemiology, in EPA, the Centers for Disease Control, and elsewhere,
- national chemicals testing supported by government and industry,
- a data bank dealing with existing chemicals.

CHAPTER 2

SCENARIOS OF THE CHEMICAL INDUSTRY, 1995

Dealing with complexity is a central problem in coming to grips with the future and designing public policy programs. Too often, legislative, administrative, regulatory, or procedural public policy is framed around only a few important factors or a small set of issues which have matured into widespread contention. This report approaches the future of toxic chemicals with the explicit purpose of engaging the future, the next 12 years, in the full complexity of the rapidly evolving situation.

Scenarios are the tool for presenting integrated images. The three snapshots presented are plausible alternative ways in which the chemical industry and other factors influencing the toxics situation could evolve. Each scenario is based on a more formal analysis of trends and factors presented in later chapters. The scenarios are constructed by permuting the critical variables which will shape the future of the industry. Permuting each of the variables, even over reasonable ranges, would create great numbers of marginally different pictures. Consequently, judgment enters into the presentation of the scenarios -- judgment as to the important variables, judgment as to how they might interact, judgment as to the range of variations. The test of the scenarios is whether the user finds them useful in stimulating and shaping his thinking about public policy. They are to serve as foils for further discussion.

Each of these scenarios is based upon a selection and permutation of the variables shown in Exhibit 1.

- The first scenario, Rapid Evolution, finds that many of the potentials for change of the structure, function, organization, and products of the industry move briskly to fruition, drastically altering structural relationships within the industry, in the feedstocks and products, and in the functional aspects of regulation.

EXHIBIT 1

Scenario Variables	Scenarios: I. Rapid Evolution	II. Multi-Dimensional Change	III. Stability
I. Social and Political Priorities			
a. Support for environmental protection	Strong support from public and political leaders	Weakening, but varies by region	Public support growing, leadership resistant
b. Attitude toward responsibility of industry, governments	Places responsibility on Federal government and industry	Leaves responsiblity to State and local governments	Mixed responsibility: Federal and State
c. Political activism; consensus	High degree of consensus	High degree of conflict	Significant degree of cooperation
II. Regulation and Political Decisionmaking			
a. Local/State/Federal/international roles	Strong Federal role, internal regulation	Federal deregulation	Mixed, all have roles
b. Litigation, mediation	High level of mediation	High level of litigation	Much litigation, much mediation
c. Liability and compensation: action, awards	Controlled, consistent awards	High, but inconsistent awards	
d. Regulatory strategies	Regulation-by-Objective	Varies widely by State	
e. Risk assessment, CBA		Emphasis on cost containment	RA and CBA widely used
f. Regulatory organization	Restructured, agency reorganized	Federal regulatory structure dismantled	OSHA/EPA regulatory coop.
g. TSCA	New Act, much pretesting	Limited to assistance to states	
III. Health, Environmental Concerns			
a. Environmental technologies	Increased environmental monitoring		
b. Health monitoring and analysis	Increased testing and monitoring	Advances in epidemiology	
c. Toxicology		Toxicology advances	Advances in detoxification
d. Costs, scale, institutionalization of analytical techniques	Industry investment high, National Center for testing	Right-to-know expanded	
e. Changing health priorities	Neurological effects	Immunological effects	Aging, birth defects
IV. Feedstocks, Materials, Products			
a. New materials: production, use	Emphasis on composites	Innovation declining	Emphasis on photovoltaics, Innovation slips
b. Biologicals, biotechnology	Some biological products in bulk, competition high, much uncertainty		Slower than expected progress in biologicals, biologicals under TSCA
c. Feedstocks	Progress on alternative feedstocks but little change	Coal gaining as feedstock	Reliance on petroleum
V. Industry Structure			
a. Shift from bulk to specialty chemicals	Offshore production of bulk grows. Shift to specialties pronounced	Joint U.S.-foreign ventures in bulks	
b. Mergers, acquisitions, diversifications...	Shake out, new growth	Consolidation, diversification	Divestitures, increased foreign ownership
c. Location, scale	New small specialty plants, new sites	Few new plants	Pla..c downsizing
d. Labor-management relationships	Labor-industry cooperation	Labor-industry conflict	
e. Industry policy, self-policing, etc.	Positive industry attitudes	Industry hard-lining	Some self-policing
f. Industry and health care	Government-industry cooperation	Right-to-know issue	
VI. International Context			
a. U.S. world trade position	Strong	Declining	Chemical exports slip
b. Competition	Middle-East, Brazilian competitors		3rd World competition
c. International environmental pressures	High cooperation between nations	Continual international disputes	International regulations and cooperation
d. War, exogenous events		Turmoil, terrorism high	

- The second scenario, Multi-Dimensional Change, chiefly emphasizes continuity but highlights developments where substantial changes could occur, creating important new regulatory implications.
- The third scenario, Stability, emphasizes continuity with minimum change in terms of the effects of forces now acting on the industry and the toxics situation.

The reader, of course, is invited to generate other scenarios using the variables in Exhibit 1 or by introducing others.

The scenarios themselves are in the form of a Table of Contents and the lead article in a topical issue of a national trade or professional publication in November, 1995. The scenarios avoid the mention of real chemicals when there is a negative connotation. In those cases, names of non-existent materials are used. On the other hand, the names of real chemicals and chemical companies are used when the implications in the scenario are neutral or positive.

The background to these variables, i.e., the analysis of the factors entering into the determination of their relative importance, are discussed in later chapters, as are many of the important social trends which will act across all the scenarios. For example, within the relatively short interval of 12 years excellent forecasts can be made about overall demographic patterns. Consequently, they are not raised specifically in the scenarios but are taken as background. On the other hand, within the framework of the scenarios, market penetration of composite materials, a specific trend is important. Some readers may choose to go to the background material before reading the scenarios.

SCENARIO 1

RAPID EVOLUTION

CHEMICAL & ENGINEERING

VIEWS

Volume 83, Number 2

January 15, 1995

News of the Week

- New continuous multi-enzyme process of Diamond Shamrock and Morton Thiokol is less expensive, more energy-saving than current processes. Page 6
- International representatives meeting in Sweden have drafted new guidelines for shipping of hazardous materials. Page 6
- A computer program developed at Caltech can analyze the toxicity of a chemical structure along over 1000 health and environment variables. Page 7
- One of three remaining laboratory animal supply companies closed its doors. Page 8
- Ireland opens world-class plant producing chemicals from peat.

Business

The focus on specialty chemicals has fueled Wall Street attention to acquisitions in the chemical industry. Page 15

International

Middle East petrochemical producers posted a market gain for the eighth straight year; Hong Kong, Singapore, and Indonesia have cornered the Asian plastics markets. Page 18

Government

Broadened government insurance and health care provisions have offset tightened liability standards and awards. Page 25

Science

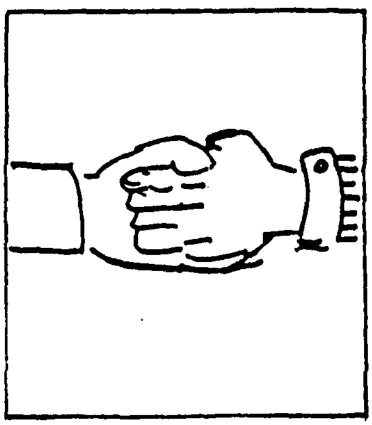
Advances in the genetics of thought and behavior control offer a means to inhibit anti-social behavior and a crucial test to the laws and ethics governing R&D. Page 40

Technology

The new biocompatible polymers and the prosthetic nervous system

Education

Bioprocess engineering graduates outnumbered traditional chemical engineering majors for the first time. Page 59



Cover Story

The rapid evolution of the chemical industry over the past decade has successfully balanced restructuring around specialties with health and environmental concerns, with some help from the government. Page 30.

THE FIVE-YEAR REPORT OF THE JOINT INDUSTRY-GOVERNMENT COUNCIL ON CHEMICAL INNOVATION

A Successful Decade of Evolution Through Government-Industry-Public Cooperation

ATLANTA, Nov. 3 -- The shakeout and regrowth of the chemical industry over the past ten years has been much more dramatic than the pundits predicted in the 1980's. Driven by a resurgent, highly-professional environmental movement and increased pressure on Federal resources to manage the complex problems of international economic competition and environmental concern and cleanup, the Joint Industry-Government Council on Chemical Innovation was officially empowered in 1989. This month JIGCCI (pronounced jig-see) released its five-year report, an integrated analysis of the health of the U.S. chemical industry. C&EV has talked with industry and government observers, who have generally lauded the JIGCCI's work. Highlights of JIGCCI's report and some of the comments of key observers follow.

Realization of the complexity of environmental problems as well as demands for government efficiency and reorganization prompted the restructuring of government regulatory oversight of chemicals in 1990. The Toxic Materials Regulatory Reform Act, which had fought its way through Congress in various forms for years, combined oversight, research, and regulatory functions of the old Office of Toxic Substances, the Food and Drug Administration, and the Occupational Safety and Health Administration, with the EPA Directorate of Public, Occupational and Environmental Health. At the same time, the Reform Act enhanced the testing requirements for new products, streamlining the testing process to centralize testing for potentially toxic substances throughout industry and government. EPA guidelines were brought into harmony with OECD guidelines as part of the 1990 renegotiation of GATT. The 'boomerang effect,' where toxic substances produced only for export returned in the form of downstream products, was an issue of growing concern that demanded international coordination. In the United Nations the developing nations pushed for the elimination of chemical dumping and for increased testing by the developed nations. The spark that finally led to the formation of the United Nations Organization for the Regulation of Chemical Industries (UNORCI) was the 1989 cyano peptine poisoning of the drinking water of Sao Paulo, Brazil, for 11 days, leading to 367 deaths and 16,000 casualties.

The chemical industry today, against this background, has substantially increased its investment in testing of chemicals both during development and throughout the product lifetime, though mostly through support of external work. Over the past six years of its operation, the National Center for Toxicology and Analytical Chemistry, housed under the joint direction of the National Bureau of Standards and the National Environmental Health Sciences Program, has -- in real terms -- increased its budget by 300% and more than tripled the number of chemical substances it screens each year.

Closely tied to this has been the substantial increase in government-sponsored environmental monitoring. The late 1980's were a time of significant innovation; the combination of fifth-generation computer capacity and expert systems, a comprehensive albeit fledgling national public health database, and scientific advances together provided the foundation for the National Health Monitoring Program.

The scientific spur was a series of rapid advances in neuroenvironmental research, which brought Dr. James Brennan and his Johns Hopkins University team the 1994 Nobel Prize in physiology and medicine. Brennan and others linked three lines of research into a revolutionary but quickly-accepted picture. The three keys were first, the neuromechanism for memory consolidation; second, a neurochemical interrupter mechanism associated with several subsidiary paths leading to decaying memory, toxic amnesia, hypnotic forgetting, and neurological-based amnesia; thirdly, the team's most recent discovery that 14 chemicals commonly used in the plastics industry are metabolically transformed into neurointerruptors in approximately 11% of the population.

The industry, while overwhelmed by adverse public reaction to these discoveries, has with a few notable exceptions neither renounced liability nor denied the potential impact on the industry.

The pervasiveness of the health problem pushed support for centralized Federal action. The health monitoring and analysis technologies team of the EPA/OSHA joint regulatory task force has placed chemical biosensors in 10,000 households and is running an epidemiological survey in conjunction with the Communicable Disease Center in Atlanta, on 100,000 American families. The full program for the analysis is presented in the National Academy of Science's report, <u>The Role of Science in Facing Neurological Risks</u> and is, of course, the subject of a comprehensive weekly report by the Associated Press. Much of the success of the National Health Monitoring Program and its speed of response are a result of the extensive and well-received action of the Software Products Division of EPA, which went into high gear in 1986.

By 1986, 18 million American households had microprocessors; many environmental groups as well as all major corporations were extensively telemated. EPA responded to the increasing pressure for sound environmental data by turning out environmental data manipulation, monitoring, and modeling software packages. They have since become global standards. The software packages are now produced in 89 languages and distributed through UNESCO. Working with EPA's Environmental Sensors Division, widespread low-cost sensors are used by industry, government, and environmental groups and have been available since 1988 at a subsidized rate to individual citizens. They have been a smashing success in environmental monitoring.

The most directly significant development over the past decade has been the accompaniment of the growing support for environmental cleanup by a nationwide wave of experiments in regulation, cleanup, compensation, and enforcement. The mixed success -- but more significantly the failures -- at State level following a move to deregulation in the mid-1980's led to a recentralization of Federal authority in the Comprehensive Environmental Control Act of 1989, that centralized regulation of the environment in the EPA and paved the way for the increase in influence of the industry advisory councils.

The extensive support for environmental cleanup and legislative innovations, of course, grew out of the Reunion Party's successes beginning in 1988 with the elections in Colorado, Montana, and South Dakota. Much of the chemical industry's general health can be attributed, in retrospect, to the rise of the Reunion Party, a once not-to-be-believed coalition of labor, public interest groups, concerned scientists, and local businessmen. Industry's response was to form its own coalition with the 25 or more unions represented in chemical manufacturing plants and in a few months of concerted effort -- and, some inside observers claim, some power plays against the few reactionary holdouts within industry councils -- to come up with an effective self-policing scheme that in some ways went beyond what political decisionmakers were ready to put forward.

The Public Health Councils that were set up -- with representation from industry, unions, Federal and State government, and the public -- have had the smarts, the dollars, and the political muscle in Statehouses as well as on Capitol Hill to formulate toxics control programs that gave industry room to maneuver in cost-effective ways and still maintain a degree of public confidence that dampened the political fires. The Federal strategy of multimedia "regulation by objective" (building on the model of the old bubble strategy) has provided incentive and room for innovation in preventive and cleanup efforts.

The industry fell in line with the formalized liability and compensation program, the heart of which was a health insurance program, to which government and industry both contribute and which is retroactive to all workers employed in the industry after 1950 for a period greater than 16 months. The big breakthrough was the ability to enjoy health program benefits without the need to tie health effects directly to a particular site or incident. The health mediation panels, with full responsibility to assign liability and benefits on an epidemiological statistical basis, have cleared the slate of 14,500 cases of litigation.

With the industry enjoying the consistency and clarity of nationwide and industry-wide rules, and freed of some of the financial risks by national environmental health insurance (the Efgar/Nekerby Law of 1989) and the accompanying cap on compensation awards, it has moved into an era of unprecedented innovation and prosperity. American specialty chemicals dominate a large proportion of the world trade and compete strongly in dozens of other niches in the global chemicals market.

The JIGCCI profile of the U.S. chemical industry focuses on this vast increase in specialty's share of chemical shipments; from 1985-

1995 they report that specialties grew 350% as a share of value of shipments. The National Specialty Chemical Association today effectively is the U.S. chemical industry. Bulk or commodity chemicals manufacture has moved outside the nation's boundaries, but U.S.-owned multinationals claim a healthy share of its ownership either directly or in productive partnership with a dozen other nations, many of them Third World nations. In the meantime, the U.S. has strengthened its position in world trade. The JIGCCI report is optimistic about the continued dominance of the U.S. in specialties, especially with the rapid growth in use of composite materials for construction, transportation, and packaging. However, introduction of these new composites has created a number of new concerns, particularly in terms of waste disposal, combustion by-products in office and residential fires, and resistance to recycling and remanufacture. The Toxic Chemicals Data Center reported 1,871 environmental incidents involving composites in 1994.

The biggest uncertainty facing the U.S. chemicals industry today is the ultimate impact of biologicals. Already making strong encroachments into the traditional commodities chemicals markets, biologicals are sending specialty chemicals manufacturers scrambling to stake out claims.

Between 1983 and 1987, 800 new chemical products were introduced into the market based on microorganism or enzyme processes which in turn were founded upon genetic manipulation. While these were a profitable, extensive, part of the pharmaceutical and specialty chemical industries, the real breakthrough came with the opening by ICI-DuPont of the ethanol-butanol facilities in Nashville, Tennessee, and Lagos, Nigeria, under their cross-licensing arrangements signed in 1992. The three-cascade process, using artificial genes in two of three stages, converts soft woods to alcohol at an 86% chemical efficiency with the capture of important by-products. The most significant other step to commodity chemicals from wood has been the development of delignon, an enzyme preparation to split lignin into useful chemicals. On that basis, we may anticipate a new family of vanillin-based chemicals entering the market in 1996-97.

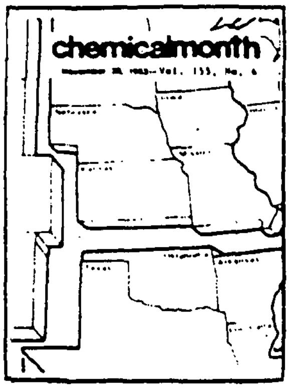
The story of the carbochemical industry, however, has not been all successes. The global market for biotechnology facilities has largely been captured by the Japanese and the Soviet Union, with the U.S. manufacturers running a poor third. Industry critics say that the JIGCCI report downplays the growing Brazilian threats in biology-based commodities. Janet C. Albertson, Director of R&D for Crotus, says, "Expectations of government and economists were way out of line. While our share of carbocommodities is growing, the Japanese have simply had a lot more time and a lot more government support than we have. A Federal policy of pushing bioprocess R&D simply doesn't mean that the industry can shift overnight."

SCENARIO 2

MULTIDIMENSIONAL CHANGE

chemicalmonth

November 30,1995—Vol. 155, No. 6



Court decisions challenge industry

Inconsistent and often contradictory state policies on victim compensation, environmental standards, and occupational health have put the chemical industry into a state of near-paranoia. Although many chemical-exporting Third World nations are troubled by economic and political turmoil, the U.S. share of world trade continues to decline.

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JFC Chemical Month, ISSN 2001-ITHX/95 (including Chemical Specialties and Chemical Industries), is published monthly, except for one issue in December, by J. F. Coates, Inc. Subscription rates: U.S. and possessions, $99 per year; single copies, $10, Japan, Y2300 per year; elsewhere on request. Executive, Editorial, Circulation, and Advertising Offices: 3738 Kanawha St., N.W., Washington, D.C. 20015. Second-class postage paid at Washington, D.C. Title not registered at U.S. Patent Office.

COURT DECISIONS RAISE NEW QUESTIONS ABOUT THE FUTURE OF THE U.S. CHEMICALS INDUSTRY

WASHINGTON, D.C., Nov. 7 -- Two court decisions dealing with victims of toxic chemicals grabbed headlines across the nation last week and threatened the coalition between Blacks, Hispanics, and blue collar workers.

In New Jersey a court awarded $10 million to families or guardians of 23 people born severely handicapped in the tiny community of Jake Flats, between 1981 and 1989. Jake Flats lies near the huge chemical facility built by Opal Chemical Company in 1968 and purchased last year jointly by IFG and Doolant Chemical.

"No value," said Judge R. Rath, "is high enough to compensate these people or their parents for the loss of life quality visited on them by callous corporations whose only interest was in making a profit." Company spokesmen refused comment pending an appeal.

Two days later a court in Texas refused compensation to workers who attributed high rates of leukemia, birth defects, and heart and nerve disorders to having worked in the Gulfstate facility of Pacific Petrochemicals, the world's largest producer of galapin. The state court ruled that the evidence presented, which was largely statistical, was persuasive but was not conclusive in establishing the necessary cause and effect relationship between exposure to chemicals and subsequent health effects in any specific case.

Political commentators suggested that the disparity in awards may open rifts between Hispanics, Blacks, and union groups who in the last election were forged into a potent political force in a dozen states, despite their fierce competition for the declining number of blue collar jobs in those same states. Hispanic community leaders were indignant at the reaction of union reps in the Northeast, who blamed the court decision on the lack of support by Hispanic workers for proposed "right-to-know" and "safe workplace" laws. Such laws were defeated in the Texas legislature three years ago despite exhaustive effort by national unions. The Texas law, had it been enacted, would, lawyers say, have meant that epidemiological evidence presented in the Albarez case would have been accepted in court.

The New Jersey case attracted special attention because of its contrast with the Texas case, but it was by no means exceptional in the size of the award. In the past two years, at least seven awards in excess of $20 million have been levied against chemical companies in the U.S.

The two decisions this week highlighted the extreme differences in awards made in different regions, which in turn reflect extreme differences in attitudes and policies that have developed in different regions and states since the stepwise Federal deregulation of the mid-1980's. Some states -- trying to lure new high tech industries and affluent professional work forces to replace the old, heavy industries they lost in the 1980's -- have mounted strong cleanup efforts and accepted rising standards of environmental safety. Other states have continued to take a hard-nosed no-concessions stand against public demands. This is particularly true of states, such as Texas and Louisiana, where bulk chemical producers have been concentrated for decades and where the supply of non-unionized labor is reliably replenished by immigration.

Battle Lines Are Drawn

"Life is full of risks," O.B. Duracy, Chairman of the Board of Global Petrochemicals, commented last week. "If they (workers) want jobs they have to be ready to get their hands dirty. Otherwise we will be forced to robotize those jobs that we haven't already automated."

Such statements, industry critics say, are responsible for increasing radicalism within some public interest groups. Public health advocates called Duracy's comment "a naked threat of reprisal." The National Society for Safety through Environmental Enforcement, NSSTEE, (pronounced "nasty") an "environmental guerilla" band of activists, has claimed or been charged by the FBI with frequent acts of violence against chemical plants and corporation executives, ranging from bomb threats to the kidnapping and non-fatal poisoning last year of Ian Hiez, President of Quik, a pesticide manufacturing company. Industry spokesmen say the FBI figures for sabotage directed at chemical companies are too low by at least a factor of two; they blame some apparent "unintentional releases" of pollutants and transport accidents involving chemicals on undetected terrorist acts or internal sabotage by malcontent workers.

This conflict and the fear of additional liabilities or compensation suits are said by some chemical executives to reinforce the strong trend toward locating new facilities "off-shore," i.e. in other countries, including Latin America. This threat remains potent, especially within the commodity chemicals industry, despite the perpetual political turmoil that has so far frustrated plans by Saudi Arabia and other Third World countries to develop major chemical industries. In the U.S. world-class facilities have been built only in Alaska, Texas, and Louisiana in the last two decades. Overall, most of the growth in the industry has been in specialty chemicals, in which this country with its strong scientific base has a commanding lead.

Investment specialist John Beard of Johnson Sears, Inc., warns that the U.S. share in world chemicals trade is still declining. The U.S. is also said to be falling behind in R&D directed at alternative feedstocks, despite its advantage in plentiful supplies of coal and wood, the two most likely prospects. Chemical producers have been lulled by the collapse of OPEC and by the general dismantling of Federal environmental regulatory agencies. Environmental and public health advocates recognize that coal-based chemicals will bring with them a host of new and poorly understood risks to public health. Neither are anxious to speed up the long-range conversion to alternative or supplementary feedstocks, although most agree that it will have to come in the next quarter-century.

European nations -- and ironically, Japan which has neither coal nor wood -- have consistently higher R&D budgets in these areas, perhaps because they are also most dependent on oil imports. U.S. companies, transfixed by the threat posed by the backlog of litigation surrounding toxic chemicals damages, are reducing R&D budgets and concentrating on high profitability lines. Foreign companies are moving into U.S. markets to fill inviting niches, while U.S. companies are busily diversifying into non-chemical products.

The backlog of victim compensation cases continues to grow despite the fact that most chemical companies, especially those with new and modern facilities, now reuse or destroy on site most of their undesirable byproducts. The volume of cases grows because of unfolding understanding of subtle and long-delayed physiological and neurological effects of the first four decades of the chemical revolution. Advances in testing, toxicology, and epidemiology suggest that these effects will continue to be discovered.

New Trouble

In July the latest epidemiological survey of 200,000 American households was completed, and the news is not likely to be good. Expectations are that the final report, when issued, will suggest a strong tie between Virus A_2, thought to be responsible for Alzheimer's Disease, and a facilitation of demyelination of the nerves' protective sheath giving access to the virus. The most common organic chemical associated with O'Neal's opening is Bilazine, the common foaming agent in polyhackalones. The first iteration of the biennial epidemiological survey, in 1986, tied 13 toxic organic materials to widespread overload of immunological systems. That news almost derailed the Federal deregulation proposals then pending in Congress; but they were rammed through while medical experts and toxicologists were still wrangling over subtle points in the conclusions. The latest survey results are almost surely going to have an even stronger political impact.

The Federal Interagency Chemicals Safety Committee, the chief remaining relic of Federal legislation in this field, has no implementation or enforcement authority but has nevertheless taken a strong role in advising, warning, and helping state and regional agencies. FICSC, familiarly called "Fix", is universally given credit for the fact that 32 states have now adopted the Toxics Control Uniform Code and joined in interstate agreements on a variety of subjects from waste handling to transport of hazardous materials to facility siting. "Take that with a grain of salt," warns Charlie Jones, Western Co-chairman of the Association of State Toxic Controls Enforcement Agencies. He points out that some of the major chemicals producing states have not accepted the code. However, one big holdout, Louisiana, is reported to be about to join, with the urging of the Big Six producers, who according to Jones are coming to see it in their own interests to lower the level of conflict.

While the chemical industry remains officially against nearly all proposed laws and regulations, claiming that the industry itself will do a more innovative and cost-effective job of protecting the public if it is left to develop "good business" procedures (the popular buzz word for self-policing), many progressive leaders within the industry are already said to be supporting the "Fix" and the states in pushing interstate regulations. "It would be a great advantage to us," one high corporate official says, "to have more consistent standards, that applied everywhere and that our competitors also had to abide by."

Spectre of Federal Regulation

The real reason that the chemical industry is beginning to be significantly more amenable to policy makers and regulators at the State level, other observers say, is the fear of another strong popular movement to re-institute Federal controls. That possibility becomes stronger with each new revelation, or allegation, of a community epidemic traced to chemical contamination, although it will be costly to rebuild a regulatory structure from the ground up.

Specialty process chemistry suppliers, with new, efficient, and generally small scale plants that incorporate processes to use or destroy up to 98% of their dangerous byproducts, might be relieved by Federal re-regulation that assured them of consistent treatment and protected them against excessive liability. In the meantime they work hard at separating themselves in the public mind and in legal relationships from the bulk manufacturers and the makers of pesticides that are widely spread over the environment.

The trigger for re-establishment of Federal controls, however, may ultimately come not from public pressure or industry despair but from the international scene. "We can simply not continue," said Senator Hawk last week in Foreign Affairs Committee hearings, "to give fuel to our enemies and alienate our potential friends by spreading our poison around the globe." Twenty-five South American and African countries will meet this week to consider a trade embargo against U.S. owned multinationals and affiliates in retaliation for the catastrophe in Niger last week, when 325 people died as a result of infiltration of 2,4-dinitropuzzilidine, a soil-treating agent produced by a U.S. company, into village wells.

If the Congress seriously considers a new TSCA (block grants to the states in 1987 replaced the Toxic Substances Control Act) it may well take as its model the new Comprehensive Risk Reduction Legislation of Alaska. This set of related laws was passed in connection with the building of world-class chemical production facilities in the late 1980's. Government, industry, public interest groups, and unions, and even representatives of other nations and migratory peoples around the northern global perimeter, took part in their development.

The two year process of negotiation and mediation reminded observers of a SALT conference or the old Law of the Sea negotiations, but it has resulted in a period of political consensus and industry innovation that the nation as a whole can only hope to achieve.

SCENARIO 3

STABILITY

CHECKLIST

CHEMWREC
NOVEMBER 1995

Volume 35, No. 11, pages 641-705 ISSN 1138-1984 JFCCHM
CHEMWREC (ISSN 1138-1984) is published monthly by J. F. Coates, Inc., at 3738 Kanawha St., N.W., Washington, D.C. 20015. Second-class postage paid at Washington, D.C. POSTMASTER: Send address changes to Subscription Services 3738 Kanawha St, N.W., Washington, D.C. 20015

Subscriptions -- 1-year prices: Client, $42; Nonclients (individual personal use) $62; Companies, instituions, libraries $172, Students, $12; Foreign postage $12 additional/year. Space freight add $100. Send payment to J. F. Coates, Inc., 3738 Kanawha St., N.W., Washington, D.C. 20015 Single copies, $22. Phone orders can be placed for printed, microfiche, and mag-tape editions by calling the sales office continental U.S. Visa or Mastercard accepted. Rates above do not apply to nonmember subscribers in Japan, who enter subscriptions with Godzilla Co. Ltd., 1-30 Nilon mashi 4-chrome, Cho-kyo, Tokyo 666, Japan; (09)727-1125.

Editorial matters: Refer all editorial matters to V. T. Coates, Editor, CHEMWREC, 3738 Kanawha St., N.W., Washington, D.C. 20015; (202) 966-9307.

Advertising: Frontier, Ltd., M. Killon, Pres., 25 Glade Way, Reston, VA 22222; (703) 123-4567.
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CEQ'S SILVER ANNIVERSARY BASH IN DENVER:

A Quarter Century of Continuity With Change

DENVER, Nov.9 -- The 25th Anniversary of The Council on Environmental Quality was celebrated today. Environmental Quality, 1995, was delivered with some fanfare yesterday at Denver headquarters to a crowd of 1200. The seven-man commission (expanded from the original three in 1990) held a two-hour press conference, followed by a 7-hour symposium and celebration. Chairman John McLeod in his retrospective hailed as the major organizational development in environmental management the movement from Federal dominance to a tripartite arrangement in which Federal, State, and international organizations collectively and interactively manage local, national, and global environment. Organizational change began in the early '80's, with somewhat questionable and mixed ideological support. The push for more State regulation and for public participation and local control steadily shifted actions from the Federal government to State and local levels. Today, in contrast to a quarter century ago, almost all waste control, waste hazard management, and landsiting problems are the responsibilities of State or local level authority. Federal government is to a great extent in a mediation and conciliation role, a knowledge generator through research and development, and liaison and coordinator on international affairs.

International regulatory bodies building basically on the American experience have increasingly assumed regulatory control over the deep oceans and the atmosphere, the Arctic, Antarctic and most of the unsupervised lands of the developing nations. The UNEP (United Nations Environmental Program) of the early '80's has flowered into several derivative organizations, the UNEM (United Nations Environmental Monitorship), the UNEIP (United Nations Environmental Inspection Program) and the UNMO (the United Nations Mediation Office).

Chairman McLeod pointed out the enormous progress in development of what in the '60's and '70's would have been called cost-benefit analysis into a complex program of socioeconomic evaluation in which routinely our multidimensional analyses are presented to Federal, State, or Local Advisory Bodies. The advisory comments are becoming increasingly relied upon by Federal agencies, governors, county officials, and mayors. The growth of the Cable Net has tremendously facilitated public discussions. Commissioner McLeod reported that on a typical evening, 600 discussions of environmental problems are going on around the country. Over the last three years, 7,000 specific environmental issues have been discussed. The Library of Congress in a recent poll found 83⅓% of LAB's issues have been satisfactorily resolved by Federal or State agencies without further challenge or litigation.

McLeod threw bouquets right and left, especially to the state advisory and consulting functions and the mediation teams routinely supplied by EPA to State agencies. As McLeod put it, cooperation is the order of the day. "We can celebrate the passage of our environmental era of travail," he said.

Two commissioners, Mary Smith, representing the affiliation of industrial workers, and George Jones, of the Environmental Cooperative, the nation's largest consortium of environmental organizations, in their own presentations, demurred graciously but unequivocally from McLeod's position. They pointed out that there are still major State and Federal problems having to do with cleanup of waste, the management of the slowly but inevitably growing biotechnology business, the questions of compensations and the key issue of right to full disclosure. Jones noted that the major organizational development over the last 10 years in his view was a formation of the OSHA/EPA Joint Regulatory Teams. They now routinely have assumed many of the regulatory functions without any need for new legislation.

The second greatest development in the last decade, according to McLeod, was the rise of the regional advisory teams, representing industry, government, public interest groups, and local municipalities. What has been particularly interesting is in those states contiguous to Mexico and Canada, foreign organizations are increasingly represented on these Councils.

Problems still reported to be intractable in Environmental Quality, 1995, are getting things sorted out with military cleanup, and our nuclear waste disposal, a spotty, irksome question. The reclamation of aquifers and our waste incineration at sea are nettlesome issues.

Environmental Quality, 1995, recites the principal structural changes in the chemical industry since 1985. McLeod talked about the general effects of integrating industry from the environmental point of view and of the propagation of American environmental standards around the world. He did note, however, the relative decline in U.S. trade position, the developing of chemical commodity industries in the Third World and the increase in the tendency of the European economic community to export high value added chemical products to the United States. The McLeod briefing called for Congressional oversight hearings on this question. Several distinguished participants at the symposium expressed suspicions that rather than tarnish the 25th Anniversary, McLeod glossed over our serious trade issues. He neglected to mention, although there is a whole chapter in the report dedicated to the question, international ownership of the U.S. chemical industry which has been slowly increasing.

McLeod cited as one of the great causes for celebration, going along with the internationalization of American environmental and health standards, multilingual software packages propagated around the world. EPA now routinely brings 1,000 interns from around the world to training programs at American universities and in the Federal agency itself.

Turning closer to the present, McLeod highlighted some possible developments and some significant achievements. He celebrated the melting away of corporate obduracy, to self-policing. He celebrated the establishment of the Clark-Johnson Bill providing retroactive health care benefits for workers in chemically related industries who develop any one of 37 disorders epidemiologically attributable to chemical products. He cited the great success in the introduction of photovoltaics in spite of the three year halt in the propagation of photovoltaics until the environmental safety of amorphous materials was fully satisfied. Acknowledging that it did give an edge to Japanese manufacturers, he nevertheless felt that the environmental preservation is well worth the cost.

Citing some future problems, he raised concerns coming out of the national epidemiological monitoring systems, particularly with regard to health implications of chemicals on birth defects, aging and neurological behavior. He cited the substantial steps yet to be made in substituting mediation and arbitration for litigation and he cited the yet to be passed and implemented National Land Bill Act which will require land siting statements with regard to all new industrial and chemical productions facilities.

McLeod was particularly pleased with the folding into EPA/OSHA of regulations that controlled biotechnology. He cited as a possible problem the 49% decline in new materials introduced into the American economy over the past 15 years.

The full CQ Report is available from the Government Printing Office for $37.50. It is available on Internat Cable callup for 3 cents per hour, and it is available on microfiche and video-disc at the standard rates of $1.00 per hour. Write to the National Environmental Information Center, Denver, for details.

CHAPTER 3

THE CHANGING PATTERNS OF THE CHEMICAL INDUSTRY

The U.S. chemical industry is maturing. While strong and profitable, it faces growing competition for world markets and rising costs of feedstock, production, and risk management. There is a strong trend toward divesting less profitable product lines, especially basic commodity chemicals, toward diversification, and toward specialty chemicals for future growth. Maintaining U.S. position in world trade will be a major priority. Increasing investment overseas, with continuing overcapacity in the U.S., is likely.

General industry strategy is to reduce costs and seek profitability with reduced risk taking. R&D investment is rising slowly; emphasis is on product improvement and selected new technologies, mostly bioengineering. Average plant size may decrease; location patterns will be relatively stable with some tendency to move closer to the wellhead. By the end of the decade there may be significant movement toward coal and biomass as feedstocks, introducing new environmental regulatory concerns. The overwhelmingly important management problems of the next decade will be waste reduction and disposal and management of risk and liability. Both will be major cost factors in decisions.

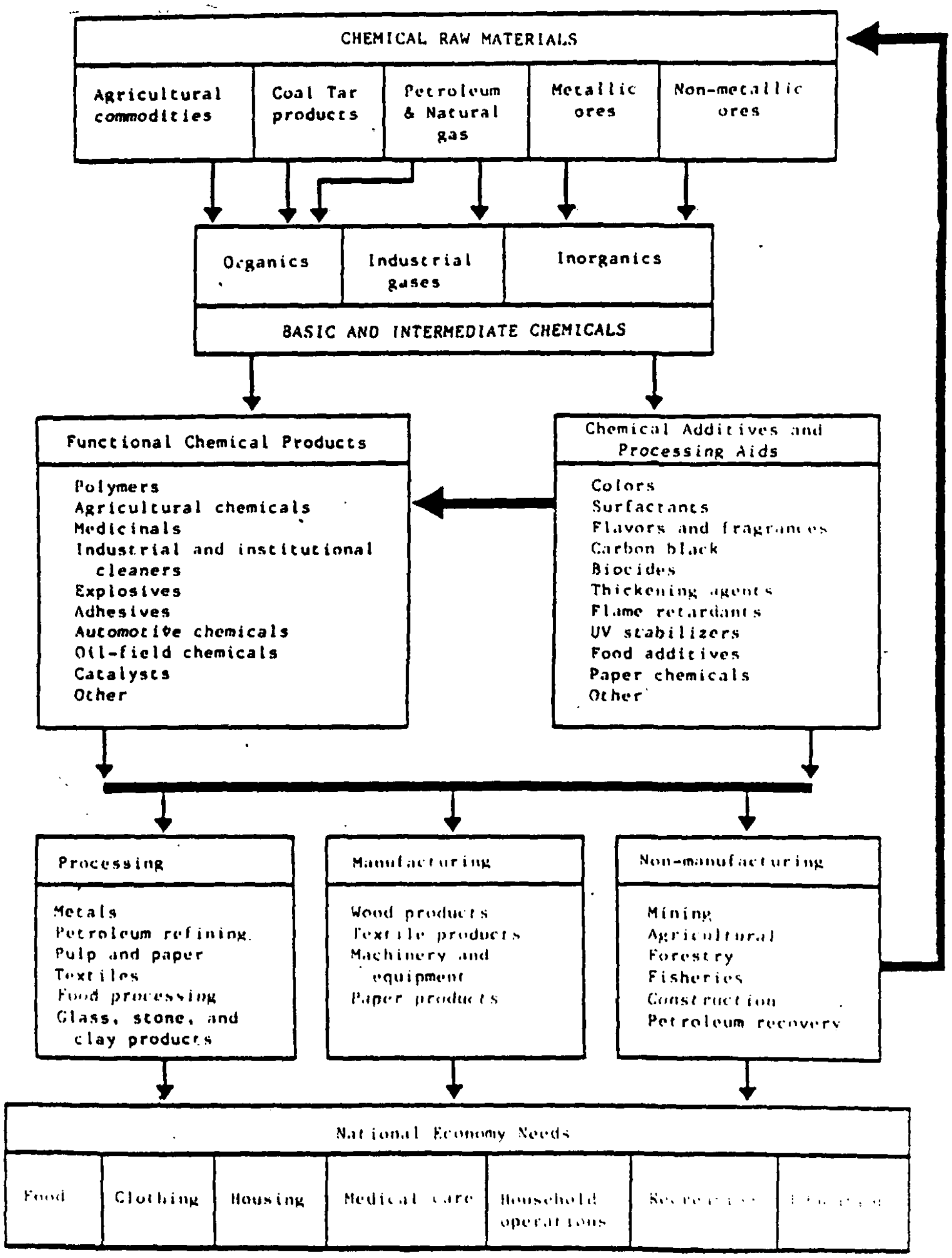
A. INDUSTRY OVERVIEW

1. The Importance of the Chemical Industry to the U.S. Economy

The U.S. chemical industry represents a significant and positive force in the economy; it is the fourth largest U.S. manufacturing industry. Many other industries, such as steel and housing construction industries, are highly dependent on chemicals (see Exhibit 2). Chemical products are an important factor in our international trade (Exhibit 3).

EXHIBIT 2

MATERIALS AND PRODUCT FLOW OF CHEMICAL INDUSTRY



Source: George W. Ingle, ed., <u>TSCA's Impact on Society and Chemical Industry</u>, ACS Symposium Series 213, Washington, D.C.: American Chemical Society, 1983, p. 24.

EXHIBIT 3

UNITED STATES TRADE BALANCE IN CHEMICALS

U.S. Chemical Trade Balance
($ billions)

	1982	1981	1980	1979	1978	1972
exports	19.89	21.20	20.74	17.31	12.62	11.71
imports	9.49	9.60	8.58	7.49	6.43	6.27
balance	10.39	11.60	12.16	9.82	6.19	5.44
E/I*	2.09	2.21	2.42	2.31	1.96	1.77

Source: Chemical & Engineering News, June 13, 1983, p.54

*E/I = Export/Import Ratio

The chemical industry is maturing. The strong growth patterns of the past, perturbed by the economic recession, are now confronting increasingly complex changes in markets, products, and technologies. Many modifications and improvements have been made to bring plants into compliance with increasing government regulations and with variables of feedstock availability and consumer product demand. Future changes may be more challenging and costly for the industry. With the maturity of the industry, corporate management may also become more risk averse and more oriented toward immediate profits rather than long-term growth.

The cost of doing business will increase. Forces driving these costs include:

-- increasing costs of manpower, new facilities, transportation, financing, machinery, and analytical instruments;

-- increasing costs and possibly decreasing quality and quantity of certain energy and feedstock sources, namely, natural gas, petroleum, and certain ores;

-- increasing societal pressure and environmental regulation for additional pollution monitoring and removal equipment, modifications and development of equipment processes to lower hazardous chemical production, and abandonment of older processes and plants that cannot be readily modernized.

Foreign competition will increase. The U.S. global market share of the chemical trade is decreasing. Lower energy and raw material costs, cheaper labor rates, less regulation, and growing markets in Third World countries will encourage a shift in production to oil- and gas-rich developing nations. This trend may be particularly important for basic, large-volume chemicals, although the large domestic market argues that the U.S. will continue to produce bulk chemicals. The U.S. will maintain its lead in production of specialty chemicals due to its scientific and technological strength.

New profit-optimizing strategies are emerging because of the trends noted above. Low profit enterprises are being shed, management is being reorganized, diversification into non-chemical areas is increasing, movement to more profitable foreign locations is increasingly attractive, the workforce is being reduced, and the emphasis on high-profit products -- specialty chemicals -- is growing.

The economic recession of 1980-82 is the immediate and visible cause of some of these changes, but most would, or should, have come about in any case as the chemical industries reach maturity after four decades of rapid growth, and as they respond to growing foreign competition.

The chemical industries have always been at the forefront of process automation. New uses of computers and telecommunications for control, monitoring, information processing, R&D, modeling, and plant design are rapidly being adopted. Further applications of computers and robotics will present new challenges and opportunities for the industry.

There is no standard definition of "commodity chemicals." They are here considered to be chemicals (a) that are bought and sold, with many suppliers so that (b) there is price competition, and (c) they are used at basic or intermediate stages of manufacturing. The following chracteristics generally apply at present to the U.S. commodity chemical industry.

- capital, energy, feedstock, and R&D/technology intensive;
- established distributing and servicing networks;
- global operations;
- high plant and equipment investment in contrast to low labor content in cost of manufacture;
- highly skilled workforce;
- high growth rate in past dependent on commodity chemicals (future growth potential may depend on specialty chemicals);
- integrated plant complexes;
- world scale capacity plants for commodity chemical production (current capacity, however, exceeds global demands);
- chemical plant sites near sources of raw material (raw materials represent over 50% of manufacturing costs, and industry outputs are highly dependent on their supply, availability, and price);
- world's largest producer of organic commodity chemicals;
- competitive position based on low price, ready availability, and high purity of commodity chemicals;
- signs of industry maturation and structural change on horizon.

This report focuses almost entirely on organic chemicals, because concern about toxic substances, and OTS regulatory activities, are now focused on organics. In the future, it should be noted, inorganic chemicals are likely to get more attention; already there is growing concern about heavy metals, and the increasing use of catalysts.

The growth rate of commodity organic chemicals has been declining for the past three decades: 1950's -- 17%; 1960's -- 13%; and 1970's -- 4.6%. The growth projection for the 1980's is 4%, only slightly above the projected growth of the GNP (2.8%). Growth in petrochemical sales is projected to be higher than growth in many basic industries, but lower than in the past. (1)* But probably

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* References are grouped by chapter at the end of the report.

more revealing is the declining ability of the industry over the same time periods to rapidly penetrate end markets or create new end markets. (2) This indicates a maturing industry.

Part of the problem for the U.S. commodity chemicals industry lies with the prospects for economic vitality of its major customers -- energy producers, automobiles, housing, textiles, steel and appliances. High interest rates, availability of capital, domestic and foreign economic downturns, increased production capacity, value of the U.S. dollar, active foreign government involvement in commodity chemicals, etc. will affect the rehabilitation of the chemical industry customers and, in turn, future growth prospects for the industry.

In 1984, with recovery from the recession well underway, optimism was rising. Data Resources, Inc., forecast a growth of "real" (1972 dollars) GNP of 5.4%, with growth in industrial production of nearly 10%. On this basis, chemical shipments were forecast to increase 9.4% over 1983, with the industry operating at 81.3% of capacity, an increase of 8.4% over 1983's average operating rate. (3)

2. The Chemical Industry and World Trade

Global trends that are expected to affect future U.S. business operations in general include: (4)

-- Increasing integration of the global economy, including the integration of China and Russia in international trade and the increasing industrialization of developing and newly industrialized countries (NICs), thereby opening new markets and creating cheap labor and raw material competition for many products;

-- Internationalization of science, with nearly every country in the world now having a top layer of Western-trained scientists and technologists;

-- Increasing political instability as the gap between the have and have-not countries widens;

-- Erosion of American dominance of international business (in 1963, two-thirds of the 100 largest multinationals were American; now fewer than half are U.S. owned);

. . .

-- International pollution, problems of environmental maintenance, the trans-border flow of pollutants, and pollution of common resources, which are becoming increasingly urgent issues within and among nations;

-- Attempts to restrict transnational data flow, raising questions of national security, economic stability, political stability, protection of private property, civil rights, etc.;

-- A new wave of automation via computer-assisted design, computer-assisted manufacturing, and industrial robotics, which raise the threat of structural unemployment but also promise to bring the benefits of automation to batch and custom manufacturing;

-- Barter and countertrade, rapidly becoming practices as a result of the worldwide recession;

-- Widespread use of computers, telecommunications, and remote sensing;

-- Continuing political instability and recurring international crises, especially in the next decade;

-- Increasing terrorism, long associated with nationalism, irredentism, and revolutionary activities, and now possible protests against environmental pollution. It is very possible that the threat of contamination may be used as a mechanism of terrorism.

These trends specifically affect chemical companies. Chemicals, particularly primary and intermediate organic chemicals, are important contributors to the U.S. export performance and chemical industry profits, and an increasing proportion of domestic chemical production has been exported. (5) However, a number of factors will tend to moderate the rate of growth of exports of U.S. commodity chemicals:

- continued near-term reliance on petroleum and natural gas;
- lower demand for organic chemical-dependent products by chemical industry customers, such as automobile manufacturer, building construction, fibers, plastics industries;
- domestic and foreign economic pressures and currency valuations;
- protectionist barriers;
- emergence of Saudi Arabia and Mexico as major commodity chemical manufacturers;
- chemical industry industrialization plans and expansion strategies of NICs such as Brazil, Korea, Mexico and Taiwan; and

- industry nationalization and State/Government ownership and direction of industry and industry economic incentives in some countries. (6)

As a result of these and other factors, such as the strong value of the U.S. dollar, U.S. position in world trade is eroding. The chemicals trade surplus fell from $14 billion in 1981 to just over $8 billion in 1983. (7)

World trade rose throughout the 1970's, but dropped 11% from 1981 to 1982 due to the world recession. (8) International trade will increase slowly as the global economy improves.

Mergers, acquisitions, and nationalizations are expected to alter the composition of the top 30 international chemical companies during the next 5-10 years. One estimate is that half of these firms will be located outside the U.S. and the EEC. (9)

The countries hit hardest by the recent recession are West Germany, Japan, and Great Britain. According to the National Economic Development Office (London), there is a shift of commodity chemicals away from the advanced countries. (10) Inorganics, fertilizers, and petrochemicals will be affected most. The chemical industry in many industrialized nations will decline or change as a result.

Availability and price of feedstocks and energy will influence location decisions, especially for energy intensive basic commodities. In addition, there will be a tendency to concentrate production close to new demand centers -- areas of increasing population and industrial and agricultural growth. This will mean increasing shifts in markets and production toward the developing and newly industrialized countries (NIC), some of which are already planning on building world class facilities.

While some LDC's and NIC's have delayed development of world class chemical facilities due to the recession, worldwide capacity in basic commodity chemicals is expected to increase through the late 1980's. (11)

Government ownership, direct subsidies, and low-cost financing will increasingly enable foreign competitors to sell chemical products below U.S. prices. (12) The motivation driving many foreign firms is changing from profits to concerns of employment, national development, and foreign currency exchange management.

New survival strategies are emerging for traditional chemical producers. British Petroleum's recent activities are exemplary of a larger industry trend toward streamlining their activities, reducing low-profitability enterprises. British Petroleum is focusing on three business areas: polyethylene, acetyls, and alcohols. It is cutting manpower by 40%; closing 16 less profitable plants; and getting out of polyvinyl chloride production. (13)

Following are some examples of the pressures from industrialized and developing countries that will influence the U.S. commodity chemical industry competitiveness over the next several years.

Developed Nations

European chemical companies complain about competition from the U.S. They have, however, also suffered in recent years from inflation and recession. Emphasis in 1983 was on reducing excess capacity -- exports and earnings dropped in Great Britain, France, and West Germany. (14) Most European companies expected to invest less in 1983 than in previous years. (15)

The response of the European chemical industry to these pressures will probably be considerably fewer producers in the commodity chemical marketplace and an industrial movement to higher value added chemical products.

Japanese companies also had very low growth in 1983 and expect little or none in 1984. (16)

World scale production facilities being built in Canada will eventually provide substantial competition for U.S. commodity chemical industry in the future. In time, Canada may even double its share of world production, particularly of commodity chemicals such as ethylene, benzene, polyethylene, styrene, etc. (17) There is talk of building a new petrochemical industry in the Maritime Provinces when world markets improve to take advantage of oil fields off the shores of Nova Scotia and Newfoundland. (18)

Saudi Arabia may become a significant competitive factor in the global production and trade of commodity chemicals, according to experts, but much depends on the future economic and political stability of the area. (19) The large oil companies are likely to be reluctant to build in this potentially troubled spot.

Mexico's chemical industry is dependent on imports of critical materials and equipment, which cannot be bought with nearly worthless pesos. Brazil's chemical industry also has suffered from inflation and the debt crisis. In spite of this, as more developing nations industrialize the Latin American petrochemicals markets will grow. (20)

From 1970 to 1980, the developing nations of the world increased their share of world chemical exports by 39%, from 4.6% to 6.4%, according to a 1982 U.N. study. The leading area in this growth was Asia, with one half of its exports accounted for by four nations -- Korea, Taiwan, Singapore, and Hong Kong. (21) Other developing nations have been the fastest growing markets for the increased exports of developing nations.

B. THE DOMESTIC CHEMICAL INDUSTRY

1. Industry Strategies

During the recession, U.S. chemical companies shut down many of their unprofitable, marginally profitable, or low-growth lines. Basic commodities plants were the target for most divestitures; many were shut down or sold to companies with diverse product lines. (22)

Chemical companies have restricted new business efforts to areas where technological advances permitted cost reduction or encouraged development of new products. New growth areas included engineering plastics, catalysts, electronic chemicals, and other specialty chemicals. There were distinct signs of a movement away from hydrocarbons, heavy organics, chloralkali plant products, and thermoplastics. (23) Many chemical companies realigned corporate management to achieve tighter control of their operations.

The end of the recession in late 1983 brought more optimistic expectations for 1984 as housing and automobile sales began to rise. However, trade magazines also expected chemical companies to monitor inventories strictly and to keep a tight rein on plant and equipment expenditures. (24) The large Federal budget and the threat of a new rise in interest rates were factors in this caution, but the largest factor may have been the continuing slide in the chemical trade balance. Other restraining forces were uncertainty over U.S. trade policy, the effects of decontrol of natural gas prices, and the possibility of new environmental legislation, especially the amendments likely to be proposed to TSCA (such as mandatory premarket toxicological testing of chemicals). (25)

Production. A combination of overcapacity, lower demand, and lower productivity have recently marked the commodity chemical industry during the general economic recession from 1980 through 1983, and was reflected in declining production. The 1982 output of chemicals and synthetic fibers was 14% lower than the 1981 output and 16% under the peak year of 1979. The largest decline was in basic organic chemicals, down 19% in 1982, and synthetic fibers, down 25%. The smallest decline was in plastics. (26)

Use of chemical plant capacity declined from 85% in 1972, to 78% in 1980, to 66% in 1982, and 63% in the first quarter of 1983. Some overcapacity in basic chemicals plants is expected to continue. (27)

There is a slow recovery in three major market areas for chemicals -- agriculture, transportation, and construction -- in 1984, but the long-term trend may well keep chemical shipments under their late 1970's' peaks for several years. It is possible that production of basic chemicals may not achieve those growth rates again; foreign competitors have comparative advantages in terms of energy and materials costs, labor costs, and social/environmental costs. Production of specialty chemicals, however, will continue to grow strongly. These are relatively high profit products, where the U.S. has the advantage in advanced chemical technologies and processes.

Finance. As a result of the recession, chemical industry profits in 1982 fell to the lowest levels since 1973, although recovery appears to have begun.

Capital expenditures for new plants and equipment by the top 14 firms are projected to remain relatively low through the 1980's although there was an upturn in early 1984. (28) With some idle capacity expected to continue into the late 1980's, relatively few new plants are anticipated. High interest rates over the next few years would further discourage industry expansion.

Overseas investment by U.S. chemical firms has remained relatively constant since 1980. It is expected to increase because of the relatively high cost of doing business in the U.S. compared to the developing world and increased foreign competition.

Employment. Chemical companies cut their workforce in 1982 by 6% because of the recession. Almost three-quarters of the jobs lost were for production and non-supervisory workers. (29) There was a further decline of about 2% in 1983. (30) While there will be some job growth in 1984, many of these jobs may not be refilled because they can be eliminated by further automation. This will be especially attractive for jobs where worker safety and health is a problem.

The most severe cuts in employment in 1982 were in plastics and fibers (down 6% from 1981 levels and 20% from 1972 levels) and in agricultural chemicals (down 5.6% from 1981, but still up 20% from 1972). In these chemicals employment will continue to decline, because of increased overseas production and automation of existing and future plants.

Employment of scientists and engineers within the chemical industry has steadily risen over the last ten years to a high in 1982 of over 60,000. A continued rise is expected. (31)

R&D. R&D spending is increasing for the chemical industry. It was $5,325 million in 1982 and is projected to increase to $8,655 million by 1986. (32) But R&D as a percentage of absolute GNP has declined, especially in basic commodity R&D. Both the maturity of the industry and the rising costs and risks of introducing new products and processes may be leading industry to focus R&D on more short-term, incremental projects. (33) Many chemical companies are emphasizing valued added drug research and moving away from R&D in traditional, volume commodity chemicals.

Most R&D funds in 1982 and 1983 went to improving existing products, (52%). In 1983, only 28% of the funds were spent for new products and 21% for new chemical processes. (34) In 1984, there is a projected increase of 10% in industry R&D, with most of it going to new products and to bioengineering. (35)

Industry/academic R&D cooperation is likely to increase significantly. Many people in the chemical industry want to shift basic research and the earlier stages of development to universities. (36) But several concerns may complicate this relationship:

- -- conflicts of interest between scientists and product developers,
- -- the likelihood of legal battles over patent rights, and
- -- potential problems arising from product liability litigation.

The chemical industry is one of the four most R&D intensive industries, and about 93% of its R&D is supported directly by private sector chemical firms. (37) Total spending for R&D in industrial chemicals increased 47% from 1971-1981. (38)

According to an NBS observer, a number of factors will encourage R&D spending: (39)

-- the Economic Recovery Act of 1981;

-- the need for innovations in process technology to increase efficiency of existing and of new operations;

-- the hope of using alternative feedstocks;

-- the need to optimize plant operations and management and gain flexibility in new plant design to meet market demands;

-- the desire to train scientists and engineers in industry-related fields;

-- the possibilities of new processes and products via biotechnology;

-- the promise of discovering or of acquiring higher value added specialty products such as pharmaceuticals; and

-- the need to offset rising energy and raw material costs.

Pilot Plants and Scale Up. Small-unit testing is important for large chemical plants, to prove the validity of basic reactions; discover and address secondary reactions and potential environmental and health hazards; boost yields to economic levels; solve incremental problems; and test construction materials and processes for larger units.

The growing complexity of process technology and higher financial stakes are leading the industry to be increasingly conservative in scaling from smaller to larger units. Fewer risks are undertaken. At the same time, computer modeling and optimization paradigms can cheaply and quickly predict scale-up problems and needs, obviating the need for pilot testing.

There is a trend toward tieing together process steps at early stages of plant scale-up. This is driving up the cost of scale-ups, but it also allows early detection and correction of the buildup of unwanted by-products.

For basic commodities, e.g., petrochemicals, plant scale-up will be increasingly challenged given the likelihood of changing feedstocks. Heavier distillates and residual oils, higher temperatures and pressures, and more active catalysts are complicating the scale-up of chemical processes. Pressures for scale-up -- competition and cost -- are reducing the typical 2-3 year pilot phase to a few months. (40)

2. Size and Location

"World class" producers (defined as the largest volume producers of bulk chemicals) are increasing in scale; for example, Cosdan's styrene plant in the 1950's produced 20 million pounds per year as top producer; in 1980, American Hoechst completed a 900 million pound per year plant in Texas. In the future, however, such increases in scale will more often be located in foreign countries than in the U.S. The only world class plants built in the U.S. during the next decade will likely be located in Alaska at sites near available feedstocks and barge, ship, or pipeline transportation.

> "Energy supplies may have some indirect effects on the location of petrochemical production.... A number of oil-producing countries have begun construction of massive petrochemical facilities, attempting to move from simple producers of crude oil to exporters of a wide variety of processed hydrocarbons. Many of these investments are being made more on the basis of national prestige and development (and in an atmosphere of abundant capital) than on strict economic considerations. Their existence may make it unprofitable for U.S. companies to build similar facilities at home." (41)

The top ten chemical producing states, in 1980, in descending order were: Texas, New Jersey, Illinois, Ohio, California, Louisiana, New York, Pennsylvania, Tennessee, and Indiana. (42) With the move toward specialty chemicals in the U.S., the average plant size will decrease. Sites with favorable transportation, water, and fuel availability will also be harder to find. This may induce some gradual changes in the pattern of plant location, but they will not be dramatic shifts.

The long-term trend toward migration of the chemical industry to the Gulf States may be weakening. (43) While the chemical industry as a whole grew 29% during 1970-1980, in Louisiana the industry only increased 22.6%, and in Texas, the leading chemical producing state, it only grew 10.7%. The fastest growth is occurring in California, 47.8% between 1977-1980, in spite of the fact that California environmental regulations are considered the strictest in the nation. (Here growth is measured on the basis of value of shipmnts minus the costs of materials and energy. During the same period, production went up by 6%. Since 1980, worldwide economic problems have pushed all measures of growth into a slump; cyclical recovery is beginning in 1983-84. However, migration trends remain the same.) There are indications of renewed interest in sites in the Great Lakes States.

Geographic proximity of industry plants to raw materials will continue to be important in the strategic planning in this industry.

The hazards involved in chemical manufacturing and waste disposal are leading to increasing public debate about acceptable sites, but these have so far not been major factors in decisions about chemical facility siting. A recent Conservation Foundation Study showed that environmental constraints rarely block siting choices. (44) Siting could, however, be significantly more controversial in the future. This would tend to lock in the present location pattern.

The chemical industry is constantly modernizing, upgrading, and maintaining its plants. Much of this renewal is on-site, but the industry will continue to phase out some low profit, inefficient plants. During the run-down period, firms will likely defer maintenance of the plants, leading to pollution increases; and after the plant is permanently closed, the machinery exposed to toxic and hazardous substances and the waste disposal facilities may remain highly dangerous to public and environmental health.

Issues that must soon be confronted by industry and government are how the dismantling and disposal of obsolete plants and clean-up of the grounds should be regulated.

3. Product Trends

Petrochemicals. The U.S. will maintain leadership in new or special grades of petrochemicals because of its technological lead in chemicals and chemical processes. (45) But production of bulk chemicals will tend to stabilize and possibly even decline in the U.S. A growing proportion of bulk chemicals will be produced in off-shore locations and Third World countries.

Other Organic Chemicals. The long-term prospects for organic chemicals will be influenced by:

-- the demands of end-product markets, namely, pharmaceuticals, gasoline octane improvers, pesticides, synthetic detergents, oil field chemicals, and protective coatings requiring new and improved intermediate organic chemicals;

-- increasing cost and decreasing availability of fossil fuels for use as energy and as feedstock;

-- reduction of excess productive capacity in industrial nations, with closing of low-profit, inefficient plants;

-- increasing international competition and export promotion programs of foreign nations;

-- the siting of large plants in gas- and oil-rich countries; the entrance of Saudi Arabia and Canada into the field by 1986 and Indonesia, Mexico, Singapore, and other Middle East nations by 1990, significantly changing the international structure of the organic chemicals industry;

-- decline of the U.S. share of the large-volume, commodity organic chemical market, with the U.S. remaining a major supplier of small-volume, specialty organic chemicals.

Urea formaldehyde may drop in production due to potential government regulation and public concern over health risks. Long-term prospects for using methanol as a primary automotive engine fuel and as a feedstock for hydrocarbon production are leading to increased R&D to improve energy efficiency of methanol manufacturing processes. Multifunction monomers are making it possible to formulate protective coatings, inks, and adhesive cheaply using radiation rather than heat. Biotechnology will provide new sources of organic chemicals based on use of waste material, but production is not expected in any volume until the late 1980's.

Agricultural Chemicals. Reduced domestic demand coupled with increasing foreign penetration of the U.S. market is forcing U.S. manufacturers to lower prices of nitrogenous fertilizers. But rising natural gas costs will increase the prices of ammonia.

Increases in the world demand for grain may result in slight increases in domestic consumption of phosphate fertilizers, but most demands will be met by existing stocks. While the proximity of U.S. manufacturers to phosphate rock resources and to seaports will act to maintain current production levels, the low cost of foreign products will eventually erode the U.S. share of the world market.

The rising costs of agricultural chemicals and new concern over groundwater contamination and non-point source water pollution may lead to a continued reduction in their production. The only growth expected over the next five years is for herbicides associated with no-till agricultures. Competition will force smaller companies out of the market and lead to increased emphasis on selective herbicides, growth regulators, and synthetic pyrethroids.

Drugs. The U.S. pharmaceutical industry is losing ground to foreign competition, according to a National Academy of Engineering (NAE) study released in July 1983. (46) U.S. share of world pharmaceutical R&D expenditures has fallen from more than 60% in the 1950's to less than 30% in 1982. The number of U.S. owned new drugs entering U.S. clinical trials has steadily dropped, from 60 per year through the 1960's to 25 per year in 1982. Foreign levels have remained constant at 20 per year. (47)

-- Small U.S. pharmaceutical firms originate fewer drugs than before 1960 and depend more on foreign firms for licensing new products.

-- The percentage of world pharmaceutical production occurring in the U.S. has fallen from 50% in 1962, to 38% in 1968, to 27% in 1978. U.S. share of world pharmaceutical exports has fallen from more than 30% before 1960 to less than 15% in 1983.

Telematics. Telematics -- the technologies and systems of computers, telecommunications, and information -- is affecting all facets of society and industry, a worldwide revolution comparable to the Industrial Revolution. Significant direct impacts will probably first come from monitoring, in computer-aided design and manufacturing, computer modeling, and the broad area of information management and availability. Indirect impacts on chemicals and the chemical industry will emerge as telematics alters social systems such as work patterns, industry organization and management, transportation, and economic and political operations. (48)

Three-dimensional visualization and design optimization capabilities of computers are already being used in computer-aided design and manufacturing. Expanding CAD/CAM applications include:

-- rapid scale-up from bench to several million pounds per day operations;

-- flexible, individualized, rapid plant design, saving labor costs and reducing waste. While destandardization may make it difficult to generalize about or predict a potential occupational hazard, computers can help pinpoint the source of a hazard and analyze possible design solutions;

-- highly integrated plant design that ensures that subsystems will mesh and that retrofits will perform as desired.

Computers and other modern instruments are assisting in automating the chemical plant testing and manufacturing process. (49) Computer controlled bench-scale testing units and six technicians can now perform the testing and recording that 25-30 technicians would do. New mass spectrometers trace catalyst poisons that once went undiscovered. Carbon analyzers, refractometers, and chromatographs provide instant and simultaneous data on product streams. On-line electronic instruments are providing information in minutes that, under the batch-mode, would take hours. Advanced mathematical models and computer simulations are providing new insights into chemical processes, encouraging the development of increasingly sophisticated chemical data banks within firms and permitting testing of chemicals on increasingly smaller scales.

Development of microprocessors enables the placement of advanced digital control technologies at key unit operations throughout chemical plants. For example, in petrochemical complexes, computers control furnaces, fractionating towers, cracked gas compressors, and other downstream units. Use of computers for process control is greatly assisting efforts to improve energy efficiency and lower waste by-products. Computer-aided design of plants is facilitating maximization of energy and feedstock use, assisting development of fully integrated manufacturing and waste disposal systems, and lowering overall pollution levels.

The move toward more comprehensive instrumentation has driven up the cost of pilot plants, but the use of computer simulations has decreased the amount of time required for, and risks involved in, scale-ups of plants.

Computers and robots will replace human mental activity in ways similar to machinery's displacement of human physical functions. This may lead to:

-- reductions in middle management, with top management accessing information directly, thereby lowering overhead costs to industry;

-- reductions in blue-collar jobs -- one estimate foresees a labor decline in manufacturing from the current 22% of the labor force to a 3-5% by 2000; although most chemical industries, being already highly automated, will be less drastically affected; and

-- increased pressures upon government and industry to retrain displaced workers. (50)

Centralized data testing and analysis and information processing is increasing. The Chemical Abstracts Service is accessed via computers and telephones by chemical companies and interested parties worldwide. The American Institute of Chemical Engineers and the Chemical Industry Institute of Toxicology are joining forces to address new technologies, while lowering individual R&D and testing costs.

Expenditures for information services will increase. The top four chemical companies are spending an average of $4 million per year for library materials, on-line bibliographic and numeric reference services, on-line technical processing, computer system support, telephone and telecommunications, and records management. (51) Additional information costs, including external and internal research reports, marketing information services, competitor analyses, and publications are often proprietary and not included in information budgeting.

Large decentralized networks are forming among institutions, regions, and individuals. Through telematics, a regional office can integrate fully into the day-to-day operations of a company, increasing overall efficiency while decreasing autonomy.

A trend towards continuous and pervasive compilation of information is emerging from increasing reliance on telematics to sort, process, store, and transmit data. For instance, every time a person or company contacts an institution he generates information which can be incorporated into a data base. A hospital stay, a job interview, a phone call to the doctor or plumber or lover, a plane trip, a drugstore purchase -- all could contribute information on the individual and, combined with other inputs, on the population. The capability for collecting microdata may affect marketing strategies, health records, risk exposures, and many other interactions between people and the man-made environment. Company data can be compiled and analyzed in new ways. But this capability will also give rise to important and complex issues involving rights to privacy, ownership of information and misuse of data.

C. CHANGES IN CHEMICAL FEEDSTOCKS, ENERGY USE, AND WASTE MANAGEMENT

1. <u>Feedstocks and Energy</u>

The feedstock mix of the chemical industry is slowly shifting, driven mainly by factors external to the industry itself:

-- the technology of feedstock utilization,

-- the costs and availability of petroleum and natural gas,

-- the balance between chemical feedstock, fuel, and energy generation uses of petroleum and natural gas,

-- regulations affecting processes and waste management,

-- economic costs associated with retrofit, construction, and operations.

Energy costs are replacing capital costs as the main driver of decisions on processes, pathways, and feedstocks, especially for commodity chemicals. (52)

The raw material hydrocarbon feedstock bases for organic chemicals will be undergoing changes over the next few decades.

Feedstock use will change slowly, as there is substantial investment in the process infrastructure of current feedstocks, especially petrochemical intermediates with high vertical and horizontal integration.

The quality of basic petrochemicals as feedstocks will decrease and become more mixed. As costs rise, the first stage will be to make more efficient use of petrochemical feedstocks rather than shift feedstock. While the use of petrochemical feedstocks will decline slowly, coal and lower grade crudes will replace petroleum and gas and new hydrocarbon sources will be used to generate the same petrochemical feedstocks through coal gasification to natural gas substitute or liquefaction to a petroleum substitute or direct from coal. What shift does occur may be first to coal and coal gasification and liquefaction products (with high capital costs) and then increasingly to biomass.

The chemical industry uses:

-- 10% of the 18 thousand cubic feet of natural gas produced each year,

-- 6% of the 15 million barrels of liquid hydrocarbons produced each day, and

-- 20% of all industrial power. (53)

Economic incentives, availability of raw materials, and energy costs are stimulating switches to new production processes. For example, pyrolysis routes to benzene are replacing traditional processes. New processes can give different mixes of by-products, impurities, wastes; the pyrolysis route to benzene often contaminates it with polynuclear aromatics. Increasing demand for fuel oil may cause a search to alternative sources of petrochemicals and derived products, such as plastic from coal or plant crops. Some strategies being used are shown in Exhibit 4.

As the use of lower grade ores and recycling increases, the demand for improved separation technology will increase. Separation aids such as flotation chemicals will be increasingly used, creating new discharges. (54)

There is increasing modification in the industry to allow for a diversity of feedstock, both between petroleum and coal and among petroleum grades.

Coal is likely to be a significant feedstock by the early 1990's. Eastman Kodak in 1983 built a 500 million pound/year acetic anhydride plant based on new process technology to utilize syngas from coal -- the first commercial U.S. use of synfuels technology. (55) Currently, while variable production costs are cheaper from coal, the high capital outlay has prevented many companies from investing in new coal-based processes.

Another possible feedstock is biomass. Although production of ethanol from corn is becoming increasingly competitive at commodity levels, commercial production of commodity organic chemicals from biomass via biotechnological processes is not expected until the mid- to late-1990's. (56) In the long term, fermentation and other biotechnology tools (e.g., enzymes, plant and animal cell cultures) will be used in the production of organic chemicals. (57) Problems in the scale-up of biochemical engineering process include heat removal, mixing, sterilization, instrumentation and controls, catalysis, and water supply, but experts expect that bioprocesses will eventually be used for production of higher value added chemicals and some commodity chemicals. (58)

EXHIBIT 4

FEEDSTOCK SECURITY POSITIONS OF SOME LEADING CHEMICAL FIRMS

Chemical Company	Hydrocarbon Base
Dupont	Merger with Conoco, expanded oil/gas exploration effort through recent acquisition (Terrapet)
Dow	Owns oil/gas properties; recently sold domestic oil and gas reserves to Apache; still owns Freeport, Texas crude oil processing refinery
Union Carbide	Purchases feedstock supplies
Monsanto	Oil/gas exploration revenues indirectly support feedstock needs; has coal resources
W. R. Grace	Oil/gas exploration revenues indirectly support some feedstock needs; plans expanded energy exploration effort through subsidiary (Union Texas Petroleum)
American Cyanamid	Purchases feedstock supplies
Celanese	Purchases feedstock supplies
PPG Industries	Purchases most feedstock supplies

Source: T. C. O'Brien, NBS and Industrial Biotechnology, Washington, D.C.: National Bureau of Standards, July 1982, p. 22.

Biotechnology, via chemoautotrophic microorganisms, can also provide a range of organic compounds from hydrogen and carbon dioxide, which are available from coal following reaction with steam. (59)

The commodity organic chemical industry views its current investments in biotechnology as a means to keep its options open. (See Exhibit 5). The industry hopes that this technology will, before the end of the decade, produce higher value added organic chemicals. Application of biotechnology on an industrial scale for the production of "traditional" commodity organic chemicals is not expected much before the end of the century. Because of the difficulties that will be encountered in displacing commodity organic chemicals from petroleum feedstocks, the value added component from biotechnology may be a comparatively small $1 billion. However, biotechnology may have a significantly greater market impact in the production of "non-traditional" commodity organic chemicals such as biopolymers. (60)

Depending upon the economics and politics of producing organic chemicals via biotechnology, biomass could become an important feedstock for the production of organic chemicals. However, considerable research effort must take place to improve the productivity and economics of the biotechnological processes for biomass conversion that are under consideration. Critical to such an improvement for bioprocesses will be advances and innovations in biotechnology "tools," such as biocatalyst, recombinant DNA, cell culture, and fermentation technologies. Further, if biotechnology is to be applied on the industrial scale envisioned by organic chemical producers, innovation must also occur in bioprocess engineering technology areas, such as process monitoring and control, product separation and recovery, aseptic operation, and process intensification. (61)

EXHIBIT 5

BIOTECHNOLOGY ACTIVITIES OF LEADING
U.S. CHEMICAL PRODUCERS

1982 Rank, Sales	Company	Classification	Biotechnology Investments: In-house R&D	Biotechnology Investments: Equity Ownership, Other
1	Dupont	Basic chemicals	X	Caltech, Harvard, Univ. of Maryland, New England Nuclear Corporation
2	Dow Chemical	Basic chemicals	X	Collaborative Genetics, Collaborative Research, Ingene
3	EXXON	Petroleum	X	Cold Spring Harbor, MIT
4	Monsanto	Basic chemicals	X	Biogen, Genentech, Genex, Collagen, Harvard Rockefeller, Washington University
5	Union Carbide	Basic chemicals	-	--
6	Shell Oil	Petroleum	X	Cetus, Celltech
7	Celanese	Basic chemicals	X	Yale
8	Standard Oil of Indiana	Petroleum	X	Cetus
9	W. R. Grace	Specialty chemicals	X	Agripartners
10	Allied Corporation	Basic chemicals	X	Biologicals, Calgene Collagen, Genetics Institute
11	Phillips Petroleum	Petroleum	X	Salk Institute Biotechnology Industrial Associates (SIBIA)
12	Atlantic Richfield	Petroleum	X	--
13	Eastman Kodak	Photo equipment	X	--
14	Mobil Oil	Petroleum	X	--
15	Hercules	Basic chemicals	-	Adria Laboratories
16	Gulf Oil	Petroleum	X	--
17	Rohm & Haas	Basic chemicals	X	Advanced Genetic Sciences
18	American Cyanamid	Basic chemicals	X	Molecular Genetics Cytogen
19	Stauffer	Basic chemicals	X	--
20	American Hoechst	Basic chemicals	X	Massachusetts-General

SOURCES: T.C. O'Brien, NBS and Industrial Biotechnology, Washington, D.C.: National Bureau of Standards, July 1982.
Office of Technology Assessment, Commercial Biotechnology, An International Analysis, Washington, D.C.: U.S. GPO, January 1984, pp. 67-70, 100-101, 416-418.
And other sources.

The technology already exists for cost-effective biological production of some commodity chemicals. Commodity chemicals most likely to be made from biomass in the future are ethanol, acetone, isopropanol, acetic acid, citric acid, propanoic acid, fumaric acid, butanol, 2,3-butanediol, methyl ethyl ketone, glycerin, tetrahydrofuran, and adipic acid, according to a recent report by the Congressional Office of Technology Assessment (OTA). But OTA also concluded that because the chemical composition of biomass is different from that of petroleum and because microorganisms have a wide range of activities, it is likely that "the most important commodity chemicals produced from biomass will be, not chemicals that directly substitute for petrochemicals, but other chemicals that together define a new structure for the chemical industry." (62) Genetic manipulation may produce microorganisms with characteristics such as tolerance to increased levels of products during bioprocess reactions, tolerance to higher temperatures, and faster rates of production. Environmental applications of biotechnology will also be important, for example in toxic waste degradation. Regulation will be a major factor in the development and timing of these applications since they will call for release of organisms directly into the environment.

In spite of current perceptions of an "oil glut", total oil production will probably peak around the year 2000, and development of new natural gas reserves, usually associated with oil discoveries, have been less than production for over a decade.

Continued dependence on petroleum as the major feedstock will depend on the oil production of Saudi Arabia and its economic and political stability, and on other factors such as U.S. and global economic growth; energy conservation; oil production and stability of other OPEC nations; and energy contributions from nuclear, coal, solar, and other sources. (63)

A chemical industry transition will take place in the future, with a shift from oil and natural gas to coal and to biomass feedstocks. Economics will dictate the timing of this transition. Technological innovation will be an essential component in the shift. The transition to alternative feedstocks will stimulate evolution and structural change in the chemical industry.

Emphasis on energy efficiency and increasing use of process heat will spur the use of by-products and wastes for energy generation.

2. Waste Management Problems and Opportunities

The Scope of the Problem. Although OTS does not directly address the regulation or tracking of hazardous wastes, TSCA does cover waste disposal and OTS deals with related problems of incineration and recycling of hazardous chemicals. The mission of OTS within EPA will be shaped by the regulatory policy environment. Management of hazardous waste, expecially toxic waste, is crystallizing public concern and policy response in many areas peripheral to waste issues. In the 1980's, it is the issue around which lines are drawn between environmentalists and industry, and which patterns state and Federal regulatory strategies. It is also a key issue in industry planning and financing. As discussed in Chapter 4, media attention and the dramatic personal nature of environmental and health problems raised by toxic wastes have made them the focal point of a broader range of concerns about chemicals, health, the environment, and balancing responsibility for maintaining the safety and quality of health and the environment.

The technology and economics of industrial waste management will also help determine the processes and products that industries manufacture and, consequently, the demand for action under TSCA. Thus OTS needs to keep up with advances in industrial waste management technology and practice as well as public and political responses to the continuing problem of hazardous waste management.

Litigation and regulation regarding hazardous wastes will be a focus of political -- and industrial -- action at least through the 1980's. Technological, economic, and management strategies to minimize risks are necessarily long-term.

In late 1983, EPA revised its 1980 estimate of total hazardous wastes in the U.S. upwards by 375%, to 150 million tons. (64) The chemical industry generates a little over 70% of this. An Associa- of State and Territorial Solid Waste Management Officials survey estimated that about 255-275 million tons of known and tracked hazardous wastes are added to the environment each year, in addition to "millions of tons" of unregulated and exempted hazardous waste. (65) This survey was done for the Congressional Office of Technology Assessment, which estimated that about 10% of all hazardous wastes are produced by unregulated small producers. (66)

Nine firms account for over 50% of all commercial waste disposal and treatment. They have increased their permitted landfill capacity and increased their chemical treatment capacity, but since these increases were mostly in or near existing sites, there is still a serious shortage of accessible sites in certain areas of the country. (67)

While the total volume of wastes is growing, the volume of waste treated by these nine firms declined from 3.7 million wet metric tons in 1980-81 to 3.6 million wet metric tons this year. (68) The effort to separate hazardous from non-hazardous waste should slow the growth in the volume of wastes treated off-site. Some large-volume waste streams have been removed from the EPA's hazardous waste list, e.g., certain paint sludges and pickled liquor sludges.

Reflecting differences in political priorities, many states have more stringent definitions of "hazardous" than does the Federal government. Under California law, for example, 15 million tons of hazardous waste were produced in California in 1980, while

EPA estimated waste generation at 2.6 million tons. (69) Other states have similar definitions but use different measures, thus arriving at a different number for total volume of hazardous waste. Often State and EPA estimates differ by an order of magnitude. There is no internationally accepted definition of hazardous waste. (70)

Many problems of hazardous waste management result not from the lack of sophisticated control technology but rather from haphazard awareness, use, enforcement, and incentive for the available technologies. There are severe gaps in worker education, public understanding, and the effectiveness of the economic and regulatory framework under which industry and waste management companies operate. RCRA mandates coordinated tracking of wastes from "cradle-to-grave," but it is far from certain that the manifest system really works. The recent book Hazardous Waste In America notes that the publicity given to waste incidents and the demand for tightly controlled, minimum-hazard waste management has led to a blind and universal public distrust of all waste operations -- including the well-managed, latest-technology ones. (71) A 1980 survey showed a majority of people would accept new facilities only if the sites were at least 100 miles away from their homes. (72)

Industry, especially larger, financially well-off companies, has moved towards treating and disposing of much of its waste on-site. Dow and DuPont each dispose of about 95% of their waste on-site. Across all industry, about 80% of hazardous wastes are managed on-site. (73) The disappearance of available waste disposal sites has created a disproportionate burden on smaller companies without the land and waste volume to provide for on-site waste disposal.

The costs of off-site chemical waste treatment are up 20% from 1981-1982 and are expected to continue rising. (74) The reasons include:

-- closure of some operations, e.g., landfills, due to public opposition or regulatory compliance problems;

-- capital expenditures required to comply with state and Federal regulations;

-- new EPA requirements for owners of sites to have extensive liability insurance.

While the Superfund law allocated $1.6 billion for cleanup of uncontrolled hazardous waste sites and for compensation, OTA estimated that cleanup of the 15,000 uncontrolled sites of previous disposals so far identified would cost $10 to $40 billion. (75) See Exhibit 6.

EXHIBIT 6

Quoted Prices for Major Hazardous Waste Firms in 1981

Type of waste management	Type or form of wastes	Price 1981	$/tonne 1981
Landfill	Drummed	$0.64–$0.91/gal ($35–$50/55 gal drum)	$168–$240
	Bulk	$0.19–$0.28/gal	$55–$83
	Type:		
	Acids/alkalis		$13–$210
	Odorous waste		$30
	Low risk hazardous waste (e.g., oil and gas drilling muds)		$13–$29
	Hazardous		$30–$80
	Extremely hazardous		$50–$140
Land treatment	All	$0.02–$0.09/gal	$5–24
Incineration clean	Relatively clean liquids, high-Btu value	$(0.05)*–$0.20/gal	$(13)*–$53
	Liquids	$0.20–$0.90/gal	$53–$237
	Solids, highly toxic liquids	$1.50–$3.00/gal	$395–$791
Chemical treatment	Acids/alkalines	$0.08–$0.35/gal	$21–$92
	Cyanides, heavy metals, highly toxic waste	$0.25–$3.00/gal	$66–$791
Resource recovery	All	$0.25–$1.00/gal	$66–$264
Deep well injection	Oily wastewater	$0.06–$0.15/gal	$16–$40
	Toxic rinse water	$0.50–$1.00/gal	$132–$264
Transportation		$0.15/ton mile	

* Some cement kilns and light aggregate manufacturers are now paying for waste.
Source: Samuel Epstein, Lester Brown, and Carl Pope, Hazardous Waste in America, San Francisco: Sierra Club Books, 1982, p. 549.

OTA also estimates that the $5 billion spent on satisfying U.S. regulation on hazardous waste disposal in 1983 will grow to $12 billion by 1990. (76)

At least 20 industrial waste exchanges, i.e., information clearinghouses that provide information on specific wastes to companies interested in using the wastes as raw materials, are now in operation. (77)

The variation in state regulation of waste disposal causes extensive legal and illegal interstate traffic in hazardous wastes (see Chapter 4). Regional differences encourage companies to seek the cheapest solution or to avoid regulation altogether by midnight dumping. Companies in Pennsylvania have to ship wastes out of state at high cost because of the scarcity of local landfills. (78)

Midnight dumping is a serious problem. EPA estimated in 1979 (before most of the RCRA regulations) that 90% of hazardous wastes were mismanaged either through ignorance or deliberate avoidance of regulation. (79) The primary cause of unsound disposal was identified as insecure surface impoundment. Other independent estimates have supported this. (80) Transport of hazardous wastes will be a growing concern, as discussed in Chapter 4.

As the use of non-petroleum feedstocks increases, the amount of waste generated will rise sharply. Secondary feedstocks such as heavier petroleum grades, coal, and syngas all generate more waste during their creation as well as creating more wastes during their utilization by the chemicals industry. The chemical process industry has been geared to maximize use of petroleum.

The shift to biological-based feedstock would require aqueous reaction conditions, generating large amounts of liquid wastes. But these wastes are generally much less toxic than those of petroleum-based chemical manufacture. Coal, however, often contains significant amounts of heavy metals and radioactive compounds.

Decisions will have to be made in the present with the certain knowledge that future science and technology will reveal new concerns about the toxicity of wastes and the ineffectiveness of various management options. For example, in the 1950's dioxin was known to be a toxic compound but was also believed to degrade rapidly in the soil; 25 years later, bitter experience revealed the shortcomings of older technology. The last word on dioxin's effect on humans is not yet in. (81)

Technological Options. There is no single best technology to deal with all toxic wastes. Incineration and other high-temperature processes and recovery and recycling are the main "permanent" means of managing wastes (see Exhibit 7). Incineration and other high-temperature processes such as molten salt, plasma arc, super critical water (374+^{o}C, 218+atm), and pyrolysis, despite their high costs, are becoming more popular. While these technologies break down most organics, even polychlorinated biphenyls (PCB's), they need effective scrubbers and they create ash and scrubber residue which, in turn, requires disposal. A manufacturer may be relieved of responsibility for a hazardous chemical by changing it into a different chemical substance by incineration.

The EPA Office of Research and Development, Oil and Hazardous Materials Spills Branch, has developed a mobile incinerator which, operating at 1200^{o}C, will destroy PCB's. Highly halogenated organics such as PCB's are the most resistant of toxic substances to degradation. (82)

Other more advanced thermal technologies still in the development stage include plasma destruction, where gases are heated to several thousand degrees in an electric field.

In October 1983, EPA estimated that 325 incinerators were operating at between 240 and 275 facilities. About half of these were operated by the chemical industry. (83)

Although process improvement, recycling, separation of wastes, recovery, etc. can significantly reduce the volume and toxicity of wastes, there are irreducible limits to this. Before 1981, only about 2% of waste products were recycled or reclaimed (84) but this is now increasing. Recovery of usable materials from wastes is expensive and the materials are often contaminated, in the end run re-

EXHIBIT 7

WASTE MANAGEMENT:

SOUNDNESS[a] and METHODS[b]

Sound Management (10% of wastes)		Unsound Management (90% of wastes)	
Incineration	(6%)	Unlined surface impoundments	(48%)
Secure landfill	(2%)	Land disposal	(30%)
Recovered	(2%)	Uncontrolled incineration	(10%)
		Other	(2%)

MANAGEMENT METHOD	COST ($/MT)	RECEIVED (1000 MT)	% CHANGE 1981-1983	% CAPACITY UTILIZED
LANDFILL		1990	+1%	5%
Drum	$110-240			
Bulk	$ 33- 83			
LAND TREATMENT	$ 5- 24	331	+17%	22%
INCINERATION		94	+18%	79%
Clean, high-BTU liquids	$(-13)-53			
Other organic liquids	$ 53-237			
Solids, highly toxic liquids	$395-791			
CHEMICAL TREATMENT		661	-10%	44%
Acids, alkalis	$ 13- 92			
Cyanides, heavy metals, highly toxic wastes	$ 66-791			
RESOURCE RECOVERY	$ 66-264	60	+60%	32%
DEEP-WELL INJECTION		385	-19%	39%
Oily wastewater	$ 13- 32			
Toxic rinses	$132-264			

[a]Source: B. Feder, "The E.P.A. gets Tough on Waste," New York Times, Dec. 22, 1980.

[b]Sources: Samuel Epstein, Lester Brown, and Carl Pope, Hazardous Waste in America, San Francisco: Sierra Club Books, 1982, pp. 9, 549; Office of Technology Assessment, Technologies and Management Strategies for Hazardous Waste Control, Washington, D.C.: U.S. GPO, March 1983, pp. 15, 129, 130.

sulting in problems both in reuse and eventual disposal. Increased recycling of products containing chemicals -- such as rubber, ceramics, oils and greases, metals, solvents, and waste acids -- will probably cause impurities to build up, concentrating any toxic contaminants if the recycling process is not carefully monitored. Additionally, new cross-contamination problems could arise from mixing during recycling. (85)

Recycling of materials -- whether using potential wastes for feedstock or energy or recycling products within a single plant -- is inherently attractive and is expanding, but is limited by the capital investment in fixed process technology of most industries and by the large volume of waste. Monsanto, instead of landfilling hazardous dibasic acid, a by-product of pesticide manufacture, has made the dibasic acid available to utilities for use in sulfur scrubbers.[86] Estimates of maximum contribution of recovery and recycling together range around 20%.(87)

Microbial engineering is perhaps the most promising technology for the long-term future, expanding the use of sewage treatment strategies to include purposefully engineered mixtures of micro-organisms to break down toxic substances in wastes. Other biochemical techniques are also expected to increase. Some experts estimate that the application of enzyme technology in waste treatment may reach $200 million by 1987, a ten-fold increase over the 1982 market. (88)

New biological wastewater treatment systems conform to EPA's definition of best practical technology currently available (BPT). They provide effective control for most toxic pollutants, removing 95% of volatile toxic organic pollutants, 87% of base/neutral pollutants, and 77% of acids. This method of waste treatment will increase in use in coming years. (89)

While recovery and recycling will increase their portion of hazardous waste management, significant economic and technical barriers remain to both biological and physical technologies.

While containment and monitoring technologies are available for relatively safe landfill/treatment facilities, the problems for the coming years are in ensuring the use of the BPT, allocation of the costs of safe waste disposal and bringing the many existing disposal sites up to acceptable safety levels.

Management Patterns. In a 1982 survey of the chemical industry, the Chemical Manufacturers Association (CMA) asked the companies how their waste disposal methods had changed over recent years. (90) The results, shown in Exhibit 8, represent about 112 chemical companies with a little over half of total chemical industry sales and employment. While the survey did not investigate the volume of wastes treated by various methods, it did reveal the sharply increased attention to recycling. Also noteworthy were the decrease in storage and increase in incineration, especially on-site incineration.

EXHIBIT 8

CHANGES IN INDUSTRY WASTE DISPOSAL PROCEDURES

Waste Disposal Procedures	Frequency of Response			
	Recent Use of Disposal Methods			
	More	Same	Less	Method Not Used Recently
Recycled	74%	21%	0%	5%
Stored on-site	16%	24%	42%	18%
Stored off-site	4%	8%	30%	58%
Incinerated on-site	36%	11%	5%	48%
Incinerated off-site	43%	15%	12%	30%
Landfilled on-site	3%	13%	30%	54%
Landfilled off-site	39%	24%	30%	7%

Source: Peat, Marwick, Mitchell & Co., An Industry Survey of Chemical Company Activities to Reduce Unreasonable Risk, Final Report, February 11, 1983, p. 58.

Twenty-one companies cited examples of other recent methods of waste disposal. The most common cited example was deepwell injection. Eight companies reported using deepwell injection: three more, three the same, and two less. Five companies reported they are using more process changes to reduce wastes.

Other disposal methods which were cited as being used more are:

chemical destruction;	chemical fixation;
biological treatment;	sell for recovery or use;
biodegradation;	detoxification; and
neutralization;	pyrolysis.

Invisible Wastes. The management of toxic and hazardous wastes is already recognized as a key issue in chemicals production. Of less prominence but equal significance are compounds which are dispersed unnoticed throughout the environment rather than confined to specific sites. They are released through normal wear and tear of use, corrosion, accidents, and uncontrolled small-scale disposal (by industry and consumer), as well as waste site leakage. There is no accurate way of tracking these environmental pollutants. The net toxicity of the chemical load they place on the environment is unknown.

Much of the problem is invisible, with unregulated production of toxic and hazardous wastes by individuals, homes, municipalities, as well as illegal use of wastes as supplemental fuels. Another unknown is small-scale waste generators (producing less than one ton a month of anything), and they are currently exempted from regulation. Incineration can sometimes be classified as small waste generators by adding a heat exchanger. Additionally, wastes burned for fuel are often exempted and may add to the uncontrolled dispersal of toxic substances.

D. RISK MANAGEMENT

1. Industry and Risk Reduction. The 1982 CMA survey of the chemical industry, already cited, found that 88% of the companies responding had established chemical hazard assessment programs. These programs responded primarily to new products and processes (85% and 76%, respectively, of new products and processes were assessed). However, a majority (57%) of new formulations of

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* This section should be read in the context of Chapter 4, Section B, dealing with political, legal, and social issues such as liability and compensation.

existing products were also examined for hazard. (91) Routine hazard assessment of existing products occurred at a lower level, mostly in response to external demands or triggers. Exhibit 9, below, shows the response rate of chemical hazard assessment programs to these triggers.

EXHIBIT 9

INDUSTRY CHEMICAL HAZARD ASSESSMENT PROGRAMS

Hazard Assessment Trigger	Response Frequency*
Routine	41%
Process Change	73%
New Data	94%
New Product Use	63%
Employee Concern	81%
Consumer Concern	78%
New Regulatory Requirements	92%

*NOTE: The responses to this survey necessarily are a self-evaluation by the responding chemical companies.

Source: Peat, Marwick, Mitchell & Co., An Industry Survey of Chemical Company Activities to Reduce Unreasonable Risk, Final Report, February 11, 1983, p. 18.

Other events identified as triggering chemical hazard assessments on existing products were:

-- labeling and bulletin changes
-- product literature revisions
-- environmental incidents and concerns
-- Material Safety Data Sheets (MSDS) cyclical review
-- sales volume changes
-- raw material changes
-- employee protection
-- insurance company requests
-- consultant recommendations
-- unspecified audits.

Finally, the survey of 112 companies (92) (representing about half the chemical industry in terms of sales and employees), asked the companies to assess the status and changes in their toxicity testing programs. The survey defined toxicity testing to include animal, environmental, epidemiological, clinical, and toxicological testing. A synopsis of the results is shown in Exhibit 10.

The same CMA survey found that 78% of responding chemical companies had toxicity tests performed to evaluate the health or environmental effects of chemicals. The companies' assessment of their toxicity testing programs is shown in Exhibit 11.

A recent publication of the Centers for Disease Control summarized what is known about cancer attributed to occupational exposure to toxic substances, as shown in Exhibit 12.

A 1977 study by the National Institute for Occupational Safety and Health (NIOSH) had placed the chemical industry twelfth on the list of industries by hazards/exposure of workers to carcinogens. (93) It differed from still earlier studies that had ranked the chemical industry at the top of the list by factoring in the amount of worker exposure as well as the volume of carcinogens. The most hazardous industries were:

Industrial and scientific instruments
(solder, asbestos, thallium)

Fabricated metal products
(nickel, lead, solvents, chromic acids, asbestos)

Electrical equipment and supplies
(lead, mercury, solvents, chlorohydrocarbons, solders)

Machinery, except electrical
(cutting oils, quench oils, lube oils)

Transportation equipment
(polymers and plastics constituents such as formaldehyde, phenol, isocyanates, amines)

Petroleum and petroleum products
(benzene, naphthalene, polycyclic aromatics)

Leather products
(chrome salts, other organics used in tanning)

Pipeline transportation
(petroleum derivatives, metals used in welding)

EXHIBIT 10

INDUSTRY REPORTED CHANGES IN TESTING PROGRAMS: A CMA SURVEY

Most of the companies reporting organizational changes designated groups or individuals with environmental, health, and safety responsibilities. One company reported that it had set up its environmental, health, and safety group as an operating expense center with an annual budget. Another company established a toxicology department and another reported that it had moved toxicological responsibilities to to a more senior organization. The organizational changes reflect the increasing responsibilities and importance of environmental, health and safety functions.

New toxicity testing facilities or equipment were reported by seven companies. One of the companies indicated that it had constructed a multi-million dollar toxicity testing laboratory. Another company spent nearly one and a half million dollars on an addition to its lab for inhalation toxicological testing.

Increased staffing for toxicological testing was reported by 11 respondents. One company reported that it expanded its health staff from 5 to 60 professionals. Another company reported that its full-time staff devoted to assessing toxicological hazards increased from 4 to 25. A third company staffed a new lab with 39 employees.

New testing policies were instituted by 11 companies. The new policies covered new, existing and acquisition product testing; raw material testing; labeling; and government regulatory compliance.

Four companies reported that they test all new products. One of these companies reported that toxicity testing is "now part of new product development and is carried out at an early stage." Another company indicated that commercialization development costs include testing costs.

Three companies reported that they have procedures in place for testing existing products: two reported that they prioritize mature chemicals for testing and one reported that it conducts annual reviews to identify chemicals for testing and proposes annual chemical testing programs to each division.

Another company reported that it establishes the toxicity of all raw materials and examines products from acquisitions. Another company added intermediate and bulk chemical testing capabilities to test for safe environmental handling of these chemicals.

Many companies cited examples of improved testing practices.

- Good laboratory practices (GLPs). Companies reported that they now adhere to GLPs. Those previously following GLPs said that their GLPs are now "formalized," "better defined," or "strengthened."
- Protocols. Protocols are now "updated," "more complex," "formalized," more comprehensive," and "better defined." Several companies designed internal testing protocols and one company "gained facility in protocol selection."
- Quality control in testing. Examples of greater quality control in testing include auditing of testing, validation procedures for studies, review procedures for reports, quality assurance programs, and careful review of subcontracted work.

Many respondents also cited examples in increased numbers of tests as a major change in testing programs. Examples of tests which are conducted more often are:

- behavioral toxicology;
- chemical fate;
- chronic;
- chronic inhalation;
- corrosion;
- environmental toxicity;
- fertility;
- flash point;
- genetic;
- in vitro mutagenicity;
- metabolic;
- metals analysis;
- molecular toxicology;
- oncogenic;
- pharmacokinetic;
- reproductive;
- sub-chronic;
- teratology; and
- wildlife.

One respondent indicated that it tests more species, more animals per species, and more samples of internal organs. Another respondent said that its testing has "greatly expanded from previous years" to the point where it now is spending over $1.5 million on contracted and cooperative toxicity testing. Another company identified increasing regulatory requirements and concern for product liability as major reasons for conducting considerably more tests.

Closely related to the increase in numbers of tests is the conduct of more sophisticated tests. Testing state of the art has advanced markedly; many current tests such as the Ames and cell transformation tests were not known in 1969. Companies reported that their current testing programs:

- emphasize bio-medical aspects of testing;
- use a tier-test approach to assess the toxicological hazards of chemicals;
- emphasize chronic, sub-chronic, and reproductive testing as opposed to the earlier emphasis on simple acute testing;
- use greater scientific depth;
- emphasize long-term testing;
- apply a greater breadth of tests;
- use more extensive histopathology;
- use more analytical chemistry; and
- apply more sophisticated analytical characterization.

Improved recordkeeping and information collection was cited by a number of respondents as an example of testing program improvements. Most of the companies cited use of computers as their improvement in recordkeeping. Respondents use computers for data collection, storage and search.

The kinds of data computerized are:

- test documentation;
- medical health and environmental data;
- toxicity reports;
- industrial hygiene data; and
- material safety data.

Companies also cited examples of recordkeeping improvements which did not involve computers. These companies:

- established archives for all data;
- expanded MSDS coverage;
- use MSDS for all products; and
- established recordkeeping and reporting systems.

Source: Peat, Marwick, Mitchell, & Co., An Industry Survey of Chemical Company Activities to Reduce Unreasonable Risk, Final Report, February 11, 1983, pp. 23-26.

EXHIBIT 11

CHEMICAL INDUSTRY SURVEY
1981 TOXICITY TESTING PROGRAMS
MEAN AND TOTAL RESPONSES [a]

	Mean Response	Total Response
Equivalent full-time staff	14	1,178
Number of new substances/ products tested	22	1,856
Number of existing substances/ products tested	29	2,418
Total number tested [b]	53	4,421
Annual in-house expense	$1,184,000	$97,103,000
Annual contracted expense	380,000	31,170,000
Annual cooperative expense	123,000	10,309,000
Total expense [b]	$1,724,000	$137,953,000
Replacement value of toxicity testing facilities in 1981	$3,148,000	$255,028,000

[a] The 122 companies represented in this survey are a cross-section of the U.S. chemical industry. Together they represent over one-half the chemical industry by measures of sales and employment. The average 1981 sales of these companies was $773 million. Responses were adjusted to the percent attributable to U.S. chemical business.

[b] Totals do not sum exactly due to a limited number of partially completed questionnaires.

Source: Peat, Marwick, Mitchell, & Co., An Industry Survey of Chemical Company Activities to Reduce Unreasonable Risk, Final Report, February 11, 1983, p. 22.

EXHIBIT 12

SELECTED OCCUPATIONAL CANCERS

Although general agreement exists concerning the overall incidence of cancer, considerable controversy surrounds the proportion of cancer cases attributable to occupational exposures. Several characteristics of cancer contribute to the difficulty in making such estimates:

1. Latency in the development of cancer. Occupational cancer usually becomes evident long after initial exposure to the carcinogen; this interval may vary from 5 years to more than 40 years, making it difficult to characterize important exposures long past.
2. Influence of exposures to multiple carcinogens. Cancer victims may have been occupationally exposed to many carcinogens; interaction of these agents or interactions between them and other factors may greatly increase the risk of cancer.

ICD-9[†]	Condition	Industry/occupation	Agent
155	Hemangiosarcoma of the liver	Vinyl chloride polymerization *Industry vintners*	Vinyl chloride monomer *Arsenical pesticides*
160.0	Malignant neoplasm of nasal cavities	Woodworkers, cabinet/furniture makers Boot and shoe producers Radium chemists, processors, dial painters Nickel smelting and refining	Hardwood dusts Unknown Radium Nickel
161	Malignant neoplasm of larynx	Asbestos industries and utilizers	Asbestos
158, 163	Mesothelioma (peritoneum) (pleura)	Asbestos industries and utilizers	Asbestos
170	Malignant neoplasm of bone	Radium chemists, processors, dial painters	Radium
187.7	Malignant neoplasm of scrotum	Automatic lathe operators, metalworkers *Coke oven workers, petroleum refiners, tar distillers*	Mineral/cutting oils *Soots and tars, tar distillates*
188	Malignant neoplasm of bladder	Rubber and dye workers	Benzidine, alpha and beta naphthylamine, auramine, magenta, 4-aminobiphenyl, 4-nitrophenyl
189	Malignant neoplasm of kidney, other, and unspecified urinary organs	Coke oven workers	Coke oven emissions
204	Lymphoid leukemia, acute	Rubber industry Radiologists	Unknown Ionizing radiation
205	Myeloid leukemia, acute	Occupations with exposure to benzene Radiologists	Benzene Ionizing radiation
207.0	*Erythroleukemia*	*Occupations with exposure to benzene*	*Benzene*

[†]Modified International Classification of Diseases (ICD) rubric.

Source: Morbidity and Mortality Weekly Report 33 (9), "Leading Work-Related Diseases and Injuries - United States," March 9, 1984, p. 126.

While the study had many limitations -- no new data was collected, only proven carcinogens were considered -- the data used were the best available and indicated that the sum occupational hazard of the chemical industry is comparable to many others.

2. Genetic Screening. The chemical industry views itself as being caught between demands to protect workers and not to discriminate. (94) The discovery of better and more accurate markers for genetically-linked susceptibilities foreshadows the speedy expansion of industrial screening of present and potential employees to reduce their risk and company liability. (See Chapter 4, Section D, for a complementary discussion of this issue.)

At least a dozen major corporations, including Dow Chemical, General Motors, Monsanto, and Firestone Tire and Rubber, have excluded fertile women of childbearing age from certain jobs in order to protect the potential fetuses from harm. Known in industry parlance as protective exclusion, this policy has drawn criticism and lawsuits on the basis of unfair/unlawful discrimination. (95)

In October 1978, four women who had undergone voluntary sterilization in order to keep their jobs at an American Cyanamid's lead pigment plant sued the company. The women charged that their civil rights had been violated; American Cyanamid claimed that it would be liable for damages if the women in question gave birth to defective children, and that its interest was to protect the potential fetuses. Although American Cyanamid was in this instance found liable, the technology of genetic screening is advancing so rapidly that legal and policy disputes will balloon through the 1980's. (96)

Genetic screening is advocated as a way of protecting both the industry and the worker against undue risk. However, the information it makes available will increase the dilemma of determining adequate levels of protection for populations at different risk, protecting the rights of workers, and assigning responsibility for avoiding and mitigating environmental and occupational risks.

3. Security Issues: Sabotage and Terrorism. A worldwide increase in terrorism, sabotage, and related criminal activity is already drawing response from the chemical industry (see Exhibit 13 below). (97) Chemical manufacturing plants, as with energy generation plants or key transportation links, are attractive targets for terrorism or ransom demands; they may represent foreign control and intervention, or a hallmark of centralized industrial power, or the source of unfair labor practices or environmental contamination. Because of the potential for theft of toxic materials or of explosions releasing toxic materials, the reliability and coordination of industrial and governmental management of security will become relatively more important in the coming years.

EXHIBIT 13

Where the security money goes

(million dollars)	Purchased security* 1967	1980	1995
Protective services			
Guard & investigative	$535	$2,945	$12,200
Central station	115	700	2,800
Armored car	103	390	1,260
Total	753	4,035	16,260
Deterrent equipment			
Fixed security	92	415	1,680
Locking	191	750	2,385
Electronic access control	1	225	1,245
Lighting	87	300	1,475
Total	371	1,690	6,785
Monitoring & detection equipment			
Electronic alarm	57	505	2,370
Monitoring & surveillance	74	680	3,690
CCTV	18	140	775
Total	149	1,325	6,835
Fire control equipment			
Automatic sprinkler	19	75	335
Chemical fire extinguisher	95	325	1,245
Total	114	400	1,580
Total purchased security	$1,387	$7,450	$31,460

*By the private sector. Source: Predicasts.

Source: Chemicalweek, February 16, 1983, p. 38.

4. Insurance. Accompanying rising liability costs is a long-term trend towards higher insurance coverage and higher rates. Chemical companies in 1981 paid liability insurance premiums of about 0.2% of total revenues. This could increase by 200% in a very short time. (98) Liability arising from pollution is covered under two kinds of insurance policies: comprehensive general liability (CGL) and environmental impairment liability (EIL). Most CGL policies written in or since the 1970's include coverage of "sudden and accidental" pollution, such as spills, but do not cover "non-sudden and gradual" pollution, such as continuing dispersal, or cleaning up waste dumps. These are the main purpose of the newer EIL policies. CGL policies have been tested and their interpretation clarified by years of litigation and revision, but EIL policies are still "in an embryonic stage." (99)

EIL policies are generally written on a claims-made contract basis, meaning that they cover only claims filed while the contract is in effect, and not claims made later but related to pollution occurring during or before the policy period. They generally cover only gradual pollution, not sudden and accidental pollution. But some insurers and corporation risk managers are now arguing that both kinds of liabilities should be included to prevent insurers from arguing over which is responsible for a given claim. A few insurers, therefore, cover both sudden and non-sudden risks on EIL policies, and nearly all allow for a buy-back of such coverage from other insurers. Well-known EIL insurers set primary limits ranging from $5 million to $30 million for one occurrence, and from $6 million to $60 million for aggregate claims.

Nearly all EIL insurers cover claims for both bodily injury and property damage resulting from environmental impairment or pollution hazard, and some also cover liability for "impairment or diminution of any environmental right or amenity covered by law." However experts say they are uncertain how this will be interpreted or defined in practice. Most insurers formally define environmental impairment as "emission, discharge, dispersal, disposal, seepage, release, or escape of any liquid, solid, gaseous, or thermal irritant, contaminant, or pollutant into or upon land, the atmosphere, or any watercourse or body of water." Some extend this to include the "generation of odor, noises, vibrations, light, electricity, radiation, changes in temperature, or any other sensory phenomena." Some common, but not universal exclusions from EIL coverage are genetic damage, workman's compensation or work-related risks, nuclear risks, and results of willful acts.

There are great differences between EIL policies, also, on the coverage of sites. Of eleven primary insurers compared by Douglas McLeod in a recent issue of Business Insurance (100), nine do not cover the costs of cleaning up the policyholders' own sites; one will do so only if the clean-up is ordered by the government. All eleven cover the policyholder's liability for cleaning up the property of a third party, but the insurer must usually give prior consent to the cleanup. Some insurers will, and some will not, cover third-party liability associated with "pre-existing conditions" at dispersed dump sites targeted by Superfund, and the conditions for such coverage differ from insurer to insurer. Some policies give blanket coverage for all sites, but some will cover only sites specified in the policy.

Some insurers will not cover the cost of defending a policyholder against pollution lawsuits, or will issue another separate policy to cover these costs. All insurers require "risk assessment," but the nature of these assessments, and whether the costs are borne by the applicant or by the insurer differs from case to case. Nearly all of these points will be argued, tested, and probably standardized over the next few years.

The first effort by chemical waste generators to recover the money paid by them for a waste site cleanup under Superfund is a suit filed by Union Carbide against International Insurance Company on November 8, 1983, (IP-83-1419-C,S.D., Ind.), with a cross-claim against the owners and operators of the site. The complaint against the insurance company alleges that coverage was demanded and denied under an applicable policy and asks for reimbursement and declaratory relief as to future costs. (101)

The overall growth of insurance for "non-sudden" pollution is reported to have been below the industry's expectations, probably because of the recession. Underwriters are still uncertain of the risks they are assuming, and are conservative about the aggregate limits of the policies. Corporate risk managers may be reluctant to buy coverage that is expensive yet would not cover a catastrophic loss. Another reason for slow growth is that while the Resource Conservation and Recovery Act requires waste handlers to be insured or to qualify as self-insurers, there has been little enforcement of this provision until recently. (The responsibility for enforcement belongs to the states after they have an EPA-approved plan for regulation of hazardous waste disposal.)

However, some insurers now report that business has picked up considerably within the last six months, and will probably continue to grow. The general trend is expected to be toward higher premiums and higher deductibles, as experience on which to base rates is accumulated. The rising costs will have a disproportionate impact on small companies. (102)

The impact of product liability awards and accompanying insurance costs on chemical industry planning and finances is substantial. Normal product liability premium costs run about 0.5% to 1.0% of sales (with the lower rates for large policies). If, for example, Dow carried its liability insurance with a commercial company, this would mean premium costs of about $100 million on sales (1982) of a little over $10 billion. The number becomes significant when compared to Dow's 1982 operating profits of $356 million. To take an extreme case, the claims filed -- though not yet awarded -- against Johns Manville for asbestos-related illness are estimated by Manville to total about $4.9 billion, about five times the company's worth. Claims stemming from Love Canal and related disposal sites have been estimated at $10 billion. (103)

Chemical companies are beginning to feel the same pressures to which pharmaceutical companies have long been subject. The case of Merrell Dow illustrates the problems of a company producing direct consumer-use products as consumers become more aware of their extensive exposure to chemicals in day-to-day life.

> Merrell Dow Pharmaceuticals unexpectedly ceased production of the anti-morning sickness drug Bendectin in 1983, saying that the company expected to lose money on it due to insurance premium costs. The U.S. sales revenues from Bendectin were about $13 million; insurance premium totalled more than $10 million for this FDA-approved drug. When scientific studies on the health effects of Bendectin -- especially teratogenicity -- were inconclusive, the company was facing several hundred lawsuits. (104)

While such multibillion dollar liability claims are the exception rather than the rule, the unpredictability of such latent claims and the contribution of such chance factors as scientific discovery, accidents, and media and public activism, which might come from five to forty years in the future, make the concern a real one for chemical companies.

There is reported to be some decrease in oversight by third party insurers. (105) It is a standard practice of insurance companies to inspect the operations of large clients and to offer substantial discounts for safe practices. While most companies -- for their own benefit -- use a good deal of external quality control, self-insurance places the burden of quality control on the company itself.

Regulations requiring the carrying of insurance, as are in effect now under Subtitle C of RCRA, encourage safe waste management to fulfill the requirements of insurance companies. (106) The threat of higher premiums or loss of coverage for violation of standards set forth in insurance policies may, in the long run, be a more effective check on waste operations than possible EPA enforcement action.

CHAPTER 4

SOCIAL AND POLITICAL TRENDS AFFECTING PRODUCTION AND REGULATION OF CHEMICALS

Political behavior will be shaped by an age group characterized by political activism and environmental and health commitments, and by greater influence of women, minorities, and the elderly. Environmental interest groups are forming alliances with other interests, such as labor. General environmental concerns will become sharply focused on direct health impacts. International environmental and health issues may be significant in both diplomatic and trade affairs. State and local toxic risk legislation will increase greatly but the public will also demand greater Federal intervention. Two factors must be reconciled in further legislation and regulation: the growing consensus favoring more flexible cross-media control strategies, and possible reduction in agency discretion as Congress reacts to loss of the legislative veto. Major policy issues will include liability and victim compensation, public and labor right-to-know provisions, and genetic screening. Further public alarms appear highly likely, especially from groundwater contamination and hazardous transport accidents, and will further stimulate demand for greater control of all toxic materials.

A. LONG-RANGE SOCIETAL TRENDS

The social and political trends which will have a direct impact on chemical industries in the next decade must be seen in the context of longer range trends affecting society as a whole. An appreciation of this context provides the filter to use in identifying and assessing the likelihood and the significance of changes in political attitudes and in governmental response that will in turn influence industry decisions. These long-range trends include changes in:

-- the age and the ethnic characteristics of the population,

-- the makeup of the labor force,

-- the location of people and of industry,

-- levels of education

-- economic conditions, and

-- international factors in America's political environment.

Changes in demographic patterns -- the age structure of the population, where people live, where and how they work or play, their income and lifestyle -- will be a factor in the long run directly affecting the chemical industry. Such trends affect the kinds of chemicals that are produced and how they are used, how many people are exposed to what kind of risks, and the likelihood that they will accept a given level of risk. The acceptance of risk, and the propensity to demand governmental action to reduce risks, is generally considered to be related to age, education, affluence, ethnicity, and culture, in ways that are significant, although still little understood.

1. Demographic Trends

The population of this country will continue to grow for at least another fifty years. But it is growing slowly. There are no indications that the present low birth rate will rise significantly in the next few years. Even by 2030, if present trends continue, the population will be only 20% larger than today, and stable. Life expectancy is rising; it has increased about 3.5 years in the last decade (1), but further dramatic increases will depend on progress in conquering the diseases related to age and reducing environmental-related diseases.

The proportion of all Americans who are over 65 has risen from 4% in 1960 to 11.4% in 1980, and will continue to rise -- to 12% in 2000 and at least 22% in 2025. (2) A large majority of these will be women. This means that greater attention will be focused on environmental causes of disease and on environmental factors that contribute to the disabilities associated with aging.

The largest and fastest growing age group for the next decade will be those from 33 to 45 years old. This will have greater impact on social behavior and political-economic institutions than the increase in numbers of the elderly.

The 33-45 year olds are the baby boom generation. The attitudinal characteristics of this age cohort have included emphasis on physical fitness, demand for environmental protection, suspicion of large institutions, and political activism. Social psychologists believe that there is a strong tendency for sociopolitical attitudes formed in youth to persist in later life.

Legal and illegal immigration will be a major factor in population growth. Because recent immigrants, Hispanics, and American Blacks have higher birth rates than the rest of the population, racial and ethnic minorities will make up a larger percentage of the population in 1995; one in four Americans will be Black or Hispanic (3) compared to 18% in 1980.

The Southwest will be increasingly bicultural and bilingual. Already New Mexico is 37% and Texas 21% Hispanic. (4)

The ethnic minorities have generally not been environmental activists, but have had other political priorities. This may tend to moderate environmental activism in the Southwest where there are many chemical industry facilities.

Of people in the labor force who are between 25 and 30 now, 86% have finished high school and about 23% have finished college.(5) The educational level of the work force and the general population will continue to rise over the next decade. The number of production jobs has been declining for several decades and will decline further with the move toward programmable automation. There is a strong and growing movement toward greater job mobility, not only mid-career retraining and second or third careers during the working lifetime, but less deliberate and less welcome employment instability in which a person may be forced to move between jobs and from white-collar to blue-collar jobs or from production to service jobs.

By all criteria, the U.S. is post-industrial. Daniel Bell defined a post-industrial society as one in which:

-- services rather than goods-production is the dominant economic activity,

-- the professional and technical class constitute the pre-eminent occupational category,

-- theoretical knowledge is the central source of innovation and of policy formulation,

-- policy is oriented toward assessment and control of technology as a determinant of future directions, and

-- a new intellectual technology supports decision-making. (6)

The percentage of U.S. jobs directly related to collecting, storing, manipulating, disseminating, and using information is estimated to have been 8% in 1900, 18% in 1950, and 52% in 1980. (7)

While the proportion of the work force likely to be exposed to toxic chemicals in the workplace is declining, both work force mobility and increased access to, and familiarity with, technical and theoretical information will tend to widely disseminate concerns about hazardous conditions in the work force, and in the community at large. Organized interests, such as labor unions and environmental groups, are acquiring technical expertise and pooling resources to encourage research in support of their political efforts.

About 70% of women in their early 20's are now in the work force, and over half of women with children under six years old are working. (8) The labor force participation for men of all ages is about 77%. In 1995, it is projected that women will make up nearly half of the work force. The number of women in professional and managerial jobs will be considerably higher than at present, as indicated by the increased number of women completing professional, managerial, and scientific training and accumulating the necessary experience for middle and upper management.

These factors tend to strengthen concerns about toxic chemicals in the workplace and their reproductive and genetic effects; they also tend to increase the influence of women and their political priorities. The large number of dual income families indicates a continuing trend toward general affluence and high expectations, and will also contribute to increased independence among workers -- that is, less inclination to accept unsatisfactory working conditions.

In 1982, there were approximately 717,000 scientists and engineers in R&D in a U.S. labor force of approximately 112 million, or 64 per 10,000 workers. (9) This ratio, which is higher than any other country except the Soviet Union, decreased slowly from 1971-1979, but has resumed its long-term rise with the development of new science-based industries. In 1981, the last data available, Japan had a ratio of 55.6, compared to 62.4 for the U.S. and between 89.8 and 102.4 (differing estimates) for the U.S.S.R. This is yet another indication of increasing sophistication about scientific and technical issues in the work force and in the population at large. Industrial and government management of toxic substances will need to be appropriately defensible, interactive, and explicit.

Household formation has increased much faster than population in recent decades. (10) While this trend faltered during the recent recession, it is unlikely to be reversed. The number of households no longer closely reflects the number of traditional families. There are many single person households. Americans are marrying later, and less permanently; there is a trend toward delayed childbirth, and about 25% of women now in their twenties, based on their own expectations, probably will remain childless. Voluntary households of unrelated adults and cohabitating non-married couples are increasing in the fastest growing age groups. It is projected that non-standard households, those not made up of traditional nuclear families, will continue to increase from under 15% in 1960 to about 30% to 35% in 1995. (11) A rapid rate of household formation obviously expands the market for housing, household furnishings, etc.

Some regions of the United States, especially in the Rocky Mountain, southern, and western regions, will continue to grow faster than the country as a whole, although the Sunbelt migration is slowing. The pace of migration over the next decade will depend on the occurrence and impact of water shortages and rising costs of water, the further expansion of domestic energy and minerals development (which is likely within the decade), and the extent to which conditions in the growing Sunbelt areas come to approximate those from which the migrants fled -- rising land and housing costs, excess labor, rising taxes, congestion and pollution, etc.(12) Industrial migration has paralleled population migration, less because of the relocation of facilities than because of the different rates of start-up, closing, or expansion of businesses in growing vs. shrinking market areas.

A stronger demographic trend is the decentralization of people and industry -- growth in rural areas, non-metropolitan counties, and smaller cities, while larger cities and metropolitan areas are stable or shrinking. By 1995 the cumulative effects of this trend over two decades will be striking; a general deconcentration and a blurring of the distinctions between urban, suburban, and rural. (13) The long-range economic effects will be much less disparity in income between regions of the country and between urban and rural areas.

All these trends point toward a diffusion, sharing, and homogenization of political attitudes and behavior across the nation.

2. International Trends

While the general trend in the U.S. and in most advanced nations is toward slow growth and eventual decline in population, world population is growing rapidly, with most of the growth concentrated in the least developed nations. By the year 2000, world population will have increased from the present five billion to at least six billion. (14) Growing urbanization and industrialization in developing nations is increasing the strain on both renewable and non-renewable resources.

National economies are increasingly intermeshed and both resource supplies and markets are becoming more highly competitive. Developing nations are struggling to develop indigenous industries, ranging from steel, chemicals, and heavy manufacturing to electronics and consumer goods.

The threat of depletion of much of the world's "renewable resources" is more likely and more immediate than depletion of nonrenewable resources. Forests, grasslands, cultivated cropland, fisheries, wildlife, and fresh water supplies are being strained by population growth, urbanization, and industrialization. (15) Significant growth in world demand for U.S. agricultural commodities and timber is expected within the next two decades.

The environmental political movement, far from disappearing, is rapidly being internationalized. International labor coalitions and foreign labor organizations are exerting increased political influence to further their increasing emphasis on health and safety. Further, international tensions and international political pressures will be increasingly important factors in the domestic political environment. American-owned multinational corporations, including chemical companies, will find rising concern about the effects of toxic chemicals in other countries, as well as in the United States.

In summary, long-range demographic and social trends indicate that the importance of environmental and public health concerns in the larger social and political agenda is likely to grow rather than to diminish.

3. Economic Conditions

Specific economic projections for the next decade would be foolhardy, but some global and national trends can serve as general assumptions to underlie the political discussion. They are:

- Increasing interdependence of world markets and national economies and currencies, and intense competition for both raw materials and markets,
- higher prices for the necessary factors of production,
- strong incentives for increased utilization of domestic resources of energy and materials,
- expansion of agriculture with emphasis on export of food,
- new and rapidly expanding industries with a high scientific component, such as biotechnology,
- as a consequence, continuing competition for capital and generally high interest rates,

- as a further consequence of new high-tech industries and automation in older industries, a large and relatively intractable problem of unemployment,
- continuing growth in social welfare costs, because of the large number of elderly and unemployed,
- in spite of these problems, a gradual return to the long-range trend of increasing affluence and decreasing disparities in income across the population.

From 1945 to 1980 Americans became steadily more prosperous. Disposable personal income and median family income increased. The percentage of people below the poverty line slowly declined. (16) The disparity of incomes between Whites and Blacks was very slightly reduced. Disparities in income between geographical regions were sharply reduced. Disparities in income between urban and rural areas were also reduced, especially in the 1970's. (17) Home ownership, possession of durable goods, and other measures of economic well-being increased steadily. The "net worth" of the nation quadrupled.

As a result of inflation, the rising costs of energy, and the recession of the early 1980's, there has been some slippage in the last three years. There was a 5.5% decrease in real income in 1980 and more thereafter. The number of people below the poverty line increased, and Black family incomes slipped relative to that of White families.

Economic forecasts are at present highly uncertain and politicized. But the most prevalent expectations are that real income will eventually resume a rising trend, although at a slower rate of growth as real economic growth slows.

America is a solidly middle class country. Compared to other nations there is relatively little disparity in standards of living, education, social behavior and social attitudes across regions, across urban/rural communities, across ethnic groups, and even across socio-economic classes. The differences may appear large and in some cases troublesome because our political philosophy of pluralistic democracy seeks to give representation, balance, and visibility to competing demands and interests. In spite of this, our geographic and social mobility, highly integrated national economy, public education systems, and national communication systems tend to reduce differences and homogenize culture, and to make the population as a whole middle class in social and political expectations and behavior.

B. POLITICAL TRENDS 1984-1995

1. The Continuing Growth of an Environmental Coalition

Health, longevity, and physical fitness are a national avocation, almost an obsession. The general public is well aware of a link between health and the physical environment. This increases public support for environmental protection. This focus of national attention will grow because:

-- we have the affluence and standard of living that provides a margin for discretionary allocation of time and money to health and physical fitness;

-- the largest and most rapidly growing layer of the population will be in their 30's and 40's, with relatively high earning power, small families, and many dual-income households;

-- this age group was socialized (matured to a stage of political awareness) during the 1970's, a period of political activism, strong environmental concern, and high distrust of government and business institutions;

-- rapid advances in medical/biological sciences are constantly producing new information about the systematic health effects of environmental factors, expecially in areas of reproductive functioning, birth defects, neuromuscular and brain function, and the sources of cancer and heart disease;

-- awareness of slow development diseases such as asbestosis and some cancers related to environmental/occupational factors will increase as the number of old people increases, especially those whose work lives began in the 1940's -- the time of the chemical industrial revolution; and

-- we have a relatively well educated population, increasingly oriented toward information and increasingly exposed to knowledge about science, technology, and related policy issues.

Public support for environmental protection, public health and ecological concerns will remain strong, according to the evidence from opinion polls. A New York Times public opinion poll in September 1982 showed that 52% of those questioned believed that protecting the environment was so important that requirements and standards could not be too high, and improvements should continue regardless of their costs. This level of support is significant, especially considering that the economy was in the midst of recession and high unemployment, with administrative policies that emphasized deductions in the scope and extent of Federal regulation. (18)

The Issues Management Letter reported in April 1984 that "For months national data have been showing strong public concern over chemical contamination issues... (A)s much as 25% of local coverage (in newspapers) is regularly devoted to health and environmental problems, no region can avoid the national trend." (19)

Few environmental questions reflect class alignments. Instead, Americans have come to regard a clean environment as a "basic material value," according to researcher Everett Carll Ladd, in Public Opinion in March 1982. An increasing number of people believe that environmental protection laws/regulations have not gone far enough according to the Roper Organization Polls, 1973-1981. (20) See Exhibit 14.

A survey by J. F. Coates, Inc. (21) shows that the following areas are of major and growing concern to constituency groups ranging from business people and scientists to public interest groups:

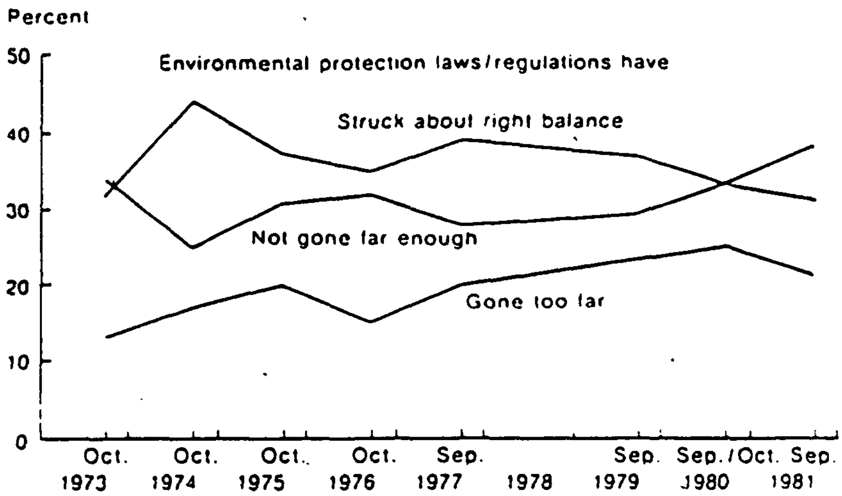
-- groundwater contamination,

-- toxic substances and hazardous wastes, and

-- chemical fertilizers and pesticides.

EXHIBIT 14

PUBLIC PERCEPTION OF ENVIRONMENTAL LAWS
AND REGULATIONS, 1973-1981



The question asked was "There are differing opinions about how far we've gone with environmental protection laws and regulations. At the present time, do you think environmental protection laws and regulations have gone too far, or not far enough, or have struck about the right balance?"

"Don't know/no answer" responses (not plotted) ranged between 10 and 21 percent.

Source: Roper Organization Polls, 1973-1981.

From: The Conservation Foundation, State of the Environment 1982, p. 425.

There has been a slight decrease in the number of Americans that consider themselves conservative, according to the April 1982 National Opinion Research Center poll. Of the registered voters in 1980, 46% of those under 30 and 22% of those over 50 identified themselves as Independent. This poll projects that in 1990, 60% of those under 30 and 45% of those over 50 will identify themselves as independents. Democrats and independents tend to be more in favor of environmental protection via regulation than are conservatives. (22)

Women have become increasingly active in political affairs and are thought to be especially favorable toward environmental and public health legislation.

While voting in local and national elections has been declining, other kinds of political activism have probably been growing. This may reflect a general re-orientation of political activity toward issues rather than toward candidates -- a depersonalization of politics, a determination on the part of individual citizens to influence decisions more specifically and directly instead of leaving them to elected representatives. One example of this trend is in the growth of ad hoc organizations formed to represent particular political viewpoints or organizational interests, the political action committee or PAC.

There were over 3300 PACs in the U.S. in 1983, a 16% increase over the previous year. Most of these PACs represent an industry or a special economic interest, although the number of PACs that are not connected to industry has grown over the last five years. Campaign and Congressional experts report that these groups will continue to be a dominant force in U.S. politics. Many of them are specifically intended to be a counterbalance to environmental and other public interest groups. (23)

Environmental Activism and Emerging Political Alliances

Conservation groups made their first big political impact in the 1982 election, led by the Sierra Club and Friends of the Earth. They actively and effectively campaigned for and against specific candidates. (24) The League of Conservation Voters, the oldest environmental political action committee, was formed in 1970. In the 1982 elections it spent over $1 million and mobilized hundreds of volunteers in 77 political campaigns.

There are 1,860 organizations actively involved with environmental concerns in the U.S. and Canada, including citizen groups, State and Federal agencies, and national and international commissions, according to the National Wildlife Federation's 1984 Conservation Directory. A decade earlier, the 1974 Directory identified only 700-800 environmental groups. (25)

The strength of these organizations lies in grass roots organization. They may be even more powerful over the next decade than they are now. Issues like toxic substances and hazardous wastes are so personal, so frightening to the average citizen, explained one environmentalist, that the issues drive themselves. (26)

As these networks, national and international, grow in number and strength, their influence and ability to mobilize public opinion and action will increase.

Environmental concerns are institutionalized in Federal and State bureaucracies, Congressional committees, and private sector institutions, e.g. organized interest groups, publications, specialized law firms, consulting firms, etc. These institutions, like all institutions, strive to perpetuate themselves by strengthening public support for environmental concerns. These interests are also buttressed by a complex legal framework, put in place in the 1970's and 1980's, that would be difficult to dismantle without great public support and Congressional action. (27)

Increasing cooperation and coordination among environmental organizations are giving them a new amount and range of influence. The ten leading environmental groups* had a combined 1983 budget of $94.9 million. (28) The leaders of these ten groups meet regularly to coordinate political and research strategies. The strengths and resources of each group can contribute to a combined front.

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*Environmental Defense Fund, Environmental Policy Institute, Izaak Walton League, National Audubon Society, Friends of the Earth, National Parks and Conservation Association, National Wildlife Federation, Natural Resources Defense Council, Sierra Club, Wilderness Society.

The Global Tomorrow Coalition was formed in 1979, sparked by the Global 2000 report. Based on a futures outlook and focusing on the interwoven issues of population, resource consumption, and environment, it incorporates influential U.S. business, religious, environmental, governmental, and scientific interests with many ties to equally influential leaders in other countries.

The Environmental Liaison Centre based in Kenya links 200 member organizations from 69 countries to environmental issues from a Third World perspective. It has ties to over 3,000 non-governmental organizations worldwide. (29)

The most politically potent alliance for the next decade may be that between labor and environmental interests. Recognition of shared goals and the power of cooperation brought together labor and environmental organizations in 1981 to form a loosely knit network. A June 1982 summit conference drew 115 representatives from both camps. (30) The network pools lobbying efforts at both State and Federal levels where their interests coincide. Much of its recent work has been on right-to-know legislation.

Many scientists have been active in the movement for environmental protection. But many scientists, and perhaps especially chemists, are closely tied professionally to large corporations, and their professional interests are targeted on the development of useful chemicals rather than on identification of their undesirable side effects or on their regulation and control. In 1965 the American Chemical Society (ACS) formed a Committee on Chemistry and Public Affairs, which adopted environmental improvement as an area particularly appropriate for its public service mandate. The ACS already had a strong interest in environmental problems centering in its Division of Water, Air, and Waste Chemistry. These two divisions of the society recruited a task force of member experts which produced, in 1969, a report entitled Cleaning Our Environment: The Chemical Basis for Action. The report highlighted several problem areas:

- *the primitive condition of fundamental knowledge about how* living things are affected by long-term, low-level exposure to pollutants,
- the even more primitive state of knowledge about the effects of pollutants on the ecology, and
- the need for better analytical chemical methods to monitor, control, and study the environment. (31)

The report included no less than 73 detailed recommendations about actions to improve "the air environment, the water environment, solid waste management, and pesticides in the environment." Recognizing that 73 recommendations was an unmanageable number, unlikely to get effective attention, the task force then went on to abstract from these 26 priority recommendations that appeared in A Supplement to the original report, published in 1971. Both the first and second sets of recommendations focused on the conventional categories of air pollution (especially motor vehicle exhausts and fossil fuel combustion), water pollution (especially eutrophication and waste water treatment sludge), and municipal refuse (especially junked automobiles). There was a great deal of attention to pesticides in the environment, which accounted for eight of the 26 priority recommendations. However, the American Chemical Society, in spite of the high concentration of industrial chemists in its membership, did not call attention to the problems associated with the manufacture, use, or disposal of other toxic chemicals and their presence in the environment.

2. Risk Management

Decisionmaking on toxic substances increasingly will be founded on institutionalized risk assessment. The evolving process of risk management--initial identification of potential hazard, the quantification of hazard and exposure analysis, assessment of the potential societal risk, and the application of this knowledge to policy--

is likely to be a key to foreseeing the effect of future public policy issues on chemical industries.

Risk assessment is especially important to regulatory agencies such as EPA, which must make policy decisions based on partial, tentative, and sometimes conflicting information, and across a wide range of qualitatively and quantitatively different hazards. As society becomes more aware of the risks posed by products, lifestyles, industries, and environment, they will increasingly demand more responsive government decisionmaking.

Interacting factors promoting the use of risk assessment include:

- The demand for answerability and openness of government policymaking; risk assessment creates a record of the data, methods, and priorities used in decisionmaking.
- The increasing sensitivity of Americans to lower levels of risk and more subtle forms of risk.
- Continuing demand for an improved lifestyle, to which health and security--freedom from imposed risk--are key contributors.
- Rise of autonomy and freedom of choice as political and social goals. These must be founded on explicit knowledge of the different options, including the risks of each.
- Improved technical capability to measure hazards; for example to detect and measure chemicals in air, water, soil, etc.; or to conduct extensive epidemiological studies in response to an observed or suspected hazard.
- Institutional experience in conducting and using risk assessment, which provides some indication of how to improve methodology and where risk assessment can most usefully be applied and updated.
- More complex and extensive computer technology, useful both directly in data handling in risk assessment and indirectly in gathering information and improving communication and expert and public participation in assessments.
- The increasing complexity of technological systems, which tends to make risks potentially more catastrophic while at the same time making them less obvious to the casual observer or the isolated expert. This increases the need for a more formalized, multidisciplinary approach to identifying and assessing risks.
- A lengthened horizon; individuals and industry are increasingly aware of the life cycle implications of a technology or process. They are concerned about risks to future generations, and risks from future use of disposal or shutdown of a current technology or process.

3. Federal Legislation

During the 1970's, public concern about the environment gave rise to a range of Federal and State legislation. But the pendulum of Congressional support for the environment swung repeatedly during this period. The environmental activism of Congress in the early 1970's gave way in the late 1970's to concerns about the effects of over-regulation.

A new generation of legislative initiatives has emerged in the last decade involving:

-- development of adequate information on the toxic effects of chemicals on human health and the environment;

-- development of information on the manner and degree to which humans and the environment may be exposed to hazards as a consequence of commerce in these chemicals;

-- notification by manufacturers to public officials of information on effects and exposure;

-- assessment of risks to human health and the environment;

-- control by suitable means of those risks perceived as unacceptable, including packaging and labeling to inform of hazard, as well as restrictions and bans, as appropriate.

The Toxic Substances Control Act of 1976 (P.L. 94-469) empowered the Federal government to control or stop the production and use of chemical substances that may present an unreasonable risk of injury to health or to the environment (Sec. 5). Manufacturers of all new chemicals and chemicals put to significant new uses must give EPA 90 days notice before manufacturing begins. Any chemical not on the inventory of existing chemicals is considered new. EPA can require testing of chemicals, whether new or already in production, only if the chemical meets all of the following criteria:

- there are grounds to conclude that it may present an unreasonable risk, <u>or</u> there may be substantial exposure,
- data for predicting health and environmental effects are inadequate, <u>and</u>

- testing is necessary to develop the data, which may relate to carcinogenic, mutagenic, teratogenic, behavioral, and synergistic effects and to persistance. (Sec.4)

EPA can regulate any aspect of the chemicals' use and can take immediate action if there is an imminent hazard. The agency can issue rules for specific chemicals requiring manufacturers and processors to report information about the chemical, production levels, projected exposure rates, etc.

TSCA established an Interagency Testing Committee (ITC) to prepare a list of chemicals recommended for priority consideration for testing. The list is to contain no more than 50 chemicals at any time; EPA must respond within 12 months either by proposing testing or declaring a rationale for not requiring testing. (Sec.4) During the first three years of implementation EPA did not respond to ITC's recommendations. In 1979 the Natural Resources Defense Council challenged EPA's lack of action in court, (NRDC vs. Costle, 14ERC 1858 (S.D.N.Y., 1980)) and the court ordered EPA to establish a schedule for clearing the backlog. EPA subsequently took action on a number of chemicals. In some cases, it negotiated agreements with manufacturers for voluntary testing.

TSCA also gave EPA authority to prohibit or limit the manufacture, processing, distribution, use, and disposal of old chemicals -- that is, those that were introduced before TSCA was passed -- if they are found to pose "an unreasonable risk." The controls that are possible range from total prohibition to labeling of contents. Regulatory limitations have been put on specific uses (or disposal) of a few chemicals including chlorofluorocarbons, asbestos, and dioxin. The difficulty is that there are about 55,000 chemicals in use, and for many of them, there are no aggregated data on manufacturers, volume, production, and sales and little information about uses, exposure, or potential effects.

Section 8 of TSCA is of particular interest because it concerns the information that manufacturers must collect or supply and this is related to the right to know issue (see Ch.4, Sec. B.). Sec. 8c and related EPA regulations require that records of adverse health and environmental reactions to chemicals be retained. Under Sec. 8d, EPA requires manufacturers, processors and distributors to submit lists of unpublished health and safety studies of which they are aware, relating to chemicals. Sec. 8e requires that EPA be informed immediately of any information or evidence that a chemical presents a substantial risk of injury to health or the environment. These sections of course supplement Sec. 4 which allows EPA to require testing.

A TSCA Improvement Amendments Bill was proposed by Congressmen Florio and Eckhart on November 3, 1983 (H.R. 4304). It would significantly strengthen TSCA in the following ways:

- The EPA Administrator would be required to promulgate a new rule mandating testing for all new chemicals requiring a Pre-Manufacturing Notice. (Sec.5)
- EPA must place a chemical on an "interim list," triggering the required filing of a PMN by all subsequent manufacturers and by the original manufacturer, if there is a change in use, exposure, or production. Substances would remain on the list until regulated or until data is submitted providing a reasonable basis to conclude regulation is not needed. (Sec.6)
- The procedure for designating a "significant new use" would be simplified: consideration of a change in only one factor (production volume, exposure) would be sufficient. (Sec.7)
- EPA could prohibit or restrict new chemicals solely on the basis of a determination that there is insufficient information to evaluate its effects, without a need to determine that there is unreasonable risk, or that it will be produced in substantial quantities (TSCA presently requires the last two findings). (Sec.8)
- EPA need not first consider using the authority of other environmental statutes before invoking TSCA. TSCA would have primary jurisdiction in appropriate cases and would therefore be equal in importance to other environmental statutes. (Sec.9)
- The grounds for withholding information as confidential would be significantly narrowed. (Sec.10)

- Penalties would be made more severe and opportunities for continual challenges after agency enforcement actions would be closed off. (Sec.11)
- EPA would be authorized to negotiate and then enforce voluntary testing agreements without losing the power to subsequently issue supplementary orders. (Sec.3)
- Substances created by genetic engineering would specifically fall under TSCA. (Sec.2)

Many critics think that TSCA -- or its implementation -- has been inadequate. Among the most controversial issues are:

- whether the reliance on negotiated test agreements meet the law's requirement that EPA respond to the Interagency Testing Committee recommendations within one year;
- whether PMN reviews are adequate, and whether manufacturers submit enough data for a judgment (the chemical industry generally favors a broad exemption for some classes of chemicals; others argue for establishment of broad categories of chemicals for which extensive data would be required);
- whether additional steps should be taken to bring the U.S. chemical review process into line with the requirements of its major trading partners, particularly OECD base requirements;
- whether public disclosure provisions are adequate; since most of the data submitted is declared confidential, critics say there is no opportunity for public oversight as TSCA was intended to provide;
- whether EPA has been too conservative in using Section 6 authority to control unreasonable risks; that is, has underestimated the risks of some chemicals;
- whether EPA has been overly reluctant to use its authority under Section 4(f) to assign regulatory priorities; for example, to designate formaldehyde as a priority chemical.

Proposals have been introduced into Congress to amend TSCA to address these issues.

A new factor in future environmental legislation will be Congressional reaction to loss of the option of a legislative veto, as a result of the Supreme Court's Chadha Decision (1983). Legislative vetos have not been widely used in environmental laws, but experts expect a general tightening up of all regulatory legislation and a reduction in the extensive amount of discretion that Congress has allowed regulatory agencies. (32)

In writing a legislative veto into a law, Congress delegates authority to the Executive Branch but reserves the right to disapprove and thus nullify specific actions or decisions based on the delegated authority.

A legislative veto seemed appropriate in regulatory legislation where scientific knowledge is necessary in devising feasible means of accomplishing Congressional objectives. Nearly two-thirds of the House voted in 1976 to apply the legislative veto to all regulatory legislation, but the measure did not win support in the Senate. Opponents, including many environmentalists, objected because the practice encourages regulatory agencies to negotiate regulatory provisions with Congressional committee staff, without the procedural safeguards and opportunities for public participation which apply to agency regulatory decisions.

The Supreme Court decision, which has no direct effect on TSCA, invalidated 207 specific veto provisions in 126 laws.

Congress is now trying to find some alternative procedure; a Constitutional amendment to salvage the legislative veto power is under consideration. In the meantime, several proposed amendments to TSCA are being rewritten as a result of the Supreme Court decision to either strengthen the law or to allow some exemptions. Experts at the Congressional Research Service and elsewhere say it is as yet impossible to evaluate either the probability of their passage or their potential impact.

The most notable recent action by Congress is the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (the Superfund). This has established a $1.6 billion fund financed by U.S. chemical producers, to clean up hazardous substance spills and inactive hazardous waste disposal sites. Congress is likely to deal in the near future with further questions of liability and compensation. This is undoubtedly the most important policy issue for chemical industries in the near future. It will be discussed in Section 8 below.

There is growing Congressional interest in governmental foresight with respect to the environment and public health. Two bills and a resolution were introduced in the 98th Congress involving establishment of a Critical Trends Analysis Office and an Interagency Council of Global Resources, Environment and Populations, and expressing a "sense of the Congress" in favor of action along the lines proposed in Global 2000. Another proposal may soon be introduced that recommends establishment of an office within the Census Bureau to coordinate Federal data collection and analysis related to global trends. (33)

Many of the attempts to reduce Federal regulation of industry are meeting strong opposition. Political interest groups, lacking an ear in the White House, are turning more to Congress for support. The courts are becoming more important in setting the regulatory agendas of Federal agencies. The extent and form of judicial review intended by Congress is increasingly being addressed in Congressional legislation, as discussed in Section 7.

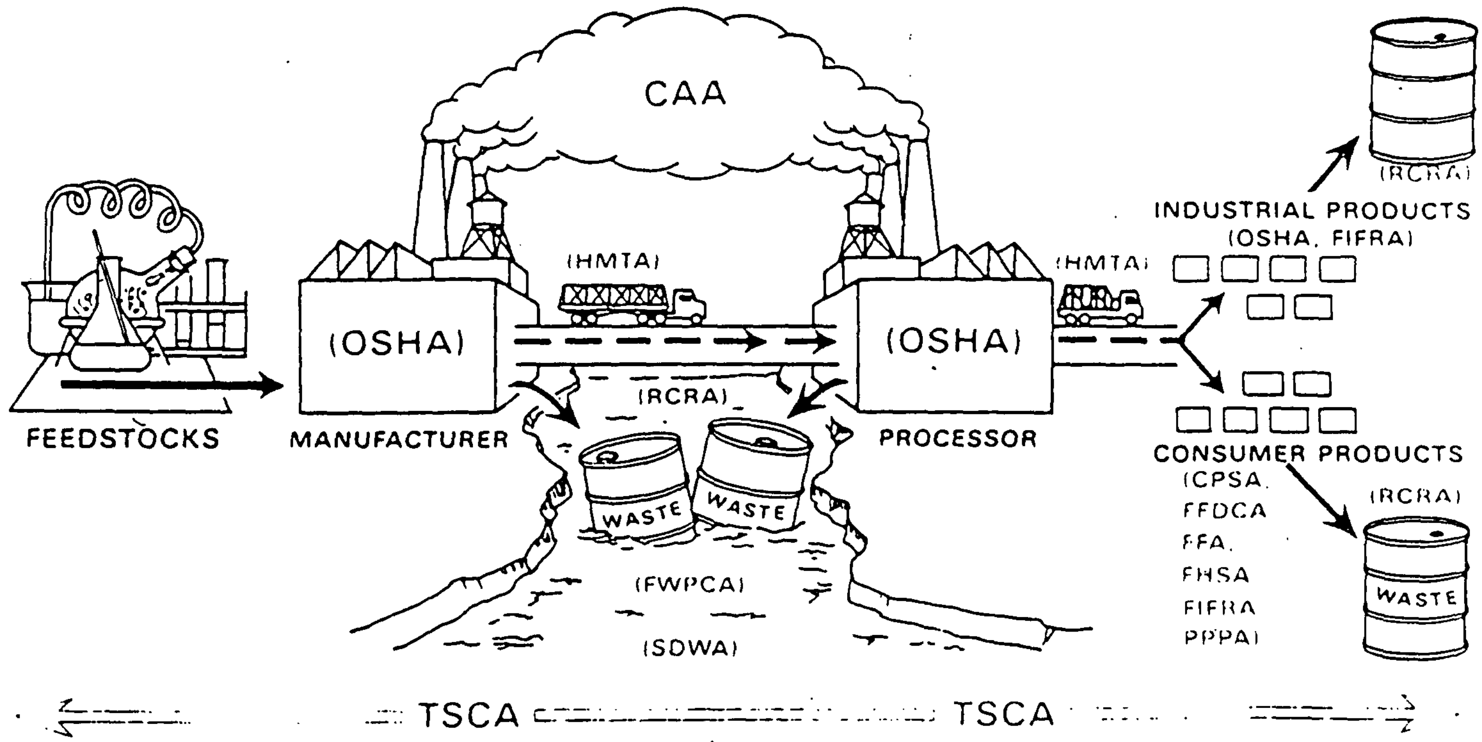
4. Federal Regulations

The responsibility for setting and enforcing regulatory guide-guidelines is a responsibility of the Executive Branch. Federal agencies interpret Congressional intent as expressed in laws setting the mandate of the agency. But they also reflect in their regulatory decisions the policies of the Administration. The legislative authorities affecting the life cycle of a chemical are identified in Exhibit 15.

The Resource Conservation and Recovery Act of 1976 (RCRA) governs the disposal of hazardous wastes from generation to disposal, providing for the tracking of wastes through a manifest sys-

EXHIBIT 15

LEGISLATIVE AUTHORITIES AFFECTING THE LIFE CYCLE OF A CHEMICAL



• KEY •

CAA	= CLEAN AIR ACT	HMTA	= HAZARDOUS MATERIALS TRANSPORTATION ACT
CPSA	= CONSUMER PRODUCT SAFETY ACT	OSHA	= OCCUPATIONAL SAFETY & HEALTH ACT
FFDCA	= FED. FOOD, DRUG, & COSMETIC ACT	PPPA	= POISON PREVENTION PACKAGING ACT
FFA	= FLAMMABLE FABRICS ACT	RCRA	= RESOURCE CONSERVATION & RECOVERY ACT
FHSA	= FED. HAZARDOUS SUBSTANCES ACT	SDWA	= SAFE DRINKING WATER ACT
FIFRA	= FED. INSECTICIDE, FUNGICIDE, & RODENTICIDE ACT	TSCA	= TOXIC SUBSTANCES CONTROL ACT
FWPCA	= FED. WATER POLLUTION CONTROL ACT		

Source: EPA Journal, July/August 1979.

tem and for approval and monitoring of disposal sites. Regulations under the Act went into effect in November 1980. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, more commonly called Superfund) was passed in 1979 and governs the cleanup of old disposal sites. Pesticides are regulated under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) first passed in 1948 and revised in 1972 and 1978. There are proposals under consideration to amend CERCLA (especially to change the tax structure under which the cleanup is funded) and to amend FIFRA (to strengthen the Act and to give EPA more authority to deal with pesticide emergencies, such as the discovery of EDB in many foods). In addition, chemicals in the environment are also regulated in various ways under provisions of the Consumer Products Safety Act, Food and Drug laws, and the Occupational Safety and Health Act, and others listed in Exhibit 15.

Within EPA, organizational structure reflects the fragmentation of the legal authority, with different offices responsible for carrying out TSCA, RCRA, CERCLA, and the older laws listed in Exhibit 15, while OSHA and CPSA, for example, are administered by entirely different agencies. The problems of coordination are constant and difficult, and in fact some observers say that there is very little coordination. The general public, on the other hand, tends not to recognize such distinctions and legal niceties so that any alarm over toxic or hazardous substances tends to add to the criticism of EPA because it is seen as the public watchdog.

The current Administration has called for more attention to balancing the costs and benefits of regulation, allowing the marketplace to function by lowering Federal intervention, and decentralizing government responsibilities through New Federalism. (34)

Between 1980 and 1983, there were declines in the number of pollution violation cases referred to government lawyers by EPA, in the number of Federal inspections of hazardous waste dumps, and in the number of hazardous waste dumps targeted for Superfund cleanup, but these are expected to rise in 1984 due to policies advocated by EPA's new administrator. (35)

New forms of indirect regulation are emerging. RCRA requires owners and operators of waste disposal sites to carry liability insurance. Insurance companies are raising their rates and developing new risk analysis techniques and inspection programs. (36) (See Chap.3, Sec.D) Self-regulatory initiatives such as the "bubble strategy" could become acceptable Federal regulatory measures with respect to chemical regulation.

The present Administration favors the return of responsibilities and regulatory control to the states, where feasible. However, the National Governors' Association says that most states are being forced to cut their budgets for environmental programs in proportion to the cuts in Federal assistance. (37)

While general environmental programs may be suffering reductions, there is a tremendous growth in the state regulation of pesticides and toxic substances.

Congressional intent to boost states' control over chemicals is illustrated by provisions in RCRA for State control of waste site selection, and by the proposed Harkin Amendment to the FIFRA, specifically allowing states to set stricter chemical regulations and requirements than those set by the Federal government. (38) Many states are passing legislation permitting cleanup of unsafe dump sites and recovery of costs from industry. As of May 1983, 31 states had laws involving cleanup and cost recovery. (39)

Recognition is growing within regulatory agencies, Congress, and attentive public interest groups that media-specific regulation, the primary thrust of regulatory strategy until now, cannot be fully successful. Further improvement of environmental quality, if pursued along the lines of concentration on clean air, clean water, waste management, etc., under separate pieces of legislation and varying strategies of achievement, will require extremely detailed and cumbersome standards and criteria and costly and elaborate systems of enforcement. In addition, this strategy has repeatedly resulted in transferring pollutants from one medium to another less regulated medium. Recent discussions among the several interested publics have appeared to point toward the development of more flexible, multi-media, holistic strategies which could allow both industry and the regulatory agencies more flexibility and discretion in achieving performance goals.

However, reaction to the loss of the legislative veto, already discussed, may push the Congress in a contrary direction toward reducing the discretion allowed to regulatory agencies. The ways in which this issue is resolved will affect the nature and rigidity of future controls over toxic materials.

5. The States and Toxic Chemicals

In April 1983, the President's Private Sector Survey on Cost Control (PPSSCC) reported that the Federal government, "could trim an estimated $465 million from EPA's budget over the next three years by handing over to the states a larger role in environmental regulation and reducing Federal support of state environmental programs." One of the specific recommendations was that the Resource Conservation and Recovery Act be amended to simplify EPA's job of issuing permits for treatment of hazardous wastes. (40)

State governments have mixed responses to such proposals at a time when state budgets are strained to the limits. Industry also tends to have mixed reactions. States, competing with each other to attract or hold industry and the employment and taxes that it generates, might be less rigorous than the Federal government pollution control. But for nation-wide companies, the diversity and uncertainty of dealing with 50 sources of varying environmental regulations and standards may outweigh any benefits they might gain. Environmentalists tend to point to the "administrative jungle" and "public health disaster" that they claim has resulted from state responsibility for control of the use of pesticides as a model of what could be expected if the states have primary responsibility for control of toxic substances. (41)

The Resource Conservation and Recovery Act of 1976 left to the states the responsibility for hazardous waste dump siting policies, with a 1985 deadline for developing comprehensive siting policies. In seven years, only 28 states adopted siting regulations. (42) These vary considerably. Most of the states have either vested final authority for siting decisions in an existing state agency or established a state-wide siting board with final authority for approving sites proposed by developers. But seven states will themselves identify acceptable sites and six states have delegated final decision-making authority to the local community or county in which the site is to be located. Some states are offering revenue sharing and other economic incentives to communities that will accept sites. Other states require developers to establish trust funds to cover any future clean-up costs. Twenty-two states have so far been unable to formulate regulations or policies to govern future hazardous waste disposal sites. (43)

Other aspects of toxic substances control are equally new and controversial areas for state governments, and some states have little expertise in these areas. In the last five to eight years there has been a decided increase in the involvement of state governments, especially state legislators, in various attempts to regulate toxic materials within their state.

State environmental legislation, as distinguished from laws pertaining to conservation, state lands, and natural resources, began in 1967, according to a recent study by the National Conference of State Legislators. (44) Between 1967 and 1975, 16 states added consolidated pollution control programs to their Health Departments, and 27 states created special environmental protection agencies or "superagencies" that combined pollution control programs and conservation and development programs. After 1975 when Oklahoma was the first state to adopt a comprehensive solid and hazardous waste management act, many states began to pass laws related to control of toxic or hazardous materials. The controls were chiefly of hazardous wastes dumping and disposal.

Between 1978 and 1983 the number of state laws relating to various aspects of control of toxic substances increased enormously. By the spring of 1983, about 500 such provisions were introduced. There are now at least 100 such pieces of legislation in 47 states and this number is projected to increase to 155 and possibly to 190. (See Exhibits 16 and 17.) According to the Conference of State Legislatures, the issues of most importance to state governments at the present are:

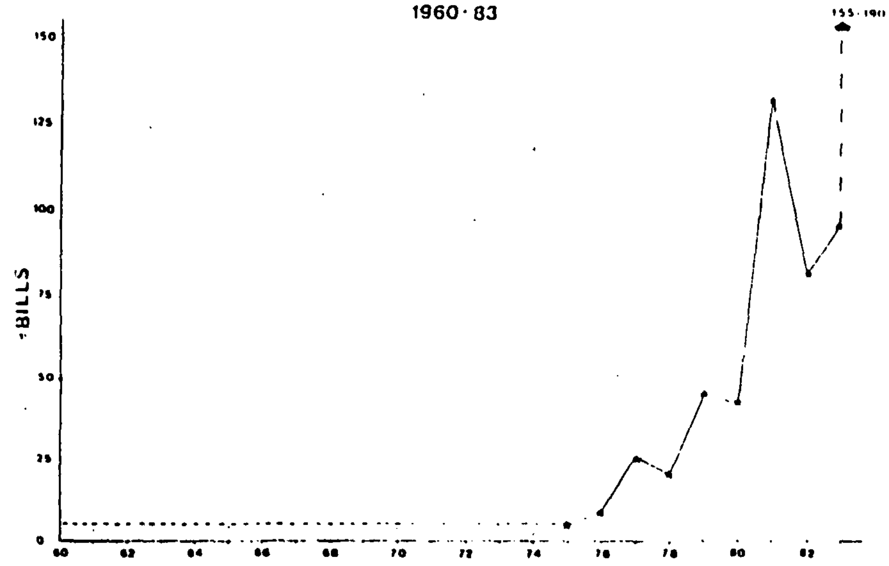
- --hazardous waste siting
- --hazardous waste transport
- --hazardous waste management
- --hazardous materials transport
- --toxics in the workplace
- --groundwater contamination
- --surface water contamination
- --chemical accidents and emergencies

The conference report noted however, that the level of awareness and understanding of toxic substance issues is still low among state legislators; they are dependent for information on the state executive branch and generally are unaware of requirements that states must implement some Federal laws in this area. "Legislatures find it difficult to get information of a technical nature in a format they can work with in making policy," the report noted, and "in many cases, information that would expedite legislative policymaking is simply not available from any source." (45)

In the 50 states, approximately 350 legislative committees possess review authority over various aspects of Federal laws pertaining to toxics. These responsibilities vary according to state constitutional and legislative structures and do not necessarily match or fit well with Federal provisions and authorities. There are 20 joint review or evaluation committees, 90 fiscal offices, and a plethora of other legislative committees, commissions, and support institutions that have some kind of review over state

EXHIBIT 16*

TOTAL TOXIC'S RELATED BILLS PASSED
1960-83

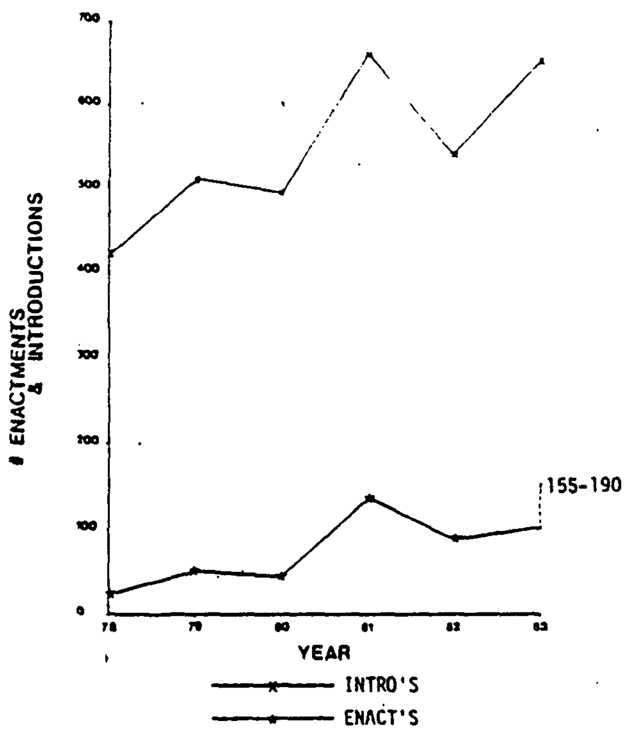


YEAR

Note: Dips in the line on alternative years reflect the fact that some State legislatures are not in session or have short dedicated sessions during those years.

EXHIBIT 17*

TOTALS: INTRODUCTIONS VS. BILLS ENACTED 1978-83



* Source: R. D. Speer, State Toxic Substances Legislation: Activities and Trends, prepared for The National Conference of State Legislatures, Denver, Colorado, and the U.S. EPA, Office of Toxics Integration, August 31, 1983, pp. 8, 19.

executive and legislative programs pertaining to toxic substance control. Most of these had no responsibility or authority related to toxic substances until the last few years. Executive branch interest in and awareness of the issues began earlier but there was no legislative or budgetary mandate for active programs. State legislatures, as indicated by the recent proliferation of bills passed or introduced in recent sessions, will be more active in toxics control in the future. But management and oversight at the state level is also becoming more diverse and fragmented, and given the tensions between executive and legislative actors in many state governments, this is likely to pose problems in itself for toxic control actions at the state level.

The most vigorous legislative action at the state level is now in tort-related law, that is, laws relating to injury or damage for which a civil action could be brought. This category includes labeling, right-to-know, confidential information provisions, and victim compensation and liability provisions. Labeling and worker right-to-know laws have been enacted in a number of states and the number is expected to increase. Many require the posting of a list of substances present at a worksite rather than specific labeling. They usually also contain provisions protecting confidential business information. The overall effect and effectiveness of such laws is unclear. The report of the National Conference of State Legislatures comments that, "States seem to be conducting a balancing act between protecting the worker and [protecting] business." (46)

About half of state liability provisions that have been recently introduced prescribe penalties for illegal waste disposal. The remainder are provisions merely recognizing liability for damage caused by hazardous materials or wastes. The Conference report notes that, "for the record...they state the obvious: if you cause harm, you are liable." Victim compensation and statutes of limitations relating to claims for compensation are, with regard to toxic substances or wastes, new areas of action for states and too new for their effects to have been felt. In the future, they may have significant impacts on interpretation of state tort law because, as noted by the Conference Report--

> "...evidence of exposure requires testimony from scientific and technical experts whose methods of determining exposure do not necessarily square with the requirements of evidence. Scientists and technicians...most often work within the limits of statistical interpretation when providing testimony in a claims case which is often viewed by the courts as inadequate for proof." (47)

A number of bills require reporting by an employer to appropriate State agencies. The Conference report provides no information about what data is to be reported, but notes that a few bills provide for specific information banks such as cancer registries which are presumably directed at providing information about the relationship of the working history of individuals with the incidence of cancer.

A few of the toxic-related bills introduced from 1980 to 1983 are appropriations for toxic clean up or for contingency planning or for special studies of problems related to toxic substances and hazardous wastes.

Recent legislative sessions have also seen the introduction of bills banning specific chemicals or classes of chemicals from landfills or even from hazardous waste disposal facilities. These bills generally respond to a particular incident or public alarm and are vigorously resisted by industry lobbyists, but are expected to increase.

Increased regulatory actions by states are generating new governmental and industrial concerns about hindrances to interstate commerce by prohibiting the movement of hazardous materials, especially wastes, across state or city borders, and the lack of standardization in regulations among states. Other concerns involve the problems faced by states in enforcing regulations and in their ability to finance monitoring and data collection programs, licensing requirements, and agency review processes.

6. Organized Crime

There is a widespread belief, and some evidence, that organized crime is deeply involved in the handling of hazardous and toxic wastes. Dr. Samuel Epstein, Lester O. Brown, and Carl Pope, in Hazardous Waste in America, published by the Sierra Club in 1982, describe and document the extent of illegal dumping of hazardous wastes, and comment:

> "Is organized crime behind the illegal dumping industry? No one knows for sure. Organized crime has been closely tied to the garbage-hauling industry, especially in the Northeast. It has been further suggested that some hazardous wastes operations are syndicate fronts." (48)

In spite of this circumspection, Epstein et al then quote several well-known law enforcement officials who are willing to say flatly that underworld figures have "gained control over substantial parts of the hazardous waste disposal industry through the establishment of 'front' organizations and the almost instantaneous replacement of companies caught illegally dumping with other phony operations." (49) They recount numerous incidents of investigations, indictments, and convictions, especially in New Jersey and Pennsylvania. The authors conclude that many reputable companies deal with illegal waste handlers by looking the other way. They suggest that the reasons are:

--the lack of adequate disposal facilities;

--the lack of adequate State regulation, and the failure of states to implement and aggressively enforce such regulations as do exist;

--the jurisdictional problems between states, and the lack of monitoring and reporting of industrial wastes leaving one state to be illegally dumped in another;

--the lack of aggressive Federal enforcement.

As to the last point, the Department of Justice brought over 60 actions against illegal dumpers between 1979 and late 1980. (50) The Sierra Club authors predict that, "the situation will further deteriorate over the next five years as the chemical industry attempts to dispose of not only the wastes they now generate but also the millions of tons being stored until new disposal facilities are available." (51)

7. Litigation

There is a trend toward greater reliance on the courts to regulate the chemical industry, to act as watchdog on Federal agencies' regulatory practices, and to adjudicate disputes. (52) Congress has used language in laws permitting judicial review of administrative rulings. For example, TSCA provides that within 60 days after promulgation of a rule, any person may file a petition for judicial review.

Increasing litigation lengthens the time before public and private decisions can be made final. There is also a trend toward increasing involvement of the courts in routine agency activities, demonstrated by the following recent examples. The courts first overturned and then sustained a January 1983 OSHA decision not to issue an emergency standard reducing workers' exposure limit to ethylene oxide, but ordered OSHA to expedite reconsideration of present standards. (53) The Supreme Court overturned the OSHA rule requiring extensive engineering changes in plants manufacturing benzene. (New rules were proposed in December 1983.) (54) The U.S. Court of Appeals overturned the Consumer Product Safety Commission's ban on the use of urea formaldehyde insulation. (55) In 1979, the court supported the joint CMA and National Resources Defense Council case forcing EPA to establish a schedule for addressing the Interagency Testing Committee's (ITC) recommendations for testing. (56)

There are three types of toxic torts: workers' compensation, product liability, and environmental harm (third party injury from hazardous substances and hazardous wastes in disposal sites). These issues are, however, hard to separate. Major recent liability suits include:

--The Johns Manville Corporation, which filed bankruptcy rather than face up to $2 billion in private liability suits involving asbestos exposure;

--The Superfund decision to spend $33 million to buy out Times Beach after the city was exposed to dioxin; (57)

--Allied Chemicals' expenditure of almost $20 million to settle kepone exposure cases out of court and to dismantle and dispose of the Hopewell, Virginia, chemical plant; (58)

--Evacuation of 263 families from Niagara Falls' Love Canal after 82 chemical compounds were identified in the water. Almost $27 million was appropriated by municipal, State and Federal agencies for temporary housing and cleanup. Over 900 notices of claims were filed against the local government, the Board of Education, and Hooker Chemical Company. (59)

8. The Developing Issues of Liability and Victim Compensation

Two recent legal studies examining questions of victim compensation are the 301e (Superfund) Study Group and the Environmental Law Institute report. (60) Both found inadequacies in present tort law remedies available to victims of hazardous waste insults. They structure the coming Congressional debate on liability and victim compensation according to two future avenues of relief: a no-fault administrative fund and access to the State courts.

Several torts are pending that may significantly alter the liabilities of government and industry. One tort involves Hooker Chemicals and Plastics' accidental mixture of the fire retardant polybrominated biphenyl (PBB) with cattle feed in Michigan in 1973, forcing the slaughter of thousands of cattle. Hooker has tentatively settled with the state of Michigan, agreeing to excavate contaminated soil, purify the groundwater, and guarantee a $2 million cleanup fund. (61)

Another victim compensation suit on behalf of 16,102 Vietnam veterans exposed to dioxin (a contaminant of the defoliant Agent Orange) has been filed against several chemical companies. Twenty-five community wells in Long Island are now closed due to contamination by trichloroethylene, a potential carcinogen, and more are expected to be closed in the near future. A suit is pending. Hundreds of women suffered toxic shock and some died following the use of tampons made with modified fibers. Dozens of product liability suits are pending. (62) Hundreds of thousands of people in World War II were exposed to the mineral asbestos while working in shipyards. Many workers have turned to the courts and product liability laws for relief.

Victim compensation rests upon proof of causation. However, definitively linking cause and effect is complicated by the complex etiology of most chronic diseases, including latency, mutiple targets/diseases, interaction of environmental factors, estimates of dose levels, misdiagnosis, individual variability, and disagreement among experts. (63)

TSCA addresses pre-manufacturing review of new chemicals and regulation of existing chemicals; RCRA addresses questions of victim compensation and final disposal of hazardous substances. Legislation recently introduced in Congress goes beyond these to address the health and environmental effects of chemicals and chemical-containing products during their normal use and market lifetime. Proposed as an amendment to TSCA, the legislation would increase the burden of liability of the manufacturer for adverse health effects arising anytime during the normal product life cycle. It would create direct access to Federal courts for complainants--a Federal cause of action. This legislation highlights two interacting trends: increasing sophistication about exposure not only from point-source waste deposits but also from nonpoint release and interaction of chemicals in the built environment, and an emphasis on a combination of regulation and increasing access to litigation to ensure the safety and health of the American public.

Because of the difficulty of definitively linking cause and effect, there is a trend in compensation mechanisms to combine limited compensation with a low threshold of proof. Whether, how, and when to compensate people for health damages caused by exposure to toxic substances, have raised broad legal and social questions. These diseases often have multiple causes and long latencies. It is often impossible to identify a single agent or manufacturer responsible for exposure leading to the disease.

Many environmentally related illnesses are clinically indistinguishable from disease of non-environmental origin or from the aging process. The best-studied example, asbestos-induced lung cancer, has a latency of 15-40 years and is so far indistinguishable from other lung cancers. Additionally, studies indicate that smoking and asbestos exposure combined have a multiplicative effect on the risk of lung cancer death. In the same fashion, certain organic phosphate pesticides and chlorinated hydrocarbons interact synergistically within the body, together generating ten times the health risk they would separately. The chlorinated hydrocarbons interfere with the action of cholinesterase in the liver, leaving nerve tissue especially susceptible to damage from the phosphates. (64)

There is continuing concern for and emphasis on the 'population at highest risk.' This population is the one most often represented in compensation and litigation and is the one that will drive the future of legislation and regulation. In the future, liability may be based on the risk contributed by an industry or product rather than on an individual's demonstrated symptomatic response to the product. Under this model of liability for potential rather than realized harm, a manufacturer would, for example, be liable for the claims of all women that had used a product later shown to be a teratogen, not just to the women who gave birth to congenitally defective children. The reasoning behind this approach is that many health problems such as leukemia or emphysema may not develop until long after the culprit exposure. Additionally, two or more factors of risk--say occupational exposure and particular water supply components--may together cause illness that would not be caused by one of the factors in isolation. This argument is being used by a group of citizens from Woburn, Massachusetts, who were exposed to high levels of trichloroethylene (TCE) and related known carcinogens in drinking water. Most of the 16 children who had contracted leukemia in Woburn since 1969 lived within a ten-block radius of two wells. The citizens of Woburn have filed suit, not only on behalf of the afflicted children, but for their own increased risk of later illness precipitated by this earlier statistically-measured exposure to TCE. (65)

If this risk recovery approach were to become established, it would have to be predicated on a universal scale linking overall risk associated with a level of exposure to a particular agent. The technical and political near-impossibility of developing any sort of comprehensive, universal scale, acceptable to all people and all interest groups, makes full realization of quantified risk recovery unlikely. However, the evolution of common law is likely to reflect the increasing concern of the public, not only for physically demonstrated illness, but for mental stress, imposed risk, and latent harm.

The pressure to place the burden of proof on scientific analysis of cause and effect is reflected in a victim compensation bill currently before Congress (H.R. 2582). This bill calls for EPA to establish a comprehensive "health effects documents" to definitively link exposure and etiology.

9. Environmental Mediation

Both regulatory decision-making procedures and court litigation cause affected parties and institutions to take strongly adversarial positions and make it difficult to achieve outcomes that are relatively acceptable, if not satisfactory, to all or most of the parties with conflicting interests and values. These procedures are also slow and costly. The concept of environmental conflict resolution or environmental mediation has developed within the last decade as an alternative to adversarial procedures and litigation.

The objective of environmental mediation is to create an opportunity for parties in conflict to cooperatively develop through direct negotiation new alternatives that can be accepted by all parties as meeting their most essential objectives. In regulatory decision-making situations, the ideal outcome is to have this negotiated, mutually agreed upon outcome embodied in official rules or regulations without the necessity for adversarial proceedings. When a neutral third party is called in to assist and facilitate the negotiations, the term "mediation" is used to describe the dispute resolution process. The term "regulatory negotiation" is used when a regulatory agency designates an official of the agency to join in the negotiations with the intent of publishing the outcome as a proposed rule, which will then move through normal rule-making procedures. (66)

Environmental mediation has been used successfully in many disputes, on a voluntary, case-by-case basis. The Conservation Foundation, for example, recently listed more than 40 cases in which environmental negotiation or mediation resulted in implementable agreements. (67) For example, officials of Montgomery County (Maryland) and local property owners negotiated, with the assistance of the Institute for Environmental Mediation, an agreement on siting of a solid waste landfill that was ratified by the county council in February 1983. Massachusetts, Virginia, Wisconsin, Montana, and Alaska have laws providing for negotiation and mediation in certain kinds of environmental disputes (68), and at least two states have adopted laws requiring mediation in the siting of hazardous waste dumps. (69) There are organizations offering environmental dispute resolution assistance in many other states. Bills have been introduced in Congress to establish a national regulatory negotiation council. (70)

This approach is likely to become more popular, but it has inherent limitations. Parties to an environmental dispute, or parties directly affected by rule-making, may have such large monetary stakes in the outcome or such an inflexible ideological position that they are unwilling to compromise, or they may fear that future positions in traditional forums will be weakened by an agreement to negotiate. There may be too many parties, with divergent or fragmented interests, to involve in a manageable negotiation. Some positions may be inherently non-negotiable. For example, while negotiation is faster, cheaper, and often fairer than the court system, both the chemical industry and interest groups are frequently unwilling to compromise on their positions. As a result, the courts will remain the favored alternative.

10. International Pressures

Proliferation of hazardous and toxic chemicals is a global problem. The appearance of DDT in Antarctica is an example of the necessity for cooperative, multinational action. Internal political factors often prevent countries from acting together on these problems. But there is growing pressure from environmental interest groups within nations and from international environmental organizations for cooperative action. The effectiveness of these groups in focusing worldwide public and political attention on chemicals in the environment will increase.

In 1979, the European Economic Community (EEC) adopted a directive (79/83/EEC) to upgrade procedures for testing, notification, and labeling of dangerous substances. (71) It specifies the type of data that must accompany a pre-market notification. (72) Although the directive itself has no power to delay or deny marketing of a chemical, EEC member nations are required by treaty to pass compatible legislation (within two years) to translate international agreement into enforceable domestic law.

Environmental groups are appearing in many developing and newly developed nations. There are also worldwide coalitions of nongovernmental organizations and programs concerned with hazardous chemical proliferation. Such international groups include:

- Consumer Interpol of the International Organization of Consumer Unions (IOCU):
- UNEP's Global Environmental Monitoring System (GEMS);
- The newly formed Pesticide Actions Network (PAN) International;
- The International Register of Potentially Toxic Chemicals (IRPTC) is operated by the United Nations Environment Programme (UNEP). IRPTC had national correspondents in 68 countries as of January 1980.
- An International Occupational Safety and Health Hazard Alert System is operated jointly by UNEP and the International Labor Organization (ILO).
- The ILO also tracks chemical hazards to workers on a regular basis.

- The International Agency for Research on Cancer (IARC), an independent body under the World Health Organization, reviews international data on the risk of cancer from chemicals to which humans may be exposed. (73, 74)

These organizations are concerned with:

-- improving the knowledge base on what constitutes a toxic or hazardous chemical, including systematizing testing and regulatory procedures among nations;

-- improving the monitoring of domestic use and international trade in these chemicals and international practices and trade in chemical wastes; and

-- improving the notification among nations when a chemical has been banned in one country or tests find that it poses adverse effects upon the environmental or public health.

Within Europe an Environmental Chemicals Documentation and Information Network (ECDIN) has been set up to provide reliable information on environmentally significant chemical products. It covers scientific data, production and trade, health, and regulatory information. (75)

The General Agreement on Tariffs and Trade (GATT), broadly geared to encourage free and equitable trade among nations, directly and significantly affects international trade and policy on toxic substances. GATT and its component agreements (particularly the 1979 Agreement on Technical Barriers to Trade, also known as the Standards Code) deals with national non-tariff barriers raised by differing product safety and health standards, exchange of information on standards, international dispute settlement, international alignment of national standards. It also encourages special assistance to developing nations to develop national standards and practices in lines with GATT. (76)

On a broader scale UNCTAD (the United Nations Conference on Trade and Development) has focused on providing developing countries with easier access to the markets of the developed countries through reductions in tariffs and nontariff trade barriers. The traditional UNCTAD view has been that developing country suppliers are disproportionately affected because of their more limited ability to comply with health and safety standards and other nontariff barriers.

Informal harmonization already marks much of regulation on environmental and specifically chemical issues. TSCA and the EEC Directive share major common features on inventory, notification, hazard assessment, and information. More formalized international harmonization has been discussed for many years, driven by a desire for:

- consistent world-wide protection of health and the environment,
- elimination of potential nontariff barriers to trade,
- stabilization of the regulatory environment for the chemical industry,
- reduction in spending on laboratories, testing, and regulatory experts now needed to satisfy the many different regulatory standards. (77)

Practical limitations on harmonization are set by the self-interests of nations in protecting their domestic industry through the use of tariff and nontariff barriers, by different priorities among nations with extremely different living standards and economic needs and consequently different levels of acceptable risk, attitudes towards cost-bearing for this reduction of environmental and health hazards, access to information by foreign governments, industry, and public interest groups vs. protection of proprietary rights. The conflict between supporters of the private right to confidentiality vs. the public right to full disclosure has been a continuing one within the U.S.; the same issue on a larger scale will be no less difficult to settle on an international level among nations.

11. U. S. Export Policy and Toxic Chemicals

Export from the United States of hazardous materials that are banned or restricted in this country is vigorously protested by international environmental and public health groups and by leading American environmentalists. Their ethical position is that the U.S. as the producing nation has a responsibility to the people of other nations, particularly those that may lack the expertise, the resources, or the responsive political system to protect the public health of their own population. But this is reinforced by perception of the risk of national embarrassment and increased international tension if there is a highly visible public health disaster that could be exploited by hostile nations or political factions. Moreover, exported toxic chemicals sometimes come home again in imported food and consumer goods.

The United States provides notification about hazardous exports to the governments of the importing nations under several Federal statutes, including TSCA. A much stronger set of controls, including a procedure that could be used in extreme cases by the Federal government to prevent the export of hazardous materials, was instituted by Executive Order 12264, January 15, 1981, but revoked a month later, when the new Administration began a review of the issue. That review has not yet been completed. (78)

The OECD is expected to approve an export notification policy (approved by OECD's Chemicals Group on Oct. 21, 1983) that calls for member nations to provide a one-time advisory notice to importing nations about hazardous substances that are regulated within the exporting nation. The United States is supporting this OECD action. (79)

Shifts in location of hazardous chemical production and waste disposal facilities to developing countries are also contributing to increasing international concerns over occupational health damage and general exposure to hazardous chemicals within these countries.

12. <u>Right to Know</u>

The conflict between a company's economic interest in keeping its product formulas proprietary and the desire of the worker and public to know the contents and formula of a product they are exposed to has flared into political and legal battles at the community, State, and Federal levels. Industry argues the need for trade secrets to maintain a competitive edge; the public argues its right to informed choice about lifestyle.

The 1978 amendments to FIFRA directed EPA to make safety and health test data available to the public; Monsanto has claimed that the disclosure demanded by EPA would make nearly $24 million worth of trade secrets available to competitors, and sued EPA accordingly in 1979. In April 1983, the court ruled in Monsanto's favor, and subsequently EPA instituted a revised registration process for pesticides. EPA has appealed the case to the Supreme Court, which should rule on it sometime in 1984. (80)

Trade secrets continue to be vital to industry innovation and success, due to the fast pace of competition and the weakness of patent protection once a formula is made public. However, the lasting trend is towards greater public and worker awareness and involvement.

Recent legislation has favored greater public disclosures, as in the 1978 amendment to FIFRA, but there has been little implementation of this. New right-to-know laws are likely, to support the interests of the worker and the community.

Fourteen states and two cities have passed stringent right-to-know or labeling laws. Another 12 states are considering similar labeling laws. (81)

The typical severity of state law and differences from state to state prompted the chemical industry to support the implementation of consistent OSHA-developed national standards on labeling.

On November 25, 1982, the Occupational Safety and Health Administration promulgated its Hazard Communication Final Rule (Fed.Reg.48, no.228, 53280-53348). It provides for the labeling and provision of a Materials Safety Data Sheet for every hazardous material used in the workplace, to show the identity and possible health effects of every hazardous component that comprises at least 1% of the material. Known carcinogens must be labeled if they comprise 0.1%, and any ingredient comprising less than 1% must be labeled if it could be hazardous at that concentration, or if there is evidence that permissible exposure limits might be exceeded in the workplace. The rule applies only to manufacturing, not to all workers who might be exposed to chemicals.

The manufacturer or importer may, to protect his economic well-being, use his own discretion in withholding the identity (although not the effects) of a chemical; there is provision for challenging this action. The rule provides an advisory (not mandatory) list of sources of data. But the manufacturer or importer may stipulate that no information is available about health effects.

The rule is less stringent than that proposed by the previous Administration in 1981. (82) The OSHA rule specifically preempts state laws, including those which are more stringent than the Federal rule. It is almost certain that the rule will be challenged in court on the grounds that the OSHA Act of 1970 was not intended to mean that state laws more stringent than Federal standards could be construed as in conflict with the Federal standard. (83)

The new OSHA rule and a series of other recent OSHA and EPA rules "ultimately should lessen employee and public exposure to dangerous chemicals," according to Timothy Atkeson of Steptoe & Johnson, Washington attorneys. "In the short run, though, they will substantially increase the product liability exposure of manufacturers and importers by providing potential plaintiffs with data on exposure, causation, injury, and possible negligence of management." (84) The EPA rules are those promulgated under TSCA, Sec. 8.

A coalition of environmental groups led by the Natural Resources Defense Council (NRDC) successfully negotiated the release of industry health and safety test data on 11 pesticides submitted under FIFRA requirements. But the release of the sensitive industry data, intended by NRDC for review by independent scientists, hinged on NRDC's guarantee to severely limit distribution of the data. (85)

The European Economic Community (EEC) in 1983 also adopted new labeling standards, increasing the disclosure required in European markets. (86)

The potential impact of accidental or intentional release of a chemical formula is especially great from foreign countries. In May 1982 the formula for Monsanto's herbicide Roundup, the best-selling herbicide around the globe, was accidentally released; Roundup provided $450 million and 40% of profits on sales, mostly from foreign countries. (87) Although Monsanto's successful suit required EPA to monitor U.S. patents for products based on the accidentally released Roundup information, the possible loss of revenue to foreign producers cannot be documented.

13. Computers and Telecommunications

A new source of communications and information available to the public appeared with the introduction and mass distribution of the microcomputer and with improvements in telecommunications.

Telematics technologies will have a significant influence on the right-to-know debate, weighting it in favor of enhanced public access and activism. While telematics does not necessarily open up access to proprietary industry information, it will provide generic changes in the management and availability of data. Sophisticated data base management, national networking, computerized recordkeeping and data processing, and the pervasiveness of computer skills and access will permit wide-ranging data to be compiled and correlated in new ways. Data that has previously been available yet isolated will be tapped for new knowledge about linkages with occupational and public health, environmental transport and impacts, and systems models.

In addition, the mass availability of cheap electronic systems is personalizing environmental, regulatory, and economic analysis and modeling. Vast amounts of data can be manipulated by individuals, organizations, and governments. As a result, governmental decisionmaking is increasingly complex, assessing the short- and long-term implications of their decisions on numerous factors. The public's ability to follow and participate in this process can be expected to increase in the future.

Computerized data base management has enabled the Audubon Society to organize an extensive, responsive national network of citizen activists. Over 50,000 of the 500,000 members of the Audubon Society are listed in a data base according to congressional districts. When relevant legislation comes up, activists in affected or key districts are automatically and quickly mobilized. (88)

14. The Media as Catalyst

The post-industrial society is characterized by an explosion of environmental and health-related information available to the public, through print, radio, and television. The media has been the major factor in public awareness and perceptions of chemicals in the environment, and in identifying emerging policy issues and "mustering the political and bureaucratic forces necessary to obtain legislation, appropriations, regulations, and new or expanded programs to address these problems." (89) Many Federal, State, and local initiatives are directly attributed to media coverage of environmental concerns and events.

But media coverage of chemical-related news is often unbalanced, capitalizing on the sensational aspects of health and environmental problems. Since Love Canal in 1978, the press has regularly provided the public with vivid, but often distorted, accounts of hazardous waste mismanagement.

According to the 1979 Directory of Environmental Periodicals, Vance Bibliographies, there then were 413 periodicals covering aspects of environmental pollution and control. This included 46 abstracting and indexing services, 195 journals, and 172 newsletters and bulletins. (90)

C. SOURCES OF INCREASED ALARM OVER TOXIC SUBSTANCES, 1984-1995

Sometime in the future, probably within the next five years, there are likely to be strong public and political demands for increased attention to existing chemicals -- those that have been produced and used in great volume for many years. Available information about these chemicals, their past and present producers, where they were produced, their health and environmental effects, and their present location, is sparse and dispersed. Some of the ways in which these demands may suddenly arise are suggested in this section. We have already identified long-range societal trends and shorter term political factors that point to sustained and increasing public support for environmental protection, and much sharper focus on direct health effects of toxic substances, and an internationalization of demands for their control.

Active demand for further governmental action to control toxic substances is likely to be episodic, and is most likely to arise as a result of specific highly publicized incidents. For example, three likely sources of such acute alarms are (a) the discovery of groundwater contamination with toxic chemicals threatening drinking water supplies, (b) one or more disasters related to transport of chemicals, and (c) discovery of widespread contamination from old, forgotten toxic wastes. The latter may sooner or later come about through the sudden release of toxic materials as a result of some natural disaster, or a technological failure such as the breaking of a dam containing polluted sediments. In each of these categories, the source of pollutants might well not be the chemical industries and might be many decades old, but the political effects would nevertheless severely impact the chemical industries because the public tends not to make such fine distinctions in demanding action.

1. Groundwater Contamination: An Inevitable Political Issue

Groundwater contamination is already becoming a matter of active public concern.

Well educated, science-oriented professionals -- scientists, engineers, teachers, editors, etc., are already highly conscious of the problem of groundwater contamination, as indicated by recent studies done for EPA. (91) In a series of workshops and surveys of participants in national meetings of several major professional societies, groundwater contamination was consistently picked as one of the half-dozen most important environmental problems of the next one to two decades. This concern will tend to become more widespread as it is reflected in the "popular science" and environmental literature.

Inevitably, further discoveries of contaminated groundwater resulting in the closing of wells and affecting the drinking water of large numbers of people, will occur and will result in a sudden focusing of attention, alarm, and demands for political action. The 1976 Resource Conservation and Recovery Act and the Toxic Substances Control Act thus could be merely the beginning of a series of attempts to protect groundwater.

About 95% of fresh water in the United States is stored in aquifers, with rivers, lakes, and other surface waters accounting for only about 4%. Between 40% and 50% of the population and 74% of U.S. cities depend on groundwater as a primary source of drinking water. (92) Western irrigation and livestock watering, which also require high quality water, also depend largely on groundwater. (See Exhibit 18.)

EXHIBIT 18

USE OF GROUNDWATER

	1950	1980
Total use of groundwater	34 bgd*	88.5 bgd
Public supplies	12%	13%
Proportion of irrigation	62%	68%
Proportion of industry use	18%	14%
Proportion of rural drinking water	8%	5%

Source: U.S. EPA, Proposed Ground Water Protection Strategy, Office of Drinking Water, 1980; unpublished data from U.S.G.S. Water Information Service reported in Veronica I. Pye, Groundwater Contamination in the United States," see footnote 95.

*billion gallons per day.

Contamination of groundwater does not necessarily or even primarily result from industrial waste. Municipal landfills, sewage, leaching from mining activities, agricultural runoff and irrigation water, animal wastes from feed lots, and highway runoff are major sources. Natural contamination -- leaching of radioactive materials and naturally occurring chemicals from the soil, and intrusion of seawater as a result of aquifer depletion -- is also important.

In 1980, EPA estimated that between 0.1% and 1.4% of aquifers were contaminated by industrial impoundments or landfills. (93) Lehr estimates as a worst case that such pollution affects between 0.2% and 2.0% of major groundwater deposits. (94) But these estimates are unrealistic. They are now recognized as far too low. They were based in part on regional assessments commissioned by EPA in the 1970's. Three of the eight assessments commissioned were never completed. At the time the regional assessments were done, sampling for organic chemicals was rarely undertaken, and pollution from natural causes and from agricultural practices was considered to be the major concern. (95) Aquifer contamination is difficult to detect and trace because of the long lag time between occurrence and detection, which usually comes only as pollutants show up in tests of wells, and because the dynamics of underground flow of water and transport of pollutants is very poorly understood. The assessments, therefore, almost certainly grossly understated the problems.

There has still been no comprehensive national survey of groundwater. EPA under the Safe Drinking Water Act requires all states to do an aquifer and injection well identification program, and some states have inventoried known cases of groundwater contamination. These inventory programs were not complete as of 1983; what data is available is being collected by the Environmental Assessment Council of The Academy of Natural Sciences and is reported in a paper prepared for The National Science Foundation in August 1983, by Veronica Pye. (96) See Exhibit 19.

EXHIBIT 19

REPORTED INCIDENTS OF GROUNDWATER CONTAMINATION

State	% of total water use from groundwater	No. of reported incidents	% of incidents threatening drinking water supplies	No. and percent incidents traced to industry waste		Major source of pollutants
Arizona	61%	23	100%	7	30%	Human/animal wastes, landfills
Connecticut	8.2%	64	59%	28	44%	Industrial wastes, petroleum products
Florida	18%	92	63%	32	35%	Saltwater intrusion, agriculture return, industrial waste
Idaho	31%	29	97%	7	24%	Human/animal wastes, industrial wastes
Illinois	8%	58	76%	12	21%	Human/animal wastes, landfills
Nebraska	68%	35	34%	0	0%	Irrigation, agriculture
New Jersey	60%	379	50%	152	40%	Industrial wastes, petroleum products
New Mexico	92%	105	83%	0	0%	Oil field brines (41%), human/animal wastes
South Carolina	23%	89	74%	28	31%	Petroleum products, industrial wastes

*As reviewed by Environmental Assessment Council, reported in Veronica I. Pye, "Groundwater Contamination in the United States," Workshop on Groundwater Resources and Contamination in the United States, Summary and Papers, National Science Foundation PRA Report 83-12, August 1983, Washington, D.C., March 14-15, 1983, pp. 36-41.

Human health can be affected by consumption of contaminated water or by consumption of fresh food irrigated by or processed with it. If the concentration of pollutants is high, skin and respiratory problems can result from showering or bathing. According to the Centers for Disease Control, reporting of disease due to water pollutants is poor and probably reflects only a fraction of cases. (97)

The EPA laboratory in Cincinnati has information on reported outbreaks of disease attributable to groundwater. (98) Between 1959 and 1980, 303 cases of illness were attributed to contamination with copper, selenium, fluoride, nitrate, arsenic, and sodium hydroxide, and 52 cases of illness (in six "outbreaks") due to toxic organic chemicals. These reported incidents do not include illnesses attributed to pathogens (bacteria, viruses, protozoa, worms, fungi) in groundwater, of which there were 31,425 cases, in 158 distinct outbreaks, from 1945 to 1980. Incidents suggestive of chronic public health effects due to contaminated groundwater have been cited for cancer, malformations, miscarriage, central nervous system disorders, and cardiovascular disease, but there are few controlled epidemiological investigations to confirm these reports. (99)

Recent authoritative assessments generally conclude that seriously degraded groundwater probably constitutes only a minor fraction of the total national groundwater supply. (100) But "of the 33 toxic organic chemicals most frequently found in groundwater, 31 have been reviewed for carcinogenicity. Two were found to be human carcinogens, 10 are confirmed animal carcinogens, but 15 have yet to be tested." (101) Carcinogenic and mutagenic effects are usually delayed and would probably not be traced to a specific environmental effect. But public concern about the relationship between environmental chemicals and such health effects is increasing, so that identification of toxic chemicals in water supplies will attract immediate attention and alarm.

2. Transport of Toxic Chemicals

Transport accidents that release toxic materials into the environment pose both acute dangers to public safety and health and long-term detrimental effects on surface and groundwater and ecological systems. (102) They also can force the evacuation of large numbers of people and impose heavy costs on local government. They have been of growing concern since the late 1960's.

The chemical manufacturers cooperatively established, in 1971, an organization called CHEMTREC, to respond to emergencies by providing information on chemicals released accidentally and by contacting the shipper, who is responsible for advising local authorities on how to handle the problem. CHEMTREC now has information on the chemical nature and characteristics of 60,000 commercial chemicals. (103)

The U.S. Department of Transportation has been collecting data on transport accidents involving hazardous materials since 1971. Hazardous materials include toxic, flammable, reactive, and corrosive materials, and the data provided in Exhibit 20 does not distinguish between these categories. A partial list of accidents involving toxic chemicals, which is merely illustrative and in no way comprehensive, is provided in Exhibit 21. Both exhibits indicate deaths, injuries, and in some cases evacuations resulting from the accidents. But toxic spills from accidents may also have long-range effects on human health through oral, dermal, and inhalation exposure and by contaminating surface water, groundwater, soil, crops, livestock, and wildlife. It is, however, likely to be incidents with multiple acute effects that provoke strong public and political reactions.

On the same day, February 26, 1978, vaporizing chlorine gas from a train derailment in Florida killed eight people and hospitalized 67; and an explosion of liquid propane gas being unloaded from a derailed railroad tank car in Tennessee killed 9 and injured 51. Even accidents that cause no acute injuries can be significant.

EXHIBIT 20

INCIDENTS BY MODE AND REPORTING YEAR

MODE	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	TOTAL
AIR	4	33	49	157	152	90	130	231	284	233	160	97	1,620
HWY(H)	1.562	3,558	5,048	7,251	8,988	10,223	13,000	15,983	15,355	14,042	7,441	5,274	107,725
HWY(P)	224	342	419	361	903	549	1,250	565	623	442	263	321	6,262
RAILWAY	343	333	409	616	676	982	1,500	1,191	1,215	1,327	1,131	830	10,553
WATER	11	9	12	26	32	13	50	47	34	42	7	9	292
FRT FRWDR	0	0	0	2	6	11	20	5	2	1	3	6	56
OTHER	121	53	66	15	12	21	0	0	11	28	58	3	388
TOTAL	2,265	4,328	6,003	8,428	10,769	11,889	15,950	18,022	17,524	16,115	9,063	6,540	126,896

DEATHS BY MODE AND REPORTING YEAR

MODE	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	TOTAL
AIR	0	0	0	4	0	0	0	0	0	0	0	0	4
HWY(H)	18	6	11	14	7	12	14	14	12	13	24	11	156
HWY(P)	5	6	7	4	20	4	17	6	6	4	3	1	83
RAILWAY	0	0	3	10	0	2	1	26	0	2	0	0	44
WATER	0	0	0	0	0	0	0	0	0	0	0	0	0
FRT FRWDR	0	0	0	0	0	0	0	0	0	0	0	0	0
OTHER	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	23	12	21	32	27	18	32	46	18	19	27	12	287

INJURIES BY MODE AND REPORTING YEAR

MODE	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	TOTAL
AIR	0	0	6	5	4	4	9	43	13	8	7	0	99
HWY(H)	122	192	297	243	395	568	447	536	608	425	368	76	4,277
HWY(P)	60	49	38	38	92	49	60	58	89	53	29	17	632
RAILWAY	21	53	152	596	96	198	233	482	228	129	221	36	2,445
WATER	48	0	3	17	2	1	0	10	1	1	0	1	84
FRT FRWDR	0	0	0	4	15	0	0	1	0	1	0	0	21
OTHER	2	0	13	0	51	0	0	0	2	2	18	0	88
TOTAL	253	294	509	903	655	820	749	1,130	941	619	643	130	7,646

DAMAGES BY MODE AND REPORTING YEAR (IN DOLLARS)

MODE	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	TOTAL
AIR	0	2,853	5,104	4,511,708	9,159	20,512	28,686	6,834	30,312	12,486	6,660	28,001	4,662,315
HWY(H)	3,118,508	3,587,379	2,604,163	3,849,176	3,028,405	3,617,548	4,272,106	7,440,533	5,372,736	4,343,739	9,656,923	8,640,420	59,531,636
HWY(P)	1,661,475	2,701,368	1,713,518	924,980	2,574,211	2,057,017	4,356,545	3,819,373	3,552,533	2,979,889	3,016,558	2,719,137	32,076,604
RAILWAY	1,491,745	1,549,355	3,021,685	11,965,143	1,481,995	2,294,633	7,815,243	6,848,364	5,781,500	2,834,030	2,652,827	4,068,195	51,804,715
WATER	201,052	1,252,096	8,009	20,117	6,331	5,270	18,258	17,912	30,364	507,427	53,045	30,000	2,149,881
FRT FRWDR	0	0	0	0	3,345	405	351	160	0	100	6,500	35	10,896
OTHER	136,005	223,925	14,439	13,035	182	3,788	9,700	0	5,100	29,365	69,108	200	504,847
TOTAL	6,608,785	9,316,976	7,366,918	21,284,159	7,103,628	7,999,173	16,500,889	18,133,176	14,772,545	10,707,036	15,461,621	15,485,988	150,740,894

Note: HWY(H) = Highway (For Hire), HWY(P) = Highway (Private), FRT FRWDR = Freight Forwarder

Source: Information Systems, Materials Transportation Bureau,

EXHIBIT 21

ACCIDENTS INVOLVING TOXIC CHEMICALS: REPRESENTATIVE INCIDENTS

February 4, 1978. Train derailment near Woodland Park, Mich. Leakage from tank car carrying ethylene oxide. Other tanks carrying a variety of intermediate chemicals were undamaged.
19 evacuated. ChemWeek, Feb. 15, 1978.

February 26, 1978. Train derailment near Youngstown, Fla., because of broken rail. Chlorine gas vaporized, 1:30 a.m.
8 killed, 67 hospitalized, 2,500 evacuated for two days.
New York Times, Feb. 27, 1978, p. 78.

February 26, 1978. Derailed tank cars of liquid propane gas, being unloaded near Waverly, Tenn., exploded. A second 20,000-gal. car was unloaded successfully.
9 dead, 51 injured, 14 buildings destroyed, 1,500 evacuated.
New York Times, Feb. 27, 1983.

December 15, 1978. Tanker semitrailer struck by locomotive at grade crossing near Boute, La. Tanker contained 7,500 gal. of liquified anhydrous ammonia. Estimated more than 18 tons vaporized.
3 killed by inhalation. C&EN, June 23, 1980, pp. 46-49.

May 8, 1979. Train derailment near Crestview, Fla. Propulsive venting and fire involving anhydrous ammonia, acetone, methanol, chlorine, phenol, carbon tetrachloride, sulfur, urea.
1 injured. C&EN, June 23, 1979, pp. 46-49.

October 29, 1979. Bottom fell from truck on Interstate 80 near Sacramento, Cal. Cargo of unnamed hazardous chemical spilled.
42,000 evacuated. Washington Star, Oct. 29, 1979.

November 8, 1979. Train derailment near Inwood, Ind. Eight breached tank cars, containing acetic anhydride, butyl methacrylate, ethyl chloride, ethylene oxide, isobutyl alcohol, methacrylic acid, propylene, naphtha, propylene oxide, sodium hydroxide, vinyl chloride. "Many" complaints of respiratory effects and nausea, subsurface ground contamination.
C&EN, June 23, 1980, pp. 46-49.

November 11, 1979. 106-car train derailment near Mississauga, Ontario. 11 tank cars carrying liquid propane exploded, chlorine gas leaked; other tank cars carrying caustic soda, styrene, toluene were not damaged.
218,000 evacuated. Newsweek, Nov. 26, 1979, p. 70, and Nov. 24, 1980, pp. 20-23.

November 12, 1979. Train tank car derailment near Holland, Mich. No leak of contents, hydrogen fluoride.
1,000 evacuated as precaution.
C&EN, Nov. 19, 1979, p. 8.

April 5, 1980. Tank car containing 13,500 gal. phosphorus trichloride struck by locomotive in switching yard, Somerville, Mass. Fumes.
11 hospitalized, 422 treated and released, 7,000 evacuated, 8 square blocks of buildings closed.
New York Times, Apr. 5, 1980.

November 6, 1981. Tanker truck leaked at truck stop on Interstate 5 near Castaic, Cal. 2,000 gal. of propylene dichloride spilled.
8 hospitalized. New York Times, Nov. 6, 1981.

February 3, 1982. Truck hit median strip near Stroudsburg, Penn. 12 tons hydrogen chloride vaporized.
1,200 evacuated in 2 sq. mi. radius.
New York Times, Feb. 4, 1982.

August 5, 1982. Tank truck split, reason unknown, on Pennsylvania Turnpike near Norristown, Penn. 5,000 gal. of two chemicals used in plastics manufacture spilled, resulting in release of hydrochloric acid.
1,500 evacuated. New York Times, Aug. 5, 1982.

August 19, 1982. Truck damaged by pre-existing corrosion, spilled 5,000 gal. of hydrochloric acid on Jersey Turnpike near Elizabeth.
32 overcome by fumes, 20 treated, 5 hospitalized.
New York Times, Aug. 19, 1982.

September 30, 1982. Derailment of 43 chemical tank cars near Livingston, La. Hydrogen chloride, sodium, vinyl chloride. Fire and explosion.
3,300 evacuated, ground and water contamination over ½-mi. radius.
New York Times, Sept. 30, 1982.

January 12, 1983. Tank truck collided with disabled tractor-trailer on I-81 near Watertown, N.J., spilling 3,700 gal. of toluene di-isocynate.
3 treated, 200 evacuated from homes, 300 from hotels, closure for one day of two shopping plazas, school, rehabilitation center.
New York Times, Jan. 12, 1983, p. 33.

April 3, 1983. Ruptured railroad tankers near downtown Denver. Spill of 18,000 gal. nitric acid.
5,000 evacuated for 8 hours.
Washington Post, Apr. 4, 1983.

In January 1983 a truck collision in Watertown, New Jersey, spilled 3700 gallons of toluene diisocyanate; only three people were treated for minor reactions, but 200 were evacuated from nearby homes, 300 were evacuated from two hotels, and two shopping plazas, a school, and a rehabilitation center were closed for two days.

In 1979 there were eight times as many toxic chemical transport accidents as in 1971, eight years earlier. During this eight years, CHEMTREC responded to 16,000 emergency calls, of which 13,500 involved transport accidents, 85% of which were rail or truck accidents. (104) The eight-fold increase is attributed to better reporting, to an 80% increase in shipments by volume, and possibly to further deterioration in railroad equipment and roadbeds. In 1979 there were 17,524 "unintended releases of materials," about 10% of which were extremely hazardous. (105) Two years earlier, in 1977, the Department of Transportation had estimated that one of every 23 railroad shipments contained hazardous material, and one of every ten truck shipments. Some reports now say that up to 15% of trucks on highways carry hazardous materials. (106) The majority of these shipments, however, involve petroleum rather than other toxic chemicals.

The number of hazardous transport accidents has declined yearly from 1980 to 1982, presumably because the economic recession reduced the volume of shipments.

In addition to CHEMTREC, which is run by the Chemical Manufacturers Association (and which will not give advice to local emergency teams on site, but will put them in touch with industry experts), there are at least six chemical industry mutual assistance organizations like CHLOREP (Chlorine Emergency Plan). These are organized around specific products or classes of products. When there is a transportation (or other) emergency involving these products, the nearest company belonging to the mutual assistance organization responds by sending a disaster management team to the spot. (107) Another group, the National Response Center, is funded by EPA and the U.S. Coast Guard and sends experts to the accident scene if needed. (108)

3. <u>Widespread Contamination from Disruption of Old Repositories of Toxics</u>

The recent incidents at Love Canal and Times Beach are undoubtedly going to be followed by similar incidents that gain nationwide publicity. Both of these incidents were fairly localized and the risks were contained. However, there are thousands of toxic waste depositories that could be disrupted by the effects of human engineering or natural disasters, and their contents widely dispersed by flood waters or other natural forces. The same is, of course, true of many small facilities actively processing or using toxic chemicals. Such occurrences have probably happened in the past without the toxic contaminants being discovered, identified, or publicized, but they may not escape notice in the future.

Toxic substances stored in the environment and subject to inadvertent release need not be the products of 20th Century chemical industries. The second half of the 19th Century was the period in which America became industrialized, and 19th Century manufacturing made plentiful use of arsenic, mercury, lead, cyanide, and other toxic materials that are enduring and do not necessarily lose their toxicity over time. Waste products from this widely dispersed, small- to medium-scale manufacturing were routinely heaped on site, poured into nearby water bodies (flowing water was assumed to cleanse itself quickly), or dumped into ravines or on unused land. (109) From time to time these old wastes come to light. A recent example occurred in North Woburn, Massachusetts, where over 100 years ago Merrimack Chemical Company began making chemicals for the textile industry. Merrimack expanded to become one of the largest producers of arsenic-based pesticides.

> In the summer of 1979, officials learned that there was an open pit, a dry lagoon, covering about an acre of land in which arsenic was piled in caked white powder several feet thick. So concentrated were the arsenic, lead, and other chemicals that a mere 45 pounds of the soil would (contain) enough to administer a lethal dosage to 100 adults.... To compound the problem the

> arsenic has been scattered widely by winds and rain and has contaminated a river watershed known as the Aberjona, which courses through Winchester on its way to the Atlantic Ocean. Nearby Mystic Lake may also be endangered. (110)

On February 21, 1981, the Boston Globe reported that the National Centers for Disease Control were examining infants in Hudson, New Hampshire, who had been exposed to high levels of arsenic found in at least 63 wells in the community. Nine other New Hampshire communities, and a few in Massachusetts, were also found to have high concentrations of arsenic (in concentrations of over 0.05 milligrams per liter). According to the Globe, the EPA had launched an investigation to "determine whether the arsenic is a natural component of the water or represents man-made pollution." Although the newspaper did not mention it, and EPA may not yet have realized it, it is quite possible that the arsenic in the New England wells is a residue from 19th Century industries.

Old and more recent accumulations of persistent toxic chemicals could thus be easily dispersed by the action of earthquakes, subsidence, storm surges, and floods, and thereby contaminate crop lands, potable water supplies, groundwater, and residential communities. Of particular concern is the accumulation of persistent toxic materials in sedimentary deposits in water bodies and behind dams. A literature search reveals that there is almost no systematic information or research on the chemical nature of sediments, which are almost certainly the current repository of two centuries of industrial by-products predating modern water pollution controls. (111)

Regular dredging and deposit of spoils on land is subject to some environmental controls, although it is not certain that the chemical contents of the deposits are generally anticipated or investigated. But the failure of hazardous dams or their emergency repair can release these wastes of twenty decades to be spread by flood waters over residential areas and farm lands and into ground and surface waters.

The Army Corps of Engineers, beginning in 1978, inspected 8,778 dams under Presidential order, following several disastrous dam failures the preceding year. Of these, 2,918 were judged unsafe and 132 required emergency repairs. (112) Over 1,582 of the dams inspected were built before 1900; these could hold polluted sediments from both 19th Century manufacturing and 20th Century chemical processing. Of these, 20% were unsafe. Many are owned by private companies, individuals, or small communities that cannot afford the high costs of repair or dismantling. The states are responsible for decisions about what must be done, but little action has been taken. (113)

4. Acid Precipitation

A pervasive and important environmental issue relevant to toxic substances is acid precipitation -- acid rain, fog, and snow. Acid rain has a direct effect on the release and transport of toxic substances, primarily heavy metals, altering the natural process of mineral leaching in soil. Experts are divided as to the relative contributions of acid rain, changing land use patterns, anthropogenic release, vegetative progression, and variations in soil composition to the leaching of metals from the soil. (114) Some recent statements by EPA scientists indicate that "proven damages" now amount to "only tens of millions" of dollars whereas control strategies could cost tens of billions. (115) Other experts think the damage is much higher. An August 1983 article in Science argued that local geological conditions may often dominate leaching, especially where the soil is naturally quite acidic, as in humus-rich soils. (116)

There is consensus, however, that for a complex combination of reasons, including the generation of sulfur dioxide by fossil fuel combustion, that the acidity of rain and surface water is increasing.

In addition to its broad effects on forests, buildings, and aquatic life, acid rain has specific effects on the leaching of toxic metals. This leaching of heavy metals, including aluminum, lead, mercury, nickel, zinc, cadmium, and manganese, has been linked to the death of plants, fish, and both aquatic and soil-based microorganisms. (117) These heavy metals are normally present in the soil primarily in nontoxic form, bound to insoluble organic complexes. (118) With the increase in soil acidity due to acid rain, however, and depending on the local composition of the soil, heavy metals are freed from these complexes into soluble, and toxic, form.

The most common toxic metal, and the most-studied one, is aluminum. Released and washed into the watershed by acid conditions, aluminum is deposited on the gills of fish as aluminum hydroxide, interfering with the uptake of oxygen and killing the fish. The dominant cause of death of fish in acid rain affected lakes is asphyxiation.

Aluminum is also toxic to plant life, damaging the roots and interfering with the uptake of liquids by the plant. This paves the way for invasion by bacteria, fungi, viruses, and other pathogens. The plant is finally killed by a combination of starvation, disease, and poisoning.

Aluminum and the heavy metals also damage soil microorganisms which decompose vegetation and recycle plant nutrients. As a result of acid rain, these microorganisms start to generate their own acids, adding to the acid burden on the soil. (119)

As yet scientifically unsubstantiated is the potential of acid rain to directly affect human health, primarily by contaminating drinking water through the leaching of metals into water supplies and in piping. Another unquantified threat is the concentration of heavy metals, especially mercury, through the food chain. (120)

Acid rain will exacerbate the chronic problem of pollution from stormwater runoff, the major non-point source of water pollution in urban areas. Stormwater runoff pollution comes from several sources, primarily,

- runoff from roadways and property in the city, discharged directly into local waterways,
- overburdening of the sewer systems, causing a sewer overflow into local streams.

The primary pollutants picked up and carried by urban stormwater are suspended solids and organic materials. The usually rapid increase in sedimentation and biochemical oxygen demand can harm aquatic life.

Runoff from urban paving also contains lead, cadmium, and other toxic substances, and constitutes a major polluter of soils, streams, and groundwater. The 30,000 miles of highways are deteriorating rapidly, accelerating leaching and creating a growing disposal problem. Much of paving was surfaced with asbestos mine tailings, and along with demolition of old buildings is likely to release asbestos fibers to the environment. In addition, buildings that were used for manufacturing, processing, and storage, especially before modern health and safety regulations, may contain residues of toxic substances. The corrosive effects of acid precipitation add to the potential for environmental dispersal of these toxic residues.

Future understanding of the contribution of acid rain to the dispersal of toxic substances in the environment, through corrosion of buildings, contamination of water, bioaccumulation, or leaching into the soil, will depend on the results of further scientific investigation as well as on the future of environmental control of sulfur dioxide and nitrous oxides release. However, acid rain is a politically significant environmental issue, of both international and interregional concern. Public acknowledgement of a close tie between acid rain and toxic metal contamination could exacerbate the issue even further.

D. A SUMMARY OF EMERGING, NEAR-TERM POLITICAL ISSUES AFFECTING THE CHEMICAL INDUSTRIES

The social, political, and environmental trends and events mentioned above will exacerbate some issues already on the public agenda and create new public policy challenges. Besides the general environmental issues already discussed, that is, demand for more rigorous control of toxic chemicals and the development of a flexible but effective all-media strategy for reducing pollution, some specific issues that will come to a head in the next two to five years should be reemphasized because they may have major impacts on the chemical industries.

One major issue will be the chemical industry's concern that trade secrets and confidential information be protected vs. the demand of public interest groups that the government make available information on:

-- the quality of health and safety testing information for chemicals;

-- chemical formulas of pesticides and other chemicals;

-- manufacturing process data, including intermediate chemicals present in the workplace;

-- analytical techniques used to obtain toxicology data; and

-- administrative proceedings involving chemical companies.

Official Federal policy is yet to be developed on interagency sharing of confidential chemical industry data.

A second major issue will be genetic screening. Some industry work environments contain carcinogens, embryo- and fetotoxins, skin and lung irritants, and other health hazards. Fear of worker compensation suits is leading some companies to screen workers for susceptibility to these conditions. This has already become a civil rights issue and a women's rights issue. The legality and social acceptability of screening workers according to fertility, genetic, or lifestyle criteria will become important political issues in the next decade. Whether screening discriminates against certain workers and whether it alleviates the industry's obligation to ensure a safe workplace will be of primary concern. The Congressional Office of Technology Assessment (121) identifies three issues that Congress faces on genetic screening. They are:

-- What actions could Congress take with respect to genetic testing in the workplace?

-- How could Congress regulate genetic testing in the workplace?

-- How could Congress foster the development and use of this technology?

Other policy issues to be resolved in the near future are:

-- How should the U.S. government react to hazardous and toxic substance problems that transcend national borders? What accountability should the U.S. have to other nations for chemical testing, monitoring exports, notifying other nations of chemical toxicity, or compensating victims of hazardous chemical exposure?

-- What responsibility does society have for compensating unwitting victims of hazardous chemicals? Which of several approaches are appropriate for victim compensation when no liable party can be found: Federal grants to states, Federal loan compensations programs, a pollution charge on manufacturers, or a fund maintained by potential polluters? Satisfactory solutions are still being sought. This issue will be of great importance to Congress, the public, industry, and government.

-- Who should have to prove the safety or hazard of a chemical? Will the trend toward placing this burden on the chemical companies place an undue economic burden upon them and also make them more susceptible to lawsuits?

-- How should the jurisdiction of agencies and courts be separated and clarified?

CHAPTER 5

FRONTIERS IN SCIENCE AND TECHNOLOGY

Scientific and technological advances are resolving old uncertainties about toxic substances and creating new policy questions. The ability to detect smaller amounts of chemicals is forcing us to deal with ever-lower levels of materials and their effects. As science links environmental conditions, chemicals, human genetics, and behavior, decisions about any single factor become questionable. Risk assessment will be a key to the interpretation of scientific data and social priorities regarding toxic substances. A particular issue will be setting acceptable levels of exposure in different environments for populations with different risks and different priorities. Understanding the synergism and antagonism of chemicals will become more important. Technological advances are occurring in analytical chemistry, toxicology, environmental transformation of chemicals, epidemiology, exposure analysis, and metabolic transformation.

Scientific and technological innovations in the generation and disposal of toxic substances are also altering regulatory needs. New products and wastes of particular concern include plastics, composites, telematics-based materials, ceramics, batteries, photovoltaics, and metals. Two generic technologies affecting toxic substances are biotechnology and telematics. The application of biotechnologies to chemical manufacture, to waste management, to environmental technologies, and to health therapy, has a potential for radical change. Telematics are directly changing both society and industry, through communication and information management, computer control of industry processes, chemical monitors, expert systems, structural modeling, and medical applications.

A. CHEMICALS, MAN, AND ENVIRONMENT: TESTING AND MONITORING TECHNOLOGIES

Three complementary factors have enhanced our ability to detect the effects of environmental factors and influences on people:

- major advances in chemical and physical analytical technology, including toxicology;
- a greatly improved ability to diagnose clinical abnormality at an early stage and assess individual susceptibilities; and
- the development of powerful methods of information collection, storage, and retrieval. (1)

1. Chemical Analysis, Toxicology and Risk Assessment

Central to the perception and regulation of toxic substances is the ability to identify, detect, and quantify chemicals in the environment and in man, and to assess both their toxicity and the factor of risk they pose to man and environment. Toxicity is an inherent characteristic of a chemical substance defining the adverse effect on an organism exposed at a given dose level (environmental toxicity broadly measures the effect of a substance on an ecosystem). The actual hazard posed by a chemical depends on the likelihood that a chemical will be present at a harmful exposure level. A chemical can have relatively high inherent toxicity but can be considered nonhazardous if actual exposure does not result in a dosage high enough to produce the toxic effect.

Toxicity is but one factor in determining the threat a substance presents to individuals, to society, and to the environment. Exposure can be estimated from production, use, and disposal information coupled with understanding of the chemistry of the substance, its environmental mobility, degradation and transformation products, metabolic uptake and breakdown. The risk to society from a substance factors in both its health hazard (including toxicity) and the level of exposure that can be expected both in numbers of people and volume of substance. Complicating these general susceptibilities are differing reactions to the same exposures and even dosages. Added on top of this, and perhaps most important of all, is the changing perception of risk -- reasonable and acceptable levels of individual and societal risk and relative acceptability of different sources and types of risk.

As measurement technology has advanced it has unveiled the pervasive low-level presence of possibly toxic substances throughout the environment and the human population. Unfortunately, understanding of the relationship between levels of exposure and levels of risk, especially in the critical region at our limits of detection, is not keeping pace with the technological capability to measure low levels of substances. This may be driving a reorientation of risk reduction away from the now unattainable goal of zero exposure, zero risk towards minimum exposure, acceptable risk. The difficulties of balancing the concerns of different sectors of society, different at-risk groups, and scientifically versus socially significant levels of risk is discussed in Chapter 4.B.2 on social trends in perception of hazard and risk.

Underlying the policy process are fundamental scientific and technological tools to investigate and describe a chemical substance and its life cycle interaction with the environment, chemical, physical, biological, and human. A comprehensive chemical analysis encompasses a host of skills and techniques: analytical chemistry, to identify and characterize a chemical; toxicity testing, to assess the inherent toxicity of a chemical; exposure analysis, to provide information about the expected use of and exposure to a substance; statistics and data processing skills, to translate laboratory and field data into information useful to policymaking; epidemiology, to acquire data on human populations to complement laboratory studies; and medicine and pharmacology, to understand the mechanism of action of a chemical.

One science to which these tools will be applied in the science of risk analysis and regulation is toxicology.

Toxicology may be applied to a single species, usually man, or the total environment.

Due to recent regulation, including TSCA, and heightened public and corporate awareness of the importance of toxicological analysis, demand is growing rapidly for better, faster, cheaper, more precise, and more accurate testing and monitoring. A parallel need is for sensible and efficient priority-setting for both research and regulation. New substances enter the market at rates estimated at from 200 to 1000 annually. (2) Estimates of the number of chemicals in commerce range from 55,000 to over 75,000, and many of these have not been tested, or only minimally so; tens of thousands have unknown production levels. (3) The Chemical Abstracts Service records over 5 million distinct known chemicals. (4) A National Academy of Science committee report on toxicity testing needs and priorities found in its study subsample that about 78% of chemicals in commerce (versus pesticides, cosmetics, drugs, and food additives) did not have even minimal toxicity information available. (5)

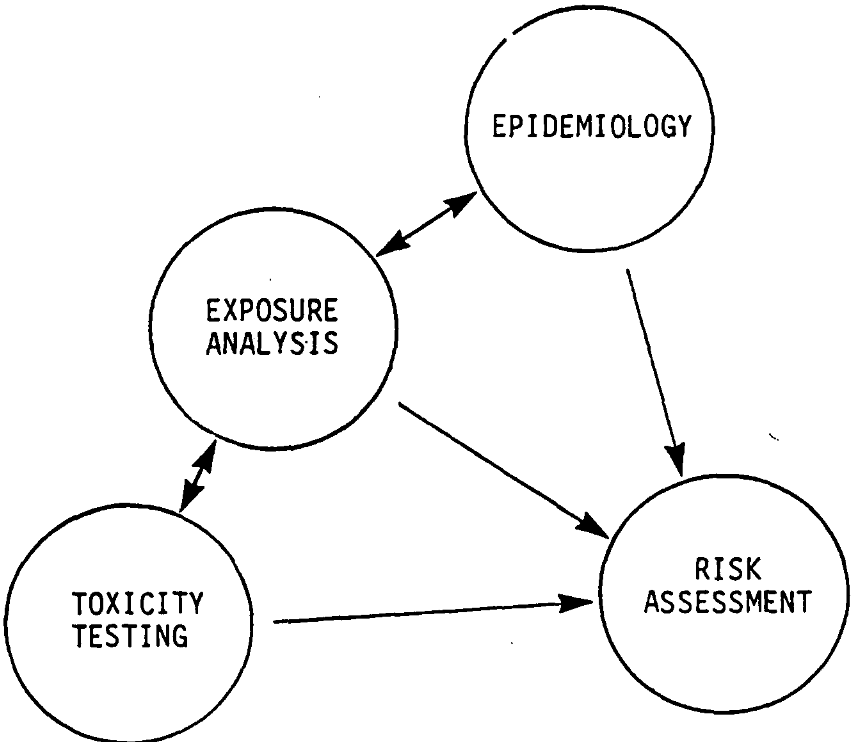
Current proposals to focus OTS' effort propose streamlining reporting requirements for classes of chemicals of consistently lowest priority, such as polymers, inorganics, and biologicals, or those no longer in production. This would be a further step in priority-setting to allocate testing, analysis, and decisionmaking resources. (6)

Priority setting issues and trends are discussed in Section B of this chapter; emerging trends in toxicology -- protocol standardization, new methodologies, computer modeling, and study of mixtures rather than isolated chemicals -- are discussed below.

Toxicological analysis, coupled with exposure analysis, epidemiology, and analytical chemistry, provides a comprehensive picture of the hazard of a chemical might pose as it moves through its life cycle. These analyses provide the foundation for risk analysis and regulation, shown schematically in Exhibit 22.

EXHIBIT 22

ANALYSIS OF TOXIC SUBSTANCES



Source: J.F. Coates, Inc., 1983

Comprehensive testing of a chemical for the purpose of analysis includes three main phases:

1. Analytical chemistry of a substance to determine its physical properties, stability, solubility, and chemical structure. This information is vital to exposure analysis, as it determines the most likely routes of exposure from the chemical standpoint.

2. Analysis of environmental transport, accumulation, and degradation, in air, water, soil, and biota. Again, this is key both to charting likely routes of exposure and to identifying natural detoxification pathways or unanticipated creation of secondary toxic products.

3. Toxicity testing to determine the inherent toxicity or the chemical, linked to a dose or exposure level. In this phase classic short-term and chronic toxicity tests are used. These tests also investigate such effects as carcinogenicity, mutagenicity, behavioral toxicity, neurotoxicity, teratogenicity, and ecotoxicity -- the adverse effect on biological systems in the the environment. The specific tests carried out under this rubric vary with the chemical, route of exposure, health priorities, and with advancing technology in testing regimes.

2. Analytical Chemistry: Pushing the Limits of Sensitivity

The first stage of evaluating a chemical's threat to society is analytical chemistry. Analytical chemistry techniques provide the tools for many other specialists -- in detection and monitoring of chemicals, in characterization, and in measuring the concentration and species of chemicals. (7)

The key trend in analytical chemistry is the increasing sensitivity and specificity of detection. We are approaching single-molecule detection. The other avenue of significant progress is computational and instrumental advances that make possible multidimensional chemical analysis, or "chemical fingerprints." (8)

Within ten years, sophisticated multi-species analyzers should enable chemists to identify the components of complex mixtures. The Food and Drug Administration uses an ICP (inductively coupled plasma) process which can scan for nearly all elements of the periodic table in a single sample. (9) This level of complexity is arriving more slowly with organic chemicals; since there are at least five million chemical entities identified, and minute differences between them in one sample may later be vital to assessing toxicity, the problem is vastly more difficult than with elements such as metals. However, the technology is now being developed to look for several organic compounds simultaneously. (10)

Pesticide chemists, who in their research must look at an entire family of compounds being applied to the land or water, have often led the way in developing techniques for looking at mixtures of organic compounds.

Telematics have revolutionized analytical chemistry; a computer can record and process and link data that would have taken 20 chemists to do ten years ago. However, the computer processing is still limited by detector technology, which is lagging. (11)

The accuracy of analytical chemistry in support of regulation is limited by the inaccuracies inherent in interlaboratory analytical variables and the limitations of reliability near highly sensitive detection levels. (12)

An evaluation by the Association of Official Analytical Chemists (AOAC) of the reproducibility of results from standardized and analytical procedures, revealed substantial disparity between labs.

The interlaboratory coefficient of variation obtained in collaborative studies increased with decreasing concentration of chemical as follows:

At 1000 ppm, 8% variation;
at 1 ppm, 16% variation; and
at 0.001 ppm (1 ppb), 60% variation. (13)

The Centers for Disease Control have set the acceptable safe level of human exposure to dioxin at 1 ppb. (14) The coefficient of variation within a single analytical chemistry laboratory was from 1/4 to 2/3 of that between laboratories. (15)

Some problems of analytical testing beyond measurement inaccuracy are "inadequate baseline data, mounting administrative costs, a projected shortage of analytical chemists, gaps in research, slowness of technology transfer, and adversarial relationships among organizations." (16)

A 1978 American Chemical Society report identified the overriding problem in toxicology to be an increasing gap between the exploding work load and the availability of qualified scientists and technicians. (17) Of special concern is striking the appropriate balance between satisfying the demand for increased testing and maintaining the quality and reliability of chemical analysis.

Two organizations that have been especially active in collaborative testing and verification are the American Society for Testing and Materials (ASTM) and the Association of Official Analytical Chemists (AOAC). The National Bureau of Standards has provided a vital function by developing and distributing Standard Reference Materials. (18) Communication, collaboration, oversight, and standardization will all be increasingly critical in the future to assure the continued quality of analytical chemistry and toxicology, and to ensure the use of the best possible technical foundation in regulatory decision making.

3. Toxicity Testing

The need for faster and cheaper toxicological regimes is pushing the state-of-the-art and could significantly enhance the availability and use of toxicological screening for the home and the Fortune 500 companies.

Standard bioassay techniques, using up to 800 animals for a single test, are often costly and time-consuming. One industry source estimated that comprehensive toxicity testing for a single potential product could cost $4 to $5 million. (16) A chart of effort for standard toxicity tests performed at Dow Chemical's Toxicology Research Laboratory is shown in Exhibit 23.

According to a 1983 Office of Technology Assessment study, only about half of pre-manufacturing notices (PMNs) report any toxicity data, although the percentage rises slightly (to about 60%) if polymers, generally accepted as non-toxic, are excluded. (20) The study found the most frequently reported information was acute oral toxicity (in 50% of PMNs for manufactured chemicals and in 43% of all PMNs). It also noted "mutagenicity tests, the only tests that bear on chronic toxicity, were reported on less than one-fifth (17%) of all PMNs." (21)

EXHIBIT 23

TOXICITY TEST EFFORT

TEST	MAN-MONTHS OF EFFORT
Acute Oral LD_{50} in Mammals	0.28
Inhalation LC_{50}	0.37
Eye Irritation	0.17
Skin Irritation	0.17
30-Day Feeding Study	3.7
90-Day Feeding Study	11.0
2-Year Feeding Study	50.9
30-Day Inhalation Study	7.0
90-Day Inhalation Study	16.8
2-Year Inhalation Study	109.5
Teratology	[illegible]
Reproduction	30.5
Mutagenesis Studies	23.7
Metabolism Studies	13.9

Source: Dow Chemical, Who Protects Our Health and Environment? 1980, p. 10

A National Research Council (NRC) study went a step further to investigate the quality of toxicity testing as measured against currently accepted reference protocols. Examining the design and results of 664 toxicity tests on a subsample of 100 substances representing pesticides, cosmetics, drugs, food additives, and chemicals in commerce, the NRC committee found

> "...only 8% of the tests in the subsample met the standards of the reference protocol guidelines and another 19% of the tests performed were judged to be adequate by the committee's standards....The quality of design, execution, and reporting of toxicity studies was not uniform among the various types of experiments....In general, chronic studies, inhalation studies, and more complex studies with specific end points (e.g., hemotoxicity, genetic toxicity, and effects on the conceptus) are most frequently needed." (22)

Exhibit 24 presents the NRC rating of test quality.

EXHIBIT 24

QUALITY RATINGS OF TOXICITY TESTS DONE ON 100 SUBSTANCES: A NATIONAL RESEARCH COUNCIL STUDY

	Subsample Category and Proportion of Tests with Indicated Rating (%) *					
	Pesticides and Inert Ingredients	Cosmetic Ingredients	Drugs and Excipients in Drug Formulations	Food Additives	Chemicals in Commerce	PROPORTION OF TESTS IN WHOLE SUBSAMPLE
Meets current guidelines	10	6	8	4	9	8
Adequate, but does not meet guidelines	22	20	19	10	20	19
Not adequate, but retesting not needed	32	38	27	31	21	29
Inadequate and retesting needed	17	31	16	31	34	26
Adequacy cannot be judged	18	5	30	24	17	19
TOTAL	100 (164 tests)	100 (98 tests)	100 (106 tests)	100 (126 tests)	100 (170 tests)	100 (664 tests)

*Percentages may not sum to 100 due to rounding.

SOURCE: National Research Council, Toxicity Testing: Strategies to Determine Needs and Priorities, D.C. National Academy Press, 1984, p. 94.

New methodologies which employ cultured cells rather than batteries of lab animals are enabling toxicologists to examine the specific effect of a chemical at the cellular or molecular level.

Such cellular regimes are attractive for several reasons: cultured human cells, or DNA, can be used where human subjects could not, giving data on human toxicity and avoiding questionable extrapolation from animal to human; maintenance and screening is much cheaper and faster for cell cultures than for lab animals; and the technique provides insight into the actual molecular mechanisms of toxicity (which might provide means of mitigating toxicity within the body after exposure).

-- At the cooperative Chemical Industry Institute of Toxicology one line of research systematically compares the mutagenic effects of chemicals directly on human DNA sequences. Results suggest that chemicals carry distinctive mutagenic fingerprints; whether generalizable to all mechanisms of toxicity or not, this raises the possibility of directly tracing a culprit chemical to a region or producer from observed toxic effects. (23)

-- A National Research Council committee recommended in a report to EPA that cell tests be used for most mutagen screening, with animal bioassays being used only if cell results are ambiguous. (24)

In addition, an array of promising regimes are being developed -- in insects, amphibians, simple animals such as the hydra. Such techniques compromise between the desirability of <u>in vitro</u> testing in a complex organism (preferably as much like man in its response as possible) and the economic necessity of reducing testing costs and time. (25)

4. <u>Telematics-Based Technologies</u>

<u>Structure Activity Relationships</u>

Extensive research is going into modeling structure activity relationships (SAR), which link biological activity to chemical structure. Using SAR rules, a new chemical might be compared to structural analogs, assigned a priority for testing based on the observed toxicity of its analogs and assessed for toxicity potential. As existing testing resources -- time, money, and lab space -- are woefully inadequate to deal with even the chemicals currently in commerce, reliable SAR algorithms could be invaluable.

Structure-activity relationships (SAR) are already being used informally in priority setting for testing and regulation for chemicals.

-- Benzene was under suspicion for excess risk of leukemia, long before the analytic verification of this, because of its capabilities of depressing the bone marrow and causing chromosomal abnormalities in a manner similar to known leukemogenic agents. The rapid acceptance of the carcinogenicity of the drug Chlornaphzine and its consequent withdrawal from use based on only a few case reports of bladder cancer was due largely to the recognition that the drug was a structural derivative of betanapthylamine, a potent bladder carcinogen among occupationally exposed workers. (26)

Further in the future, SAR may significantly displace analytical chemistry and toxicity testing, both to assess the inherent toxicity of chemicals and rank them for regulation or further testing. Fast-paced advances in computer expert systems, graphics capability, pattern recognition, and comprehensive database management will accelerate the implementation of SAR as a low-cost, fast method of analyzing the potential health effects and environmental fate of new chemicals.

The effective and reliable use of SAR relies critically upon the very costly accumulation of a comprehensive database of known correlations between chemical structures and biological effects, especially toxicity. Once this supporting database is established, generalized rules can be inferred -- such as the predictable unit of toxicity associated with a phenol group or polyhalogenation -- on the genetic, behavioral, mutagenic, carcinogenic, reproductive, neurotoxic, and other toxic effects.

Biosensors

In vivo biosensors are being developed to monitor -- and in many cases control -- the serum levels of glucose, antibodies against specific disease, albumin, urea, viruses, reproductive hormones, cancer-linked proteins, and pH and carbon dioxide. (27) Based on a blend of new techniques - immunological, electronic, biomaterials, membrane, enzyme - these biosensors can be as small as a few millimeters square. Such sophisticated technology could in the near future be adapted to monitor the biological presence of toxic substances or their degradation products, providing personal, portable toxicological screens. Miniature computerized biosensors could monitor metabolic processes and help control vital body functions such as heartbeat, ovulation, or fetal development. Further down the road biosensors might be equipped to automatically dispense neutralizing or therapeutic agents.

5. Chemical Mixtures: Synergy and Antagonism

Toxicology of chemicals acting in combination rather than in isolation present a major avenue of research for the future. As primary toxins are gradually controlled, the more subtle effects of mixtures will be revealed. (28)

Chemicals are transformed as they move through the environment or through an organism's biochemistry; the same chemical released under different conditions or in association with different mixtures of chemicals presents correspondingly different toxicological problems. Most current techniques examine only a single chemical at a time and consequently cannot pick up any synergistic or antagonistic interaction of chemicals.

Interacting synergistically within the body, certain organic phosphate pesticides and chlorinated hydrocarbons together generate ten times the health risk they would separately. (The chlorinated hydrocarbons interfere with the action of cholinesterase in the liver, leaving nerve tissue especially susceptible to damage from the phosphates.) (29)

Often the epidemiological and analytical tools are not fine-grained enough to distinguish between additive and multiplicative models of chemical interaction. However, the distinction may become vital in future controversies over compensation and liability for risk.

Carcinogens are generally classed as initiators or as promoters which seem to precipitate potential tumors once they have been initiated. Carcinogenesis is considered to be the result of a complex interaction between initiator and promoter, and between genetic, chemical, and environmental factors. (30) Both testing and regulation will have to cope with this increasing awareness of chemical mixtures, rather than individual chemicals, as toxic substances.

6. Institutions

Private contract labs are likely to remain the dominant providers of toxicity testing as the demand for testing rises.

Although significant reliability problems ranging from poor quality control to outright fraud have been revealed by recent investigations (the most noteworthy being the 1983 exposure of Industrial Bio-Test Laboratories), oversight mechanisms are responding. Examples include the Toxicology Laboratory Accreditation Board or T-Labs sponsored by the Society of Toxicology, FDA's Good Laboratory Practices program, and the Chemical Industry Institute of Toxicology efforts in "testing the tests." (31) In-house industry testing is not likely to extend much beyond the needs created by regulation, primarily for economic reasons. Toxicity testing in other developed countries is generally on a par with the U.S.; OECD standards set the pace for many protocols. (32) Increasing international standardization should discourage duplication of efforts and allow use of foreign data to fulfill U.S. regulatory requirements.

7. Epidemiology

Epidemiology, the study of the distribution and determinants of disease frequency in human populations, provides another building block of the scientific assessment for risk of disease due to exposure to health hazards. Identification of the observed distribution of a disease in a population is referred to as descriptive epidemiology. (A classic example of descriptive epidemiology observations leading to hypothesis about the cause of disease is the 1854 study by John Snow. Snow observed that the death rates from cholera in London were five times higher in districts which were supplied drinking water by the Southwark and Vauxhall water company than in districts supplied by the Lambeth water company. This observation eventually led to the identification of sewage-contaminated drinking water as the major cause of cholera.) (33) While descriptive epidemiology is useful in generating hypotheses and establishing correlations, it is rarely useful in verifying a cause-and-effect relationship between a particular exposure and a specific disease. Descriptive epidemiology must be supported by analytical epidemiology, designed to identify the determinants of disease and oriented towards specific groups of interest, often a population at high risk.

Epidemiology is a coarse science. Because of the number of variables involved -- genetic and biochemical differences, length, timing, and route of exposure, latency period, subgroups at high risk, interacting factors -- it is essentially a reactive science. The now well-established link between estrogens and human cancers was not shown until 1971, when a specific group of young girls who had been exposed to diethylstilbesterol (DES) in utero developed vaginal adenocarcinoma with latencies of 14 to 22 years. (34)

The strengths of epidemiology are three-fold. (35) First, it allows direct measurement of risk of disease in a human population rather than laboratory animals. Secondly, it can provide insight into the mechanisms of a disease.

For instance, epidemiological studies of kidney transfer patients who had received immunosuppressive drugs helped destroy the concept of immunologic surveillance as a cancer control mechanism. Epidemiology also revealed that leukemia is associated with an inherited disease involving high chromosome fragility, leading to subsequently-verified inferences that a primary step in leukemia is chromosome breakage. (36)

The third strength is the ability to extrapolate epidemiologic information to predict human health hazards at low levels of exposure that cannot be studied directly.

There are also major weaknesses to epidemiology. Most important is the latent period between exposure to a cause of a disease and the actual manifestation of the disease itself. For most chronic diseases these latent periods are quite long, from 5 years to over 50 years. Secondly, epidemiology does poorly at tracking down the causes of very low levels of risk. The lowest excess cancer risk that is directly observable in a group of exposed individuals and is generally accepted as being specifically due to that factor is the 30% excess risk of childhood leukemia among children who were exposed to radiation in utero in the last trimester of pregnancy. (37) It becomes next to impossible to say with any certainty that a very low level of risk is caused by a similarly low level of exposure to a single substance. This is partly due to another weakness of epidemiology, its inherent inability to isolate a single toxic substance, or control the unknown risk factors for the disease in question. One general health effect, such as a rise in lung cancer, may mask several different exposures or causes. Detailed, long-term information about individual exposures to specified substances and environments could significantly improve and focus epidemiological studies of actual exposure, this would likely entail significantly stepped-up information gathering.

Dozens of Federal and state databases with extensive information on health, occupation, lifestyle, industry, chemicals, etc. already exist. The volume of data creates no big technical barriers, but accessibility and comparability of data could. Data is often compiled according to political boundaries, but would in many cases be more appropriate for toxics investigation by environmental boundaries, such as airsheds, watersheds, or aquifiers. Or, the information needed may not be available for large groups of people or over a long period of time, factors critical to epidemiological work on low levels of risk.

Privacy issues are a potentially major concern, although ongoing epidemiological monitoring has not run into any big difficulties or public protests; for example, the Centers for Disease Control Birth Defects Monitoring Program receives regular reports from 1200 hospitals and health care centers across the nation, encompassing one-third of U.S. births. (38) However, industries, health care institutions, and other groups may raise restrictive barriers for fear of liability or privacy suits. Technical and public attention to these issues is mandatory if epidemiologic information is to realize an important role in the identification and quantification of health hazards in the future.

Epidemiological Techniques

Some of the important new techniques of epidemiology are study of sentinel diseases, low-cost retrospective studies, metabolic or biochemical epidemiology, evaluation of special risk groups, and identification of specific exposure monitors. (39)

Sentinel diseases can act as very sensitive indicators of general, low-level environmental hazard. Of particular concern are reproductive problems, including congenital defects, spontaneous abortion, and infertility, which in the population at highest risk may act as sentinel diseases and warn of health hazards for the general population.

Retrospective case control epidemiology uses data and samples stored from past studies to examine new questions. (40)

Biochemical or metabolic epidemiology focuses on specific tissue dosages and effects which result from more general environmental exposures. These may reveal biochemical changes long before the development of external symptoms, providing an early warning system.

The study of special risk groups also can help focus on the actual levels of risk by revealing a much more sensitive response to a substance. For example, a study of saccharin and bladder cancer used a population of nonsmoking women, a group with a much lower risk of bladder cancer than the general population. Identifying special risk groups may also provide unique opportunities to evaluate disease promoters and cofactors that require a subpopulation that has already been exposed to a disease risk factor.

Studies of exposure indicators can reveal chemical means of monitoring past exposure. Analytical chemistry techniques allow assessment of the probability and magnitude of past exposure to certain substances by evaluating the persistence of these substances or their degradation products in body tissues. Recent studies have indicated the value of assessing chromosomal abnormalities in circulating lymphocytes as an index of previous exposure to ionizing radiation, and have held out the possibility that such assays may be an accurate indicator of past exposure to mutagens in general. (41)

8. <u>Environmental Technology</u>

Environmental technologies -- sampling, monitoring, pollution control, and cleanup -- are rapidly becoming more sophisticated with next-generation analytical tools and the advent of new telematics and biology-based technologies. These new technologies are increasing awareness of the presence and fate of chemicals in the environment, but understanding and policy are lagging behind.

We can achieve a new scale of integration with satellite and computer technologies; investigate new places with temperature- and corrosion-resistant equipment; reach new detail with highly sensitive detectors; and track new compounds with qualitatively different, biochemistry-based detectors.

The outstanding trend is increasing sensitivity to chemical agents in all environmental media. Dioxin can be detected at the level of a few parts per quadrillion; the effects of organic contamination at that level is unknown, however. (42) This sensitivity is revealing the pervasiveness of chemical contamination in the environment, heightening the need for understanding of dose-response relationships and for consistent policy on limiting chemical release and managing contamination.

Many more chemicals can be detected than can be identified; only 9-14% (by weight) of compounds detected in a 1980 EPA National Organics Reconnaissance Survey were actually characterized. (43) Even more troublesome is the widening gap between the ability to detect chemicals at extremely low levels and the ability to understand the health and environmental implications of chemicals at such concentrations. This gap is likely to exacerbate the conflict over limits of acceptability for release and control of chemicals in the environment.

The technologies sufficient for portable, comprehensive, personal monitors are now being developed. (44) As waste containment procedures are upgraded, and as point-source pollution control is fully deployed, the contribution of minor contaminants and small-scale, overlooked wastes to the total environmental load will grow. As government assurances of safety are shown to be misleading in the light of better data, individuals may turn to personal or community-sponsored monitoring systems. This in turn is likely to increase the awareness, concern, and activism of citizens on the quality of their personal environment and contamination of water, air, and built environment.

Remote sensing and computer modeling technologies are becoming more and more vital to identifying and tracking environmental contaminants, especially as awareness of transnational transport of chemicals grows. International data is becoming important to the complete modeling of the environment and of chemical transport. Satellite observation in some cases can provide unique tracking of the conditions in an airshed or watershed following a chemical spill or from a chronic source. (45) Fingerprints of air masses measure airborne concentrations of chemicals, matching them with known chemical profiles characteristic of a specific geographic area. Once fingerprinted, the air masses can be traced as they move across the country, through the atmosphere.

Fiberoptic sensing and robotics are providing means to analyze chemical processes inside such previously inaccessible places as radioactive or highly toxic waste disposal sites or in extremely hot or corrosive process streams. (46)

Biotechnology holds great promise for detecting and neutralizing potentially toxic chemicals, especially in waste treatment and drinking water quality control. The potential of biotechnology is such that, in theory, any organic contaminant can be altered or degraded by a naturally occurring or an engineered enzyme system.

-- Some microorganisms produce enzymes which polymerize and effectively neutralize some organic compounds, precursors to carcinogens, which now cannot be removed from drinking water. (47)

Development of genetically engineered microorganisms for toxic waste treatment could be hastened by natural mutation among microorganisms extensively exposed to toxic substances. While the detoxification capability of the microorganisms might be enhanced, the possibility that undesirable but hardy microorganisms resistant to all sorts of toxic compounds might arise cannot be overlooked.

As biological systems evolved in an aqueous environment, biotechnology-based monitoring and cleanup is especially suited to dealing with groundwater contamination and industrial wastewater treatment. However, as with all pollution control systems, biology-based technologies will themselves present a new waste disposal problem.

In the future it is likely that more emphasis will be placed on gathering extensive information about the transport and transformation of chemicals in the environment. (48) Much of this data can be predicted from laboratory analysis, and computer modeling and expert systems are likely to play an increased role. However, priorities for research must be set, as it is far beyond our capability or knowledge to continually and thoroughly inventory the environment for all chemicals present.

B. PRIORITY SETTING: THE IMPLICATIONS OF INCREASED INFORMATION AND LIMITED RESOURCES

1. Defining Hazard

Quantifying the inherent toxicity of a substance is often less important than estimating the actual hazard it poses to individuals and society. Overall, hazard to society increases with:

- the number of people exposed,
- the individual exposure levels in that population and exposure among particularly susceptible groups,
- the route, frequency, and duration of exposure,
- the likelihood of a toxic response at that exposure level,
- the severity of that potential toxic response,
- the costs to society of compensating for and treating health effects. (49)

This coarse definition of hazard has several shortcomings. It averages the hazard over the entire population at risk, downplaying the variation in response between outlying individuals at highest and lowest risk. An averaged level of individual exposure in, say, a certain occupational environment, does not reflect the potentially wide differences in actual individual exposures; a few meters might make all the difference between a lethal and a harmless level of exposure. Similarly, "safe" levels of exposure might vary as much as an order of magnitude among individuals, due to individual genetic variability. (50)

Future regulation will need to reflect changing perceptions of risk, broadening the question from health hazards to include the societal costs and opportunities in terms of economics and lifestyle. Under TSCA the Congress charges EPA with avoiding "unreasonable risk" to society from toxic substances -- leaving the determination of unreasonable to EPA. EPA incorporates four factors into its definition of unreasonable risk under TSCA:

1. The toxicity of the chemical;
2. Anticipated exposure from use of the chemical;
3. The availability of substitute materials; and
4. The costs of regulatory control measures.

(See Chapter 4.B.2 for a related overview of trends in perception of hazard and risk.)

2. The Need to Set Priorities

Priorities will have to be set. With limited time, money, manpower, facilities, and equipment, and the need to not unduly delay the commercialization of products, a ranking system must be established for consideration of chemicals to be tested, for actual testing, and for regulation. Even at the current level of testing, costs are high:

-- The annual cost of analytical testing in the U.S. was estimated to be about $50 billion in 1982. (51)

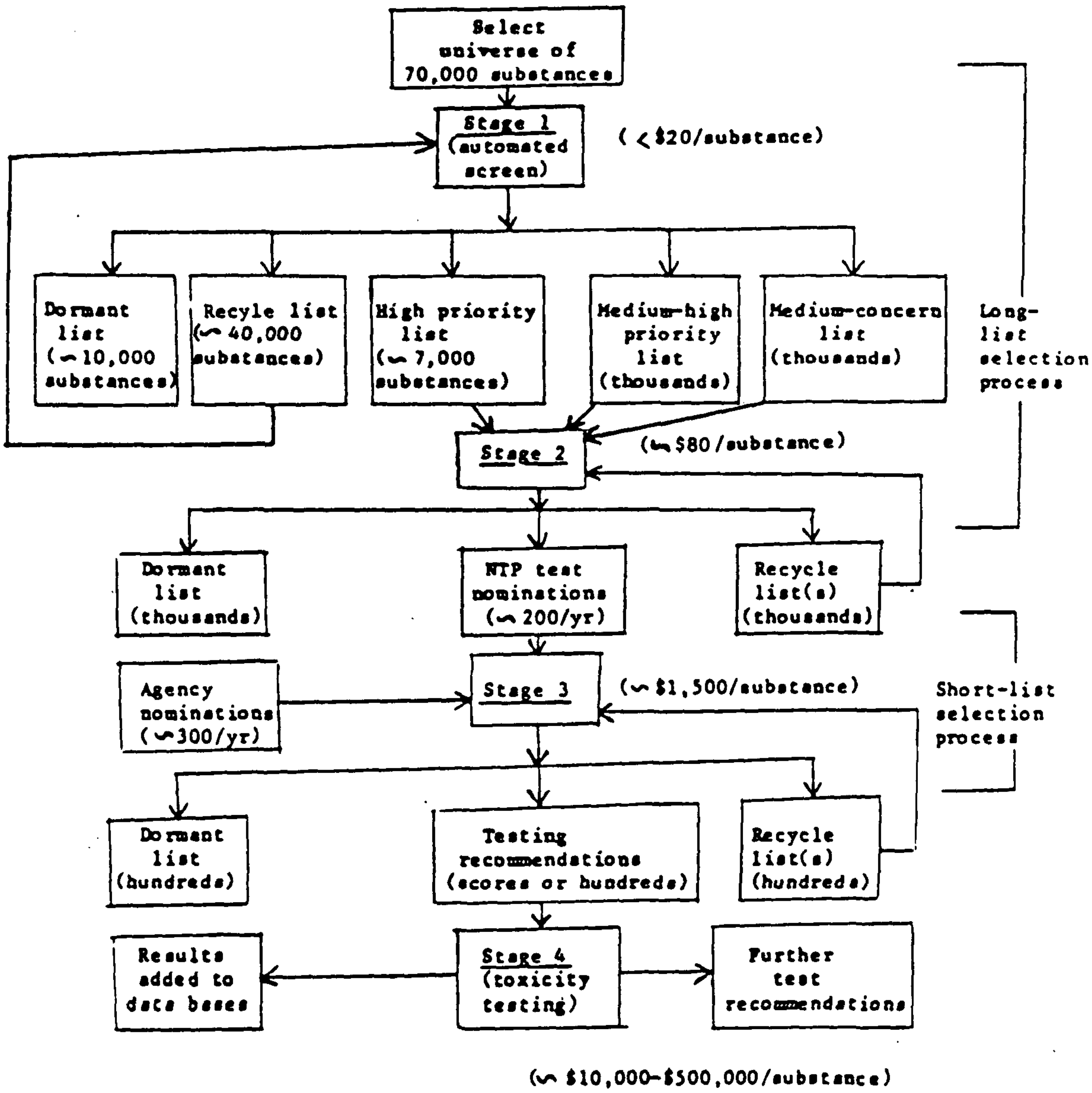
-- The average chemical company spends about $1.7 million per year specifically on toxicity testing according to a 1981 survey conducted for the CMA (112 companies varying in size responding to the survey together represented just over half of the chemical industry in terms of sales volume and employment.). (52)

Exhibit 25 shows a preliminary scheme for setting testing priorities which incorporates known correlations of structure and toxic effect, exposure estimates, relative concern over different classes of toxic effects, the costs of possible mistakes or misclassifications, as well as the goal of cost-effectiveness.

Most priority-setting mechanisms divide ranking criteria into two classes of environmental and human effects: biological activity, including toxicity, and exposure potential, including production volume and occupational exposure. Ross and Lu (53) proposed an exemplary two-phase scoring system to screen chemicals for TSCA evaluation. Exhibit 26 shows a list of their scoring factors (25 in all, in 10 categories) to rank chemicals for priority testing. A 1979 Interagency Testing Committee workshop to review their priority-setting system similarly divided scoring into potential exposure and biological effects, but did not generate a detailed new scheme. (54)

EXHIBIT 25

PROCESS FOR SETTING TESTING PRIORITIES



Source: National Research Council, Strategies to Determine Needs and Priorities for Toxicity Testing, Volume 2: Development, Washington, D.C: National Academy Press, 1982, p. 22.

EXHIBIT 26

PROPOSED SCORING FACTORS FOR EPA EVALUATION OF PRIORITY CHEMICALS UNDER TSCA
(Ross and Lu, 1981)

PHASE I: BIOLOGICAL EFFECTS

1. Oncogenicity
2. Mutagenicity
3. Embryotoxicity and fetotoxicity
4. Reproductive effects for terrestrial animals
5. Chronic toxicity
   -- in terrestrial animals
   -- in aquatic animals
   -- in plants, fungi, and bacteria
6. Acute toxicity
   -- in terrestrial animals
   -- in aquatic animals
   -- in plants, fungi, and bacteria

PHASE II: EXPOSURE POTENTIAL

7. Production volume
8. Environmental exposure
   -- environmental transport and transformation
   -- bioconcentration
   -- environmental release
   -- quantity processed
   -- quantity in products
9. Occupational exposure
   -- number of workers potentially exposed
   -- quantity of chemical manufactured and processed
   -- number of total worker hours
   -- quantity of chemical used in industrial products
   -- level of potential occupational exposure
10. Consumer exposure
   -- number of consumers potentially exposed
   -- frequency of consumer exposure
   -- intensity of consumer exposure

Source: Robert H. Ross and Paul Lu, Chemical Scoring System Development, work sponsored by the Assessment Division, Office of Pesticides and Toxic Substances, EPA, Draft, June 1981. p.5.

Ross and Lu also acknowledged the important role of subjective professional judgment in interpreting uneven and limited data and reconciling tests and information of species and sources, from various protocols. Despite the need for explicit, socially and scientifically accountable rules for priority setting, expert judgment will remain a key in establishing priorities for testing as well as in application of test results to risk analysis and regulation.

3. <u>New Health Concerns</u>

The changing population profile will be one driver of new priorities; the most outstanding of these will likely be the effects of chemicals on aging and on reproduction. Diagnoses of subtle behavioral and mental problems will also fuel increasing concern. Public concern over chronic and genetic risks is increasing the need for test regimes which reveal the implications of long-term chemical exposure. Carcinogenicity and mutagenicity tend to factor more heavily into perceived risk than do systemic or potentially reversible effects such as pulmonary disease. (55) Under TSCA, priority attention is to be paid to substances known or thought to cause or contribute to cancer, birth defects, or gene mutations. As more is learned about behavioral toxicity, neurotoxicity, and immunotoxicity, their significance in determining overall toxicity of a chemical is likely to increase.

Exhibit 27 shows one possible means of ranking different health effects according to the relative public concern they evoke. It ranks irreversible effects worse than reversible ones, and dread and life-threatening effects worse than structural or functional ones. The purpose of such a ranking system would be to give decisionmakers some sense of priorities when allocating resources, time, and money to chemical testing and analysis.

<u>Aging</u>

The maturing baby boom generation will eventually be older workers and older decisionmakers who have a vested interest in the

EXHIBIT 27

A POSSIBLE RANKING OF SPECIFIC CHEMICALLY-INDUCED HEALTH EFFECTS IN HUMANS

Effect	Score
Carcinogenesis, somatic and germ cell mutagenesis, liver necrosis, uremia, bone marrow depression, embryotoxicity, fetotoxicity, mucous membrane corrosion	9
Pulmonary fibrosis, pneumoconiosis, teratogenesis, aplastic anemia, immune suppression	7
Osteoporosis, convulsions, asphyxiation	6
Narcosis, permanent skin damage	5
Skin and eye corrosion, peripheral neuropathy, corneal opacity, retinal damage	4
Pulmonary and skin sensitization, cholestasis, mixed-function oxidase induction, methemoglobinemia, behavioral changes, infertility, lithiasis	3
Skin, eye, pulmonary, and mucous membrane irritation; depression of the central nervous system, fume fever, cholinesterase inhibition	2

The ranking is based on a scoring system that ranks irreversible effects worse than reversible ones, and life-threatening effects worse than structural or functional ones. This reflects a difference in public perception of severity of effects. This ranking is a "crude approximation."

Source: National Research Council, Strategies to Determine Needs and Priorities for Toxicity Testing, Volume 2: Development, Washington, D.C: National Academy Press, 1982, p. 37.

particular toxic susceptibilities of the aged. Exposure profiles will change as more people work and are active in their later years.

Differing susceptibility to toxic effects is a firmly established characteristic of age. (56) Aging is associated, for instance, with generally decreased ability to resist mutagens via natural DNA repair mechanisms. Current research into the biology of aging may reveal substances which hasten or delay the aging process, perhaps creating a new descriptor of toxicity: gerontogenesis.

Birth Defects

A combination of social, medical, and economic factors are increasing the concern over the causes and occurrence of birth defects. As more women enter the workforce, as mothers delay childbearing, and as more is learned about effects of chemicals on pre- and post-natal development, reproduction teratology will gain in significance.

- Over 15 million Americans suffer from one or more types of birth defects, 80% of which are thought to be caused by heritable genetic factors.
- Fifty percent of all miscarriages and at least 40% of all infant deaths are attributed to genetic factors.
- Nearly 3,000 genetic diseases have already been identified and catalogued.
- The life-years lost to these diseases are estimated to be six and a half times as many as those lost to heart disease. (57)

These are essentially all due to genetic factors present in the population. However, environmental factors and mutagens, in particular, may exacerbate birth defects or cause non-heritable ones of their own.

We have limited knowledge of the natural base rate of mutations in humans and the cumulative effects of various mutagens in the environment. Mutation is essential to the survival of a species, allowing for flexibility and adaptation while being overwhelmingly harmful or deadly to most individuals.

In most cases, the relative contributors of "natural" background mutation and mutation caused by anthropogenic factors cannot be distinguished.

> "The bottom line in all of this discussion is that we have a substantial amount of evidence to believe that cancer is like almost every other human disease we know of -- that is, it is due to the exposure of a susceptible individual to a specific environmental agent. Therefore, it is probably reasonable to contend that close to 100 percent of human cancers are environmentally induced and at the same time that close to 100 percent of human cancers are influenced by host factors." (58)

Scientific studies on changing rates of birth defects are conflicting; most point toward a significant increase in reported birth defects. However, they disagree as to whether this represents an increased susceptibility to birth defects or merely the heightened medical and public awareness. Rising public sensitivity to physical and behavioral abnormalities may be a significant factor, so that mild afflictions that might previously have gone unnoticed are now linked to genetic abnormalities. Data from a National Health Interview Survey show a 15% increase in the number of American school children enrolled in some form of special education since 1975. (59) It is not clear whether this number represents a real increase in need, increased resources for special education, or a lowered threshold of concern.

Improved medical care, especially neonatal intensive care, health care and nutrition during pregnancy, and fetal monitoring and screening, is improving the general health of both mother and child and perhaps reducing susceptibility to genetic or environmental sources of birth defects. However, the significantly increased survival rate of premature and underweight babies, more likely to have birth defects, partly counteracts this. Environmental factors, both natural and anthropogenic, have been linked to birth defects. Increasing amounts of toxic substances in the workplace, cigarette smoking, and viruses and bacteria all have been linked to birth defects. The importance of these factors in causing birth defects is unknown.

A study of 10,000 babies conducted by Johns Hopkins University indicated that these factors cancelled each other out. (60)

All agree that public sensitivity to birth defects is on the rise. This concern will translate into increased political pressure to identify and eliminate the causes of birth defects, with an emphasis on man-made causes -- such as toxic substances.

4. Exposure, Environment, and Risk: New Sources of Concern

Better data collection and processing for state-of-the-environment assessment are needed on:

- the natural or existing background levels of chemicals, especially in geographical areas subject to future development;
- the types and concentrations of chemicals normally present in the human body; and
- the effects of environmental chemicals and associated stimuli (such as vibration, noise, heat) on the human body.

Natural Versus Man-Made Hazards

Differing perceptions of natural vs. man-made toxic agents will shape the thrust of research and regulation on toxic substances. Advances in biochemistry and environmental science are likely to uncover more and more "natural" toxins which will have to be incorporated into toxicology testing regimes and risk assessment. Naturally occurring toxins include estrogen, which apparently is a significant contributor to breast cancer, and the alkaloid solanine, a neurotoxin found in sub-toxic concentrations in potatoes. (61)

Pervasive Environmental Contaminants

As waste management handling improves and point-source contamination from waste sites decreases, toxic contamination from accidents and non-point sources will rise in relative importance.

On a broader level, this anticipated shift in emphasis from point to non-point sources of environmental contamination may be expected to broaden the scope of regulation of industrial chemicals to include lower-level, more dispersed exposure from by-products, consumer use, inert ingredients, contaminants of products, etc. (62)

Non-industrial sources of toxic substances, such as the generation of polycyclic organic matter from residential wood burning, will be a growing contributor, relatively, to the total toxic load on the environment. These more dispersed sources will be more difficult and costly to monitor, control, and regulate.

Indoor Air Pollution

The movement to energy conservation is likely to result in better insulation and lower rates of turnover of air inside structures. One consequence of that is an increase in indoor pollutants, including carbon monoxide, from domestic toxic materials. Especially troublesome sources are: gas stoves and other appliances, kerosene heaters, wood stoves and fireplaces, cigarette smoke, and formaldehyde insulation. Radon from rock, sand, and concrete used in construction is a recognized problem. Recent research indicates health problems resulting from inhaling sodium dodecyl sulfate, an anionic detergent used in carpet shampoos. (63)

C. TRENDS IN MATERIALS AND PRODUCTS

The end use of most chemicals is products and materials. New materials result from improvement or replacement of existing materials (as plastics replace wood in construction) or from new markets which require new sorts of products and materials (such as the semiconductor industry).

Overarching trends in materials science, reflecting a new emphasis on optimizing use, are towards:

- substitution, especially of non-metals for metals;
- increased durability;
- improved cost-effectiveness and energy efficiency;
- minimal environmental and health hazards; and
- maximum recycling potential.

Interest in conservation has also spurred research in surface science and in synthetic materials which combine abundant elements (such as silicon and carbon) to replace limited or non-renewable materials such as metals.

Materials are increasing in complexity. This will alter the product mix of the chemical industry and could increase the likelihood of toxic hazard from use, exposure to, combustion, or disposal of such complex materials.

Specific materials science innovations are highlighted below under the headings metals and alloys, polymers (plastics and rubbers), ceramics, composites, telematics-related materials, and energy-related materials. Trends in biomedical materials and biotechnology-engendered materials are discussed in other sections of this paper.

1. Metals and Alloys

Process improvements in manufacturing are enabling metallurgists to alter the microscopic structures of metals and alloys. Rapid solidification produces amorphous glassy metals with high heat and corrosion resistance and good paramagnetic qualities. These materials are the foundation of many performance advances in the aerospace industry and will probably find application in pollution control technology. (64)

2. Surface Science and Catalysis

Corrosion is the source of unwanted deterioration and failure of materials. Surface science priorities include reducing corrosion in all materials and minimizing waste of resources and energy.

-- New coatings are combining lubrication with corrosion resistance.

-- Lasers are being increasingly turned to surface modification through precise, metal-thrifty cladding, alloying, hardening, and melting.

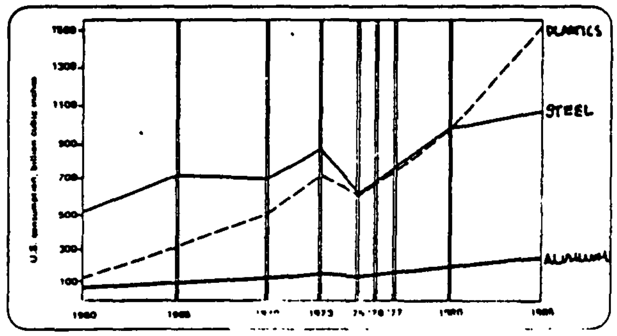
-- Ion beams can lay down coatings 1000 times thinner than traditional platings. Ion implantation creates thin layers of corrosion-resistant surface alloys. (65)

3. Polymers, Plastics, and Synthetic Rubbers

Plastics are rapidly replacing metals in many applications; the biggest markets are packaging, housing, construction, and transportation. (66) The first high-volume plastic-bodied car, the 1984 Pontiac Fiero, contains 300 pounds of plastics, twice the typical amount. (67) Process improvements are increasing the energy-efficiency of plastics and hastening their use. Plastics and synthetic rubbers are direct petrochemical products; research into coal-based polymers is just beginning. As overseas competition in basic plastics like polystyrene grows, the U.S. is switching to specialty products. (68)

EXHIBIT 28

TRENDS IN U.S. CONSUMPTION OF PLASTICS AND KEY METALS, 1960-1985



Source: The Center for Integrative Studies, Facts and Trends, 1979, p. 18.

4. Ceramics and Other Inorganic Materials

High-technology ceramics, especially silicon ceramics, are stable at extremely high temperatures; applications under investigation include turbines, heat exchangers, and energy-conversion (such as synfuels production). (69) The field is the focus of unrestrained enthusiasm of materials scientists.

5. Composites

As their name indicates, composites combine materials from almost all other classes. The general structure is a reinforcing fiber -- graphite, glass, ceramic, i.e., -- distributed in a matrix -- often a polymer, or perhaps a metal. A presently common composite material is fiberglass, in which thin threads of glass act as a strengthening material in a matrix of epoxy. In the future scores of materials may be used as the base or matrix and scores of materials as the reinforcing fibers. These will have different properties and characteristics, new uses, and unknown health and environmental effects.

The materials in new high strength composite materials may include not only fibers or carbon, but beryllium, quartz, and new forms of fiberglass. The environmental problem is that as they are used, recycled, or destroyed by combustion, fibers may be released to the environment. The very small particles may create diseases analogous to black lung, asbestosis, and other problems known to occur from the inhalation of fibrous material. (70) Improperly disposed products degrade very slowly, potentially creating leaching problems, of especial concern with such products as boron fibers and metal whiskers. An EPA-sponsored mini-assessment of composites reported no significant health hazards in use or recycling but did call for further research on the effects of combustion of these materials. (71)

--A recent example stems from the use of a new high strength material based on carbon fibers imbedded in epoxy matrix in high performance aircraft. A fire released a large number of these carbon fibers in the smoky plume from the burning aircraft. The fibers are electrically conductive; the smoky plume settling on electric motors and other electrical equipment unexpectedly caused a large number of electrical shorts. This highlights the importance of subtle side effects with regard to new technologies. (72)

6. <u>Telematics-Related Materials</u>

The high-growth computer and telecommunications industries rely on extremely high value-added products. The field is still in its infancy; expansion and evolution of new products are likely to maintain a growth rate near the 13-15% a year of electronic chemicals. (73) The lifecycle -- especially disposal -- of telematics devices may present future environmental health hazards.

-- The shift to electronic storage, processing, and transmission of information is fueling a 35% a year expansion in the market for magnetic storage media (such as floppy disks. (74)

-- The performance reliability advantages of fiberoptics over electric lines is encouraging development of optical glasses and fibers which are already finding applications in other markets such as medicine. (75) The special environmental needs of telematics equipment demand sensors with new piezoelectric and thermoelectric materials. Quality control technology and management will be a vital, generic prerequisite to production and use of all these materials.

EXHIBIT 29

Burgeoning uses of chemicals and plastics in electronics

Market	1982 (Million dollars)	1987 (Million dollars)	Annual growth (avg.)
Semiconductors	$750	$1,500	15%
Passive components	250	400	10
Printed wiring boards	650	900	7
Photovoltaics	60	320	40
	$1,710	$3,120	13%

Source: Chemicalweek, "Electronic Chemicals: Everyone is scrambling for a piece of the action," April 20, 1983, p. 32.

-- A 1983 California survey showed that 36 of 40 underground storage tanks in the Silicon Valley area were leaking potentially toxic materials. These storage tanks were the depositories/repositories for the many chip manufacturing and electronics firms in the area. At the Fairchild plant in San Jose, workers discovered that a faulty storage tank had discharged some 58,000 gallons of mildly carcinogenic solvent trichloroethane into the underground water supply. (76)

-- A 1980 survey by the California Department of Industrial Relations found that the semiconductor industry had 1.3 illnesses per 100 workers, compared with 0.4 per 100 workers for general manufacturing industries. Compensation data from 1980 to 1982 show that almost half (46.9%) of all occupational illnesses among semiconductor workers in California resulted from exposure to toxic materials, more than twice the incidence of illnesses from toxic exposures among workers in other manufacturing industries. (77)

7. Energy-Related Materials

The continuing search for diverse energy technologies and sources is creating needs for new materials. Use of lower grade crude oils is spurring the development of new catalysts such as zeolites. (78) The search for high-temperature superconductors has spawned a new class of materials known as molecular conductors, including polymers such as polyacetylene and crystalline salts of metals such as platinum. (79)

Enhanced Oil Recovery

Chemical agents, including surfactants, polymers, carbon dioxide, modified starches, and salts are being injected underground on a massive scale to increase oil recovery. Injection rates may reach 100 billion pounds per year by 1985. The environmental fate and long-term effects of such large-scale chemical infusions are unknown. (80)

Batteries

Deployment of batteries as energy storage devices would increase the occurrence of lead, cadmium, sulfur, nickel, or other materials not now generally deployed in the environment in large quantities. If the electric car becomes a substantial fraction of the auto fleet, this growth in battery manufacture, use, and disposal could be substantial. The materials used in batteries are almost universally toxic to humans and biota. Further problems could arise from the large-scale use of batteries in hearing aids, calculators, computers, radios, and other portable devices. (81)

Photovoltaics

Fast-paced technical advances in the design and manufacture of photovoltaic energy systems have made specialized applications economical and are making massive deployment of photovoltaics inevitable. (82) The combination of extensive, dispersed application of new materials in photovoltaics could create a new, pervasive toxicity problem.

Although forecasts differ in their pacing of photovoltaic penetration of the electricity market, all agree that the 1990's will find economic photovoltaics filling 20-30% of the electricity demand. This scale of use implies the annual manufacture of literally millions of individual photovoltaic cells. (83)

Exposure to toxic substances could occur during mining and manufacture, from occupational exposure to toxic gases or dusts, from malfunction or accidental exposure (say through a residential fire), during system use, from wastes from mining and manufacture, or from disposal of photovoltaic systems at the end of the product lifecycle. Fire toxicity is a special, unquantified concern for photovoltaics.

Generally, many of the materials and to a lesser extent the processes used in photovoltaic manufacturing are similar to those of the semiconductor electronics industry. While the semiconductor industry has in its short lifetime recorded no significant occupational or environmental incidents, the long-term potential both for occupationally-related risks and for waste disposal problems has not been systematically explored.

The materials used in photovoltaics fall into three basic categories: photovoltaic semiconductor materials such as doped silicon, ceramic and polymer support materials, and the glasses used to enclose the photovoltaic cells. Mining, purification, manufacture, widespread use, and final disposal and dispersal of these materials all might present new hazards.

--Gallium arsenide can give rise to volatilized arsenic and the highly toxic arsenic trioxide during a fire.

--Silicon dopants such as boron trichloride and phosphine are known as toxic agents. They are used in very small concentrations in the silicon-based photovoltaic cell, about one part per million.

--Other potential photovoltaic materials include germanium, cadmium (as cadmium sulfide), indium, antimony, and copper sulfate -- almost universally bad actors.

--Many specialized ceramics, glasses, and non-conductive polymers are being developed specifically for photovoltaic applications. It is likely that different materials will be manufactured for different applications, say residential versus centralized utility. More well-known polymers such as polymethyl methacrylate and polyvinyl chloride are also being used and modified for photovoltaics. (84)

The broad range of potential applications of photovoltaics will disperse these materials throughout society. Photovoltaics are already economical for many stand-alone or remote operations, such as boat and train batteries, portable clocks, calculators, remote village electricity generation, and field communications. In the near future extensive residential application is likely, and further down the road grid-connected, central utility use can be expected. Regional energy needs and economics will determine the speed and extent of photovoltaic adoption and consequently the patterns of potential toxic exposure.

8. <u>Agricultural Chemicals</u>

Agricultural chemicals as such do not fall under the regulatory purview of OTS, although the office does have responsibility for chemicals used as intermediates in pesticide manufacture. The future of agricultural chemicals is closely tied to that of commercial chemicals under TSCA, for several reasons:

- -- Agricultural chemicals -- pesticides and fertilizers -- are a continuing, highly visible, political and regulatory issue. Their production, use and misuse, international trade, disposal, and environmental dispersal all involve politically potent issues; the resolution of these will unavoidably affect policy on other classes of chemicals and health hazards.
- -- Pesticides and fertilizers are a significant source of the chemical load on the environment; they create degradation products which can interact with other chemicals in the soil, water, and biota. Neither industrial toxic chemicals or agricultural chemicals should be regulated in isolation. Organochlorine residues from such pesticides as Chlordane, Aldrin, DDT, and heptachlor have been found in over 90% of people tested, representative of the general population. (85)
- -- The technology of agricultural chemicals analysis is quite advanced and can, in some cases, provide lessons for other classes of chemicals. Some areas of concern particularly relevant to OTS missions and toxic substances are the array of new biology-based technologies and the misuse of agricultural chemicals.
- -- Both accidental and deliberate misuse of pesticides and, to a lesser extent, fertilizers, is extensive. (86) A USDA survey in Nebraska found that one-third of pesticide applicators used faulty equipment or techniques. (87) State oversight of pesticide use, disposal, and health impacts varies widely, and may leave gaps in monitoring or enforcement of government regulation. Public, industry, and regulatory response to incidents or trends in toxic exposures will affect the political and regulatory climate for all toxic substances.
- -- The many biology- and biochemistry-based pesticides which are replacing traditional chemical pesticides hold the promise of substantially reducing the amount of chemicals

needed in agriculture. These include allelopathic chemicals, natural herbicides produced by plants or microbes; social insecticides, which interfere with the normal social patterns of pests; microbial insecticides, naturally produced by bacteria, viruses, and fungi; and biological pesticides, which target pests with natural predators or parasites. (88) The imminent widespread use of these new technologies could substantially alter the profile of chemicals released to the environment. They could raise new concerns about the toxic effects of artificially-produced molecules and organisms dispersed on a very broad scale throughout the environment. (A recent suit brought in 1983 to block the use of a genetically-engineered bacterium to prevent frost formation on potatoes marked both the first proposed field use of genetically engineered organisms and the first corresponding legal protest.)

D. TELEMATICS (TELECOMMUNICATIONS, COMPUTERS, INFORMATION TECHNOLOGIES)

The convergence of computers and communication technologies is of fundamental and revolutionary importance to all areas of science and technology and to all areas of public health and environmental management (see Exhibit 30 below). (These technologies are also treated in Chapter 3, Section B.3, Product Trends in the Domestic Chemicals Industry.)

The ability to assimilate and manipulate complex systems interrelationships is making computers invaluable in modeling such systems as:

- -- the environment surrounding a proposed waste site;
- -- movement and transformation of chemicals in the environment;
- -- pharmacokinetic transformation of compounds within the human body;
- -- the links between chemical structure and biological activity;
- -- complex, multiphase reaction pathways in chemical manufacture.

Possible applications of data management particularly relevant to chemicals are:

EXHIBIT 30

BIOMEDICAL TELEMATICS INSTRUMENTS

Location	Function				
	Research	Diagnostic	Monitoring	Therapeutic	Prosthetic
Subcutaneous	Microelectronics for totally implantable telemetry of flow, pressure, and dimension, for example	Totally implantable telemetry for coronary by-pass graft monitoring	Cerebral pressure telemetry microtransducers and electronics	Microelectrodes for neural stimulator for pain relief	Cardiac pacemaker microelectronics: auditory prosthesis microelectronics
Supercutaneous	Microtransducers for animal backpack telemetry of flow and pressure, for example	Ingestible pH telemetry capsule	Ambulatory care ECG telemetry with active microelectronics	Microelectrodes and electronics for bladder stimulator	Hearing aid
Percutaneous	Implantable biopotential and temperature microtransducers with externalized leads	Catheter-tip blood gas sensor	Transvenous pacing lead for monitoring and stimulation; catheter-tip pressure sensor	Electrical stimulation of bone for enhanced healing	Microsensors for left ventricle assist drive
Transcutaneous	Gamma ray microtransducer arrays for radioisotope imaging; blood pressure sensor array with piezoresistive microtransducers	Computerized X-ray tomography detector arrays	Piezoelectric transducer arrays for ultrasonic imaging; blood gas monitor microsensors	Microtemperature sensors for hyperthermia; microsensors for defibrillators	Microoptical sensors and tactile stimulators for optical-to-tactile reading aid for the blind
Extracutaneous	Electron microscope	Mass spectrometer, cell sorter	Miniature silicon gas chromatograph for breath analysis	Microsensors for kidney dialysis machine	Voice-actuated wheelchair controller

-- Compilation of a comprehensive national epidemiological database, beginning as a matter of course at birth; and accumulating information on health, occupation, lifestyle, and family up until cause of death. The newly developed National Death Index takes one step towards this. (89)

-- Coordination of the existing toxicology databases such as RTECS (Registry of Toxic Effects of Chemical Substances), TOXLINE, CANCERLINE, The Toxicology Data Bank, EMIC (Environmental Mutagen Information Center), AGRICOLA, and EPB (Environmental Periodicals Bibliography). (90)

Comprehensive data on chemicals throughout the lifecycle is becoming increasingly accessible to all levels of users through increased networking and lowered cost. The Chemical Substances Information Network (CSIN), a project of the Interagency Toxic Substances Data Committee, has achieved a high level of integration and completeness by linking over 200 autonomous specialized data bases into a single universal library. (91) The data bases linked through CSIN cumulatively provide information on chemical nomenclature, composition, structure, properties, toxicity, production, uses, health and environmental effects, and regulation. The central access hub of CSIN allows users to access a wide range of information relevant to a single chemical or issue in a single procedure, overcoming such problems as the listing of chemicals under different names in different data bases.

-- The smart card, a wallet-sized storehouse of personal information such as medical records, resumes, and financial transactions, could provide a useful tool for epidemiology or occupational exposure records.

-- Real-time tracking of chemical transport (with the help of satellite observation) can help avoid or mitigate accidents during natural hazards and provide information on traffic, accidents, and safety along shipping routes. (See Chapter 3.C.2.)

The microprocessor, so-called brain on a chip, will become a tool for wide-scale, low-cost, highly complex, monitoring and evaluation of the natural environment, the workplace, and the home. The ability of low-cost microprocessors to afford independent, free-standing monitoring of large numbers of parameters in the environment will become the basement knowledge for improved environmental management. (92) The smart card, and increased monitoring in general, will clearly raise issues of privacy and civil rights. This will include, although it will certainly not be limited to, monitoring of the environment.

Telematics is restructuring social systems such as work (with flextime and remote terminals), transportation (teleconferencing replaces some travel), education, health care (with remote diagnosis via telematics), population distribution (decentralization), recreation (video games), and computer crime. These changes will, in turn, broadly affect the social environment of production, use, and exposure to chemicals. The home could become a concern for occupational safety and health if significant numbers of workers shift towards part-time or full-time work at home. (93)

E. BIOTECHNOLOGY AND TOXIC SUBSTANCES

Recent advances in molecular biology have created an entirely new set of tools for man, tools whose potential has barely begun to be realized. Applications are emerging not only in the production of chemicals, but in the manufacture of almost all goods and in the control of the environment.

The term biotechnology encompasses a group of related technologies based on converging advances in immunology, molecular biology, and microbiology. The key technique is recombinant DNA manipulation -- the ability to identify, isolate, and transfer a gene coding for a particular protein, and then recombine it with the genes of a foreign cell. Given suitable growth conditions, this cell will then express its newly acquired gene by producing the protein for which the new gene codes. Biotechnology has enabled the production of human insulin by transferring the human gene for insulin to a yeast cell, which in culture will produce large amounts of human insulin indistinguishable from that produced in the human body.

Since DNA, the basic constituent of genes, is universal to all living organisms, in theory any gene could be transferred to any other organism. In practice, however, significant barriers remain because of the complex differences in cellular mechanisms for control of gene expression.

The other new tool of biotechnology is the production of monoclonal antibodies (MAbs) through cell fusion. Antibodies are produced by human cells in response to foreign molecules -- such as flu virus proteins -- that enter the body. They are unique in their high specificity and high affinity for particular substances. Extremely homogeneous preparations of MAbs can be made which are similarly specific and will bind tightly and exclusively to a single substance. Potential applications include:

-- preparation of extremely pure vaccines;

-- purification (for example, by passing a dilute solution of a desired product over a column of MAbs specific for that product);

-- diagnosis (highly sensitive MAbs are already being used to track down proteins associated with cancer in the body);

-- detection and analysis;

-- therapy.

Paralleling the development of these laboratory techniques have been engineering techniques for handling biological and biochemical products -- cells, proteins, DNA, membranes, enzymes, hormones, and other proteins, etc. -- in a variety of settings. The generic new capabilities provided by these biotechnologies are changing the pharmaceutical and chemical industries, revolutionizing traditional agriculture, affecting medical technologies and environmental detection and monitoring technologies. (94)

The application of biotechnology creates new processes for production of existing products as well as for producing entirely new ones. The growth of a new industry based on biotechnology entails the development of new feedstocks, process engineering, control systems, testing, and waste disposal techniques. Some active areas of research in bioprocess engineering include:

-- development and improvement of engineering for continuous bioprocessing systems, such as the fluidized-bed biological reactor;

-- immobilized enzymes and cells (biocatalysts), using techniques including microencapsulation, entrapment in a polymer matrix, and adsorption to a physical substrate. (95)

Industry trends in this area are discussed in Chapter 3.C.

Biotechnology is now being used primarily for low-volume specialized products. So far, scale-up of bioprocesses has proven to be expensive and technically difficult. Current and near-term applications include:

-- pharmaceuticals, where the high value-added, low-volume preparation of biologicals such as insulin provides a natural area of application for biotechnology;

-- specialty chemicals, such as amino acids, enzymes, vitamins, and steroids;

-- pollution cleanup and waste management, where mixtures of micro-organisms can be used to neutralize or digest undesirable waste products;

-- microbial mining, using bacteria which naturally concentrate heavy metals;

-- single-cell protein production, primarily for animal feed; and

-- microbial enhanced oil recovery.

The principles and techniques of biotechnology can be applied to industrial processes in different ways according to the product or process desired.

-- Isolated enzymes or enzyme complexes can catalyze a single specific reaction, such as the conversion of glucose to fructose in the production of high-fructose corn syrup.

-- Micro-organisms (bacteria, fungi, and yeasts, primarily) can be cultured for high-volume production of basic cell matter, as in the production of single cell protein or baker's yeast.

-- Mixtures of micro-organisms, genetically engineered or not, can be used for complex processes such as waste conversion or the production of ethanol. Standard sewage treatment uses micro-organisms in this manner.

-- Micro-organisms that have been genetically engineered can be used to produce and collect a desired gene product such as interferon, hormones, and growth regulators.

Biotechnology and bioprocess engineering offer distinct advantages and disadvantages in comparison with traditional manufacturing processes. (96)

-- In some cases, biotechnology can provide a product that otherwise could not be obtained, as with human insulin.

-- Biotechnology takes advantage of the complex biological systems produced by nature to provide pre-packaged conversion systems.

-- Reaction conditions for biological processes are usually mild (atmospheric pressures, low temperatures less than 160°F) compared to standard manufacturing processes. The occupational hazards of the new biotechnology industries will likely be quite different from those of the current organic chemical industry.

- -- The inherent instability of biological organisms and processes makes quality control vital to bioprocess engineering. Even with modern monitoring and control systems, a genetically engineered organism may spontaneously revert or mutate, in rare cases rendering it ineffective or possibly toxic.
- -- Biological processes create new waste problems, requiring disposal and treatment of large volumes of wastewater and biocatalysts.
- -- In some cases, biotechnology may solve problems much more cheaply than other methods. Bacteria have been engineered to prevent the crystallization of frost that bacteria normally initiate on potatoes. (97) Standard approaches to prevent subsequent crop damage, such as smudge pots and heaters, are more expensive.
- -- Recombinant DNA technology is more selective and specific than traditional chemical mutation techniques used in the fermentation industry.

Biotechnology is making new feedstocks technically and economically feasible for organic chemical production. As the use of biotechnology grows, this difference in feedstocks will alter the entire industrial flow cycle, from mining and harvest to transport, process engineering, and waste disposal. New product mixes will emerge. Old feedstocks, especially petroleum products, will slowly be displaced. This shift to new processes and products will change occupational and consumer exposure to toxic substances, and alter the release of potentially toxic substances to the environment from industrial processes.

- -- Biotechnology is now primarily using feedstocks such as corn starch and beet molasses that have an established production infrastructure for reliable supply, cost, and quality control. In theory, any organic chemical can be produced by either chemical or organic synthesis from any carbon source.
- -- Lignocellulose from wood and woody plants is a potentially plentiful source of carbon, but there is now a lack of cheap efficient mechanisms for conversion to glucose and a strong competing demand from energy and forest products markets.
- -- Petroleum and coal are also potential biotechnology feedstocks. Pfizer operates a citric acid plant that can use either molasses or refined hydrocarbons. (98) The existing

capital and plant investment in the traditional petrochemical industry will likely prevent any significant utilization of biomass as a feedstock in the near term.

-- Agricultural products and by-products are currently used for the majority of industrial biotechnology production.

-- Industrial, agricultural, and municipal wastes so far have found little use as a feedstock for biotechnology.

There has been as yet no comprehensive study of the applicability of present toxicity testing to biocatalysts, or to products and wastes of industrial biotechnology. While many processes are using natural biological materials that apparently are non-toxic, there may be an increasing need for new toxicological regimes for biotechnological processes.

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APPENDIX

LIST OF WORKSHOP PARTICIPANTS AND INTERVIEWEES

JFCOATES INC.
3738 KANAWHA STREET, N.W. WASHINGTON, D.C. 20015

TOXICS '95
REVIEW WORKSHOP
September 14, 1983

8:30 Welcome, Coffee

9:00 Introductions

About this Project: Vary Coates, Project Manager
Ellen Selonick, EPA Program Manager

9:00 Plenary Round Robin: Your most important overall comments on the discussion papers.

10:15 Paper Review Sessions: Working Groups

- Comments, Criticisms, Suggestions
- Questions for the Participants
- Nominal Group Exercise:
  Trends and Factors--Priorities for Analysis

12:15 Lunch Break

1:00 Working Group Reports and Further Discussion of Papers

2:00 The Future of Chemicals Production, Use, and Control: The Implications of the Trends.

- General Discussion
- Working Groups: Brainwriting Exercise
- Report Back, Further Discussion, and Summation

4:00 Adjourn

Project Team:

Vary T. Coates, Ph.D., Project Manager
Joseph F. Coates
Lisa Heinz
Tracie Monk
Beverly Goldberg, Workshop Coordinator

Participants

TOXICS '95

Review Workshop

September 14, 1983

Jim Aidala
Environmental Policy Division
Congressional Research Service
423 Madison Building
Library of Congress
Washington, D.C. 20540
287-7254

Scott Baker
Senior Staff Officer
Toxicology Programs
Suite 651
National Academy of Sciences
2122 Pennsylvania Avenue, N.W.
Washington, D.C. 20037
334-2536

Ed Bergen
OSHA
Department of Labor
200 Constitution Avenue, N.W.
Washington, D.C. 20210
523-8021

Paul Bickert
Office of Toxic Substances
EPA 207 East Tower
401 M Street, S.W.
Washington, D.C. 20460
382-3683

Dr. Shirley Briggs
Director
Rachel Carson Council
8940 Jones Mill Road
Chevy Chase, Md. 20815
652-1977

Eloise Brooks, Director
Division of Industrial Operations
Office of Industry Policy
Department of Transportation
400 Seventh Street, N.W.
Washington, D.C. 20590
426-4214

Dr. Ken Burgess
Dow Chemical Company
Midland, Mich.
(517) 536-3177

Christopher Cathcart
Chemical Manufacturers Assoc.
2501 M Street, N.W.
Washington, D.C. 20037
887-1265

Dr. Charles Eby
Monsanto Corporation
1101 17th Street, N.W.
Washington, D.C. 20036
452-8880

Fran Irwin
The Conservation Foundation
1717 Massachusetts Avenue, N.W.
Washington, D.C. 20036
797-4300

David Kiefer
Managing Editor
Chemical & Engineering News
1155 16th Street, N.W.
Washington, D.C. 20036
872-4489

Dr. Winston Nottingham
Room 340
National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20006
357-7503

Dr. Jane Robens
Agricultural Research Service
Safety and Health Division
Beltsville, Md. 20705
(301) 344-3381

Kenneth Rosenbaum
Environmental Law Institute
Suite 600
1346 Connecticut Avenue, N.W.
Washington, D.C. 20036
452-9600

Ellen Selonick
Program Manager
Office of Toxic Substances
EPA 230 East Tower
401 M Street, S.W.
Washington, D.C. 20460
382-3701

Dr. Robert Simon
Chemical Sciences and Technology
National Academy of Sciences
NAS 273
2101 Constitution Avenue, N.W.
Washington, D.C. 20006
334-2156

Joe Uehlein
Industrial Union Department
AFL-CIO
815 16th Street, N.W.
Washington, D.C. 20005
842-7815

J.F. Coates, Inc.

Dr. Vary T. Coates, Project Manager

Joseph F. Coates

Lisa Heinz

Tracie Monk

Beverly Goldberg, Workshop Coordinator

Participants

TOXICS '95

Review Workshop

December 14, 1983

Jim Aidala
Environmental Policy Division
Congressional Research Service
423 Madison Building
Library of Congress
Washington, D.C. 20540
287-7254

Ed Bergen
OSHA
Department of Labor
200 Constitution Avenue, N.W.
Washington, D.C. 20210
523-8021

Justin Powell
Office of Toxic Substances
EPA
401 M Street, S.W.
Washington, D.C. 20460
382-3689

Dr. Stephen Quigley
4849 Connecticut Avenue, N.W.
Washington, D.C. 20008
695-5400

Kenneth Rosenbaum
Environmental Law Institute
Suite 600
1346 Connecticut Avenue, N.W.
Washington, D.C. 20036
452-9600

Ellen Selonick
Program Manager
Office of Toxic Substances
EPA 230 East Tower
401 M Street, S.W.
Washington, D.C. 20460
382-3701

Some of the people who contributed substantially to this report through discussion and interviews are listed below:

Gail Bingham, Associate, The Conservation Foundation

Dr. Charles Brown, Biometry Branch, National Cancer Institute

Leslie Cheek, Vice President, Federal Affairs, Crum & Forster Insurance Companies

Donald N. Collins, Vice President, Communications, The Fertilizer Institute

Ed Davidson, Director, Member Services, Chemical Specialties Manufacturers Association

Chester Dickerson, Director of Agricultural Affairs, Monsanto Corporation

Dr. Thomas Dietz, Graduate Projects in Science, Technology and Public Policy, The George Washington University

Dr. James E. Gibson, Chemical Industry Institute of Toxicology

Dr. Linda Greer, Staff Scientist, Toxic Chemicals Program, Environmental Defense Fund

Erik Jansson, Research Associate, Friends of the Earth

Dr. Irene Ann Jillson, Policy Research, Inc.

George Kaiser, At-Sea Incineration

Dr. Ed Lawless, Midwest Research Institute

Dr. Ben Luberoff, Editor, Chemtech

Dr. Myron Numan, Environmental Studies Board, National Academy of Sciences

Dr. Edna Palson, Director, Toxicology Information Center, National Academy of Sciences

Sheldon W. Samuels, Director, Health and Safety, Industrial Union Department, AFL-CIO

Joe Techet, Corn Product Corporation

Vincent Tocci, Director, Public Relations, American Chemical Society

Gerard J. Waldron, Congressional Aide, Representative Ed Markey, 7th District, Massachusetts

Michael Walsh, Institute for Water Resources, Army Corps of Engineers

Liz Davenport, Environmental Action

Dr. Geraldine Cox, Vice President, Technical Director, Chemical Manufacturers Association

Dr. Gary Hertz, Acting Director, Center for Analytical Chemistry, National Bureau of Standards

Dr. Sam Shapiro, Professor, Health Policy, Johns Hopkins University

Bob Reineke, Chemical Waste Management, Inc.

Dr. Clement Bezold, Institute for Alternative Futures

Dr. Earl Pollack, Chief, Biometry Branch, National Cancer Institute

Dr. Larry Edmonds, Birth Defects Branch, Centers for Disease Control

Lawrence Norton, Director, Operations, National Agricultural Chemicals Association

Russ Bunker, Office of Safety, Federal Railroad Administration

Godfrey P. Oakley, Director, Birth Defects Branch, Centers for Disease Control

Dr. Robert Dickson, National Institute of Environmental Health Sciences

Dr. Will Carpenter, Director, Environmental Operations, Monsanto Corporation

Dr. Ron Condray, Monsanto Corporation

Sam Gusman, Director, Toxics Research, Conservation Foundation