CHEMICALS WITHOUT HARM

POLICIES FOR A SUSTAINABLE WORLD

KEN GEISER

Chemicals without Harm

Urban and Industrial Environments

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Policies for a Sustainable World

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To Dillon, Lindsey, and Maeve and to the future of our children

Contents

Preface

This book is about chemicals and chemical policy. It starts from the premise that there is a problem with chemicals—the economy that supports our lifestyle and has raised the prospects of millions of people around the world is based on hazardous chemicals. Chemicals are used in the production of the vast reservoir of products and services that lie at the heart of national economies. These chemicals have enriched the lives of people throughout the world and improved their productivity and enjoyment of life. However, many of these same chemicals can pose significant risks to human health and too often disrupt and compromise the careful balances of natural ecosystems. Over the last 50 years we have invested heavily in regulations, barriers, and protections to control hazardous chemical exposures, emissions, and effluents. But we have been like parents carefully draping children to protect them from the rain, and we have little noticed that the rain showers have turned into torrents. A control strategy for chemical use is costly and never perfect; it leaves open all the points in the life cycle of chemicals where chemicals leak and flow into air sheds, water bodies, and soils and where they persist, accumulate, transform, and reappear in different guises. Ten years of this, maybe twenty, but fifty or a hundred years of this strategy and the environment is so altered that there no longer exists anything that could be called a background level.

The problem with synthetic chemicals is similar to the problem with many other technologies—we rush to develop and enjoy the fruits of novel technologies, long before we fully understand their consequences and create the systems needed to address their costs. The hazardous chemical control strategy might have been a good one—if there had only been a few hundred really dangerous chemicals. But that did not turn out to be the case. Many chemicals present hazardous properties. There truly are really dangerous chemicals, but there are many others that present varied types and degrees of hazard, and there are, also, many that

are relatively benign. We could spend the next fifty years trying to build better and better controls around more and more chemicals, or we could reconsider this strategy. If we are going to make big efforts to address the chemicals problem, it would be better if we worked to develop safer chemicals and moved thoughtfully and progressively to convert our economy to safer and more sustainable chemicals.

There is no assumption here that this is an easy path or that we can simply synthesize loads of safe chemicals and substitute them here and there in a myriad of applications. Transforming our economy to safer chemicals is a grand mission, and it will take more than a generation. But if we are going to ever create an economy that is safer and more sustainable, we should get moving, pull together the many forces that are working to build that economy, better integrate and support them, and develop the goals, plans, and policies that will guide us and keep us on track.

There are solutions to the chemicals problem. We can have safer products, safer workplaces, and safer communities. We can have a vibrant, innovative, and rewarding economy, and it can be founded solidly on highly effective synthetic chemicals—just new and different ones. We need a sustainable chemical industry and robust product manufacturing industries; they just need to be more thoughtfully directed to delivering safer chemicals and products. We need chemists, toxicologists, and environmental health scientists who are knowledgeable, creative, and committed to assessing and making chemicals that are safer and more sustainable.

During the 1980s, I helped to draft a series of bills that would become the Massachusetts Toxics Use Reduction Act, and for more than a decade, I had the opportunity to lead the Massachusetts Toxics Use Reduction Institute at the University of Massachusetts Lowell. For nearly twenty-five years I taught in an interdisciplinary academic department dedicated to occupational and environmental health and served in a university devoted to science and technical innovation. Working with others, I helped to establish the Lowell Center for Sustainable Production that has championed the development of safer chemical policy. During these years I joined many others in developing and managing several safer chemical state, interstate, and non-governmental organizations. Through all of this I have learned how to think about chemicals and industrial production from chemists, industrial product managers, business leaders, government agents, health scientists, environmental advocates, students, staff, and academic colleagues. I hope that I have served these people and institutions well, but I know that I have learned much from them and that all

that experience has provided me a clearer understanding of what has worked and not worked in chemical policy and what might be more effective. This book is built on that learning.

This is not a study. It offers no new research. It is more of a proposal—or a set of proposals, some quite simple and easy to adopt and others well beyond what is currently likely. I am aware that the argument here suggests changes of such magnitude that it would take enormous forces and decades to achieve. However, I hope the ambition of these thoughts does not reduce the value of the recommendations. We need to think big and audacious ideas or we will never have a chance to realize them.

I use the concept of a mental frame or framework here. The idea of problem framing has long been of interest to me. In my graduate work, I was influenced by the work of Don Schon, Marty Rein, William Gamson, and Lisa Peattie, each of whom was interested in public controversies and the way in which action and practice are shaped by underlying stories that explain a problem and determine the way in which solutions are framed. I use that perspective here.

In this writing I have wandered far from my original training in environmental law and policy. That framework held a special place for federal government policy and government regulation, in particular. However, the government that I studied and engaged with for some forty years has changed dramatically. There are no big visions and grand gestures now. We are quite far from the Great Society Program, the Apollo Project, and the building of the National Interstate and Defense Highway System. Indeed, we have not seen a major new federal environmental statute in thirty years. I am aware of how difficult it would be in the foreseeable future to achieve major statutory changes in federal chemical policy. That is why much of what I describe here could be accomplished either through federal initiative or without it. So it is not surprising that I have looked elsewhere for the forces of change. What I have found is hundreds of local, state, corporate, trade union, nonprofit, and international initiatives that are struggling to advance a safer system of chemicals. So my challenge became more like an auto mechanic picking up components here and there and trying to conceive and assemble a new and different vehicle. Certainly, some of these ideas are more developed than others. However, even if the solutions that I suggest here do not seem practical or achievable, I hope that my effort to reframe the chemicals problem is useful for others who might see different solutions.

Like any writing that arises out of the lived history of the writer, the subject has been broadly shaped by colleagues. I am grateful for all of the

ideas and support that I have received over these past several years. Many people have offered ideas and comments and provided time for interviews and substantive discussions. I thank Paul Anastas, Ingela Andersson, Monica Becker, Bjorn Beeler, Ann Blake, Bill Carroll, Richard Clapp, Cathy Crumbly, Buzz Cue, Clive Davies, Richard Dennison, Joe DiGangi, Mike Ellenbecker, Art Fong, John Frazier, Terri Goldberg, Elizabeth Harriman, Lauren Heine, Helen Holder, Tom Lent, Annie Leonard, Richard Liroff, Kaj Madsen, Tim Malloy, Rachel Massey, Gina McCarthy, Roger McFadden, Greg Morose, Marty Mulvihill, Kevin Munn, Dara O'Rouke, Pierre Quiblier, Margaret Quinn, Debbie Raphael, Meg Schwartzman, Alex Stone, Beverley Thorpe, Yve Torre, Howard Williams, Mike Wilson, and Martin Wolf. I am grateful for all the information, ideas, and comments; however the proposals developed here are my own.

Many other people took time to read chapters and review even quite crude text for which I am immensely grateful. For these reviews, I thank Mike Belliveau, Charlotte Brody, Ryan Bouldin, Amy Cannon, Gary Cohen, Sally Edwards, Joel Garrett, Jim Geiser, David Kriebel, Joanie Parker, Mark Rossi, Ted Smith, Joel Tickner, Bill Walsh, John Warner, and Rand Wilson.

By focusing on chemicals it should be clear that we are not just addressing a human health problem or an environmental problem. This is an industrial problem, a technology problem, a science problem, and sadly, in our country, a political problem. However, for every problem, there is an opportunity. We can do more and better. We need new and better policies, programs, and practices, and we need safer chemicals—effective, appropriate, and highly functional chemicals, if not without harm then at least with a lot less.

1

The Problem with Chemicals

Dr. John Warner sits in a light-filled office in a nondescript suburban office park north of Boston. He will tell you that 60 percent of the chemicals on the market today are dangerous and have no safer alternative as a substitute.

John is a chemist and one of the guiding lights of a dynamic international movement among chemists called green chemistry. He and his colleagues are challenging the fundamental way that chemists are trained and conduct their research. For John, it is not enough for a chemist to know organic and inorganic chemistry, chemical synthesis, and chemical process control. Green chemistry requires that chemists also understand toxicology, pharmacology, and environmental science as well as the public health and environmental laws and regulations that affect chemicals. However, even though he established the nation's first doctoral degree program in green chemistry at the University of Massachusetts's Boston campus, John grew frustrated with the academic approach to chemistry. Ten years ago, he left the university world to set up the Warner-Babcock Institute for Green Chemistry, a chemical research and development laboratory for promoting green chemistry in private industry.

Across the country in an upscale office building in downtown San Francisco, Dara O'Rourke describes a new vision for the commercial product market. Dara sees a day when shoppers around the world snap little cell phone photos of the bar codes of products that they are planning to buy and instantly read out the product ingredients and the color-coded scores that tell them how safe and socially acceptable the products are. These are not just abstract thoughts. Dara, a faculty member at the University of California at Berkeley, is the founder of *GoodGuide*, a new innovative, Internet-based consumer education tool. *GoodGuide* provides an "app" for mobile smart phones that allows consumers to see

color-coded ratings on the health, environmental, and social effects of products before they purchase them.

Further down the San Francisco peninsula, Helen Holder sits in the corporate offices of Hewlett Packard (HP), one of the world's leading manufacturers of consumer electronics, and reviews hazard information on hundreds of chemicals that could become constituents in laptops and printers. Helen is the Corporate Materials Selection Manager for HP, and her job is to evaluate and recommend the safest and highest performing materials for the company's products. She has helped the firm's hundreds of component suppliers find alternatives to the lead, mercury, cadmium, and brominated flame retardants that are now banned in electronic products sold in Europe. Her work has made HP a leader in its industry and earned the company high marks on environmental activists' scorecards. She understands the powerful role that a corporation like HP can play in shifting suppliers to safer chemicals, and she uses that role to push for higher standards for the entire computer and electronics industry.

Charlotte Brody is a nurse by training and one of the founders of Health Care without Harm, an international network of health care practitioners and advocates engaged in making hospitals and clinics safer and more sustainable. Today, she directs the Health Initiatives at BlueGreen Alliance, a coalition of fourteen trade union and environmental organizations working to build a safer, cleaner, and more competitive economy. "Lots of people are getting more information about hazardous chemicals," Charlotte claims, "but workers were being left out." Working with several trade unions, she devised a new online chemical hazard communication tool that provides workers with the health and safety information they need to protect themselves and to negotiate for changes in workplace technologies that would reduce the use of hazardous chemicals.[1]

Roger McFadden is the Director of Sustainability for Staples, the world's largest office supply retailer. For Roger, the issue of hazardous chemicals in products is central to his business. "My company is committed to selling products that its customers know are safe and environmentally friendly. It's a matter of customer trust and social responsibility," Roger says with a big, gregarious smile. From Roger's office outside Denver he can see the majestic foothills of the Rocky Mountains. "Protecting the environment is the new icon of competitive advantage," he says glibly, not revealing how hard he is working to pressure Staples' hundreds of vendors to reveal the chemical constituents of the products that they offer Staples to sell to the firm's worldwide customer base.[2]

What links these committed individuals together is a vision of a more sustainable world that is free of many of the risks associated with the manufacture and use of toxic and hazardous chemicals. Each is a contributor to a transformation that is taking place in the way we conventionally think about chemicals and chemical policy. They are not alone. There are hundreds of scientists, corporate managers, environmental activists, and government leaders across the country who are fashioning a new approach to chemicals—a new, twenty-first-century approach to chemical design and management.

For years our conventional approach to chemicals has been wildly entrepreneurial and opportunistic. Today, there are literally thousands of synthetic chemicals used to make our clothing, cosmetics, personal care products, vehicles, electronic gadgets, household products, recreation equipment, and toys. Many of those who live in highly industrialized societies are able to live rich, long, and comfortable lives because of the products of the modern chemical industry. But these chemicals—the chemicals of the synthetic chemical revolution—also harbor a darker side. Many of these highly useful chemicals are also persistent, toxic, and dangerous to our health and the environment that supports us. As C. P. Snow once noted, "Technology…is a queer thing. It brings you great gifts with one hand, and it stabs you in the back with the other."[3]

This is a basic irony of technological development, but it is not destiny. Now, in the twenty-first century, we could change the course of the synthetic chemical revolution that we have inherited. We could be designing molecules, synthesizing compounds, mixing chemicals, and manufacturing products that are safe and compatible with human health and ecological systems. However, to do so will require a dramatic shift in how we think about chemistry, the chemical industry, and the government we expect to protect us.

1.1 Chemicals in the Environment and Us

The academic fields of chemistry and chemical engineering largely emerged from the scientific developments of the eighteenth and nineteenth centuries. Scientific knowledge and conceptual understanding of molecules and chemical reactions came from the early British work on gases and dyestuffs and the German work on coal-based chemical derivatives. During the nineteenth century, leading scientists such as Hilaire de Chardonnet, Alfred Nobel, Ernest and Alfred Solvey, John Wesley Hyatt,

Charles Martin Hall, and Herbert Dow pioneered new chemical synthesis and process innovations. By the early 1900s, the new chemical industries were producing a host of novel synthetic chemicals ranging from dyes and inks, to kerosene, aluminum, dynamite, sodium nitrate, ammonium cyanide, and chlorinated hydrocarbons, which were rapidly transforming everything from foods and drugs to domestic products and building materials.[4]

Industrialized nations began the twentieth century with a wealth of minerals that could be mined to make inorganic chemicals and coal and petroleum that could be processed to make organic chemicals. Two major World Wars later, and these economies have been transformed into gigantic commercial engines for converting synthetic chemicals into thousands of inexpensive, useful, and appealing commercial products. Corporations and government agencies poured large investments into chemical research and huge chemical manufacturing facilities that could pump out millions of pounds of polymers, solvents, fibers, paints, inks, mastics, resins, pharmaceuticals, and pesticides.

However, this impressive wave of chemical innovation brought problems. Some of these chemicals brought injury and disability to workers, and once they dribbled out into the environment, they contaminated the air and polluted the rivers. When Rachel Carson began *Silent Spring* during the late 1950s, she intended to examine the chemical threats to wildlife, but when she connected those hazards to human disease, she ignited a firestorm of public concern. Over the decades since then, public awareness and fear have focused on pesticides on foods, mercury in fish, dioxins in waste incineration, lead in paints, halogens in plastics, heavy metals in packaging, phthalates in cosmetics, and the buildup of persistent and bioaccumulative chemicals in soils, sediments, and our own human bodies. The newest research shows that people are exposed daily to low levels of a constantly changing, complex mixture of synthetic chemicals. The result is that most of us—those of us living in highly industrialized societies and those living in much less developed areas—carry within us a rich mixture of synthetic chemicals, many of which did not exist in our grandparents' time.[5]

It is not difficult to find the sources of these chemicals. Workers often experience chemical exposures at work. Although some of the most dangerous chemicals are reasonably controlled at U.S. worksites, there are many jobs in this country where workers still work with significant exposures to hazardous chemicals. Chemical processing, metal working, paper making, chemical product formulation, construction, mining, janitorial

cleaning, and hairdressing expose workers to recognized carcinogens, reproductive toxins, neurotoxins, sensitizers, and many other chemicals of concern.

Consumers experience exposure to hazardous chemicals as they appear in household products. Formaldehyde, a recognized carcinogen, shows up in air fresheners, toilet bowl cleaners, and many household cleaning products. Toluene, a neurotoxin, is used in various adhesives, paint thinners, sealants, disinfectants, and nail polishes. Shampoos, cosmetics, soaps, and lotions may contain diethanolamine, a compound that can degrade into a nitrosodiethanolamine, a probable carcinogen. Garments may be dyed with azo dyes, treated with disinfectants, and coated with perfluorinated compounds, leaving small residues of potential carcinogens and endocrine disruptors. Percholoethylene, a probable carcinogen, is used to dry clean garments. Oil- and enamel-based paints, paint strippers, and paint thinners contain volatile compounds such as acetone, methylene chloride, and petroleum distillates. Biocides are added as preservatives in many formulated products. Upholstered furniture, sleepwear, and mattresses may be treated with brominated flame retardants. Phthalates, which are linked to birth defects and endocrine disruption, are used as plasticizers in some shower curtains, raincoats, shampoo bottles, furniture, and children's toys. Indeed, children's products are little safer than common domestic products. More than 17 million toys were recalled in 2007 because they violated federal lead paint standards. In 2010 the Consumer Products Safety Commission recalled 55,000 units of children's costume jewelry that contained high levels of cadmium, and 12 million promotional drinking glasses sold at McDonald's were recalled because of cadmium in the painted coating.[6]

As products enter our homes, the constituent chemicals can migrate from the product into the air we breathe, the food we eat, or the things we touch. The U.S. Environmental Protection Agency (EPA) has found levels of a dozen common organic compounds to be two to five times greater inside homes than outside. Studies taken of household air show that the dust that floats about in our houses is littered with persistent chemicals degraded from household furnishings and products. According to the Environmental Working Group, an environmental advocacy organization, the average American is exposed daily to more than 100 chemicals of concern in cosmetics and personal care products applied directly to the skin.[7]

In 2008 the federal Centers for Disease Control (CDC) tested blood and urine from a broad, national sample of Americans for 212 substances

ranging from heavy metals to polycyclic aromatic hydrocarbons, dioxins, phthalates, and various pesticides and found traces of these chemicals widely dispersed throughout the nation's population. While brominated flame retardants were found in nearly all participants, 90 percent of the sample showed traces of bisphenol A, a production chemical used to make polycarbonate and epoxy resins. Perfluoroctanoic acid, a byproduct in the production of stain resistant and non-slip surface coatings, was found in a majority of participants.[8]

Once in us, some synthetic chemicals can cause acute and severe injury. In 2011 the American Association of Poison Control Centers reported that more than 2,334,000 people in the United States, including 1,145,000 children, sought help for harmful exposures to products containing hazardous chemicals, including personal care products, pesticides, hobby supplies, and paints.[9]

The chronic, longer term health effects of chemical exposures are more difficult to determine. However, the weight of evidence suggests that a concerning number of synthetic chemicals found in workplaces and products is associated with cancer, reproductive dysfunctions, developmental disorders, and immunological damage. Many pesticides and agricultural chemicals in common use contain known or suspected carcinogens and endocrine disrupters, and chronic, low-level exposure to some of these is linked with neurological, developmental, and other effects in children. Isocyanates, amines, formaldehyde, and aldehydes used in building products (paints, caulks, adhesives, foams, insulation) are known chemical sensitizers. Polybrominated diphenyl ethers, pentachlorophenol, and bisphenol A can interfere with adult hormonal activity, potentially resulting in developmental disorders among fetuses and children. Research on the health and environmental effects of the new generation of nano-scaled and synthetic biochemicals is just now emerging but already suggests a reasonable basis for concern.[10]

The National Research Council estimates that chemical exposures play a role in at least one in four cases of developmental disorders. Asthma has been linked to long-term exposure to urban air pollution and chemicals such as formaldehyde and phthalates. The U.S. President's Cancer Panel released a report in 2010 identifying many cancer-causing agents that are common in industrial, agricultural, medical, and military workplaces. Epidemiological studies of occupational exposures show strong correlations between exposures to chemicals such as benzene, asbestos, and arsenic and specific cancers.[11]

The harms from hazardous chemical exposure rest heaviest on vulnerable populations. Communities of color, indigenous peoples, and low-income communities bear a disproportionate burden of hazardous chemical exposure and the potential adverse health effects. Children are particularly susceptible to the effects of chemical exposures because their organs and immune systems are still developing.[12]

Chemical contamination also threatens the health of eco-systems and wildlife. A recent assessment of western national parks by the EPA found widespread chemical contamination with persistent, bioaccumulative, and toxic chemicals and endocrine-disrupting chemicals among several indicator species. A study of chemical contaminants in wild bird eggs in Maine found mercury and several chlorinated, brominated, and perfluorinated compounds, all known to cause adverse health effects in animals.[13]

This is only what we know. Although we have good science on some chemicals, for most substances, we do not have enough studies to know the potential hazards, and we certainly do not know the consequences of the multiple and continuous exposures to the broad mixes of chemicals that we get every day. Thus, we are faced with a complex chemicals problem. We rely on a host of chemicals that are central to our economy but could be dangerous to our health. However, instead of throwing our government and industrial talents to developing industrial chemicals that are safe and environmentally compatible, we have erected complex legal and physical infrastructures to ensure that people are not exposed to dangerous chemicals—at least not "unreasonably" exposed—and that the environment is not jeopardized—at least not "significantly."

1.2 Toxic Chemical Policies

The development of synthetic, organic chemicals has never been put to a democratic vote. No government has turned to its citizens and asked what chemicals should be part of their economy and what chemicals should not. Instead, governments rely largely on the private market to make decisions about the chemicals that go into products and make up the structural and functional materials of modern society. Each year the chemical manufacturing industries pump out thousands of synthetic chemicals, and thousands of large and small product formulators and manufacturers turn those chemicals into commercial, industrial, and agricultural products. The chemicals used to make these products are deter-

mined within the multiple transactions of the vast chemical market that links chemical manufacturers and product manufacturers.

Large and powerful interests guard that chemical market. With billions of dollars of chemical sales each year, those who own and invest in chemical manufacturing corporations have aggressively fought to limit government efforts to regulate the chemicals market. While government agencies are empowered by laws to regulate chemicals used in workplaces and formed into products and chemicals that show up in wastes and emissions, few chemicals are actually prohibited from manufacture and use. Instead, chemical manufacturing firms and their "downstream" manufacturing customers work within a loose legal environment of chemical control laws that offers exposure limits for some chemicals, restricted uses for others, testing and registration requirements, product labeling standards, and liability penalties for chemical damages.

With an estimated 30,000 chemical substances in use in industry, it would take a monumental effort by governments to identify, test, and regulate each of the chemicals used in workplaces and products. Indeed, for many chemicals there simply is not enough information to determine whether they pose risks substantial enough to warrant regulation. Until recently many of the largest volume production chemicals—those manufactured in volumes over a million pounds per year—had little or no health or environmental effects data publically available, and even today there is insufficient information on most of the substances manufactured at lower volumes.

Where adequate data do exist, current government policies often require extensive and costly risk assessments to determine human health threats, and when government officials do decide that regulations are necessary, they are often required to balance their risk management options against economic consequences to ensure that current industries are not overburdened financially. Thus, the government laws that have been passed to regulate chemical manufacture and use provide far less than comprehensive and protective vehicles for ensuring the safety of industrial and agricultural chemicals and the chemicals that show up as constituents in commercial products.

1.3 New Initiatives in Chemicals Policy

In 2006, the European Union enacted a new, far-reaching policy overhauling most of Europe's conventional laws for managing industrial chemicals. This broad policy shift marks a significant historical

development in the procedures by which governments seek to manage the risks of chemicals. Commonly referred to as REACH (Regulation, Evaluation, and Authorization of Chemicals), this new regulation establishes a new European chemicals agency and sets out a comprehensive program to register all chemicals in commerce, test and evaluate several thousand chemicals of concern, and require special government authorization for the use of those chemicals of highest concern. It requires governments of the twenty-seven member nations of the European Union to rewrite and harmonize their differing national chemical management laws, and it creates a broad array of new responsibilities for firms manufacturing and using chemicals in Europe.

The fact that the European Union initiated such a major overhaul and saw it through to parliamentary approval is fairly remarkable considering the complexity of the policy and the significant opposition that it generated. Given that the European chemical market is the largest in the world, the procedures put forward under REACH have a significant impact on the global chemical market and, by default, have become an international standard.[14]

Today, there is a growing interest in the United States in going beyond a singular focus on toxic and hazardous chemicals and developing broader policies for managing chemicals. These chemical policies are comprehensive policies that address a broad range of chemicals and place a high priority on replacing higher hazard substances with lower hazard substances. Such policies transcend the chemical-by-chemical control policies of the past, which promoted efforts to phase out the most dangerous chemicals, but failed to consider their substitutes or the many other chemicals of concern. This focus on both hazardous and safer chemicals makes these chemical policies more proactive and more market changing than the narrowly conceived chemical control policies of the past.

Converting to aqueous cleaners and degreasers, switching to low-volatile coatings, transitioning to biobased mastics and adhesives, selecting non-chlorinated polymers, and converting to environmentally friendly inks and dyes are procedures encouraged by these new, safer chemicals policies. Indeed, rather than "chemical bans," the terms "chemical conversions" and "chemical substitutions" best characterize the active component of these policies.

Brand name manufacturers in the apparel, furniture, household products, automotive, and electronic industries are drawing up lists of hazardous chemicals to avoid and substituting safer alternatives where they find opportunities. Leading retailers in clothing, housewares, groceries, and

office supplies are requiring that product manufacturers limit the use of chemicals of broad public concern in the products that they retail. The health care industry has begun to conduct professional reviews of the hazardous chemicals used in hospitals and clinics.

These safer chemical policies are putting pressure on the manufacture of highly hazardous chemicals, but they are also encouraging chemists to develop newer, safer chemicals such as lactic acid, citrates, methyl esters, cellulose, glycerol, sorbitol, and polysaccharides. There is a growing demand for new chemicals, new chemical processes, and nonchemical technologies that can substitute for the toxic legacy of the twentieth-century chemicals. Here lies a great opportunity for science and engineering. "Green chemistry" and "green engineering" are terms used to describe the development of these new, safer chemistries and chemical processes. Green chemistry offers a new perspective to conventional chemistry by seeking chemical synthesis that reduces or avoids hazardous molecules or processes. Green engineering encourages technical and process procedures that encourage recycling, avoid wastes, reduce resource consumption, and promote inherently safer technologies. Many university centers and corporate programs around the world are now promoting green chemistry and engineering.

Today, well into this new century, we can see initiatives that are pushing forward to correct the unresolved problems of the synthetic chemical revolution, and the results promise a healthy, new frontier. The transformation that is now just emerging is taking the lessons of some two hundred years of chemistry and chemical production and marrying them with a commitment to public health and environmental protection. The chemicals of the future are being fashioned today around concepts such as green, clean, benign, zero-waste, atom-efficient, safe, and sustainable chemistry. These changes are just beginning. However, there is no guarantee that this transition will succeed. Massive barriers and openly hostile resistances exist. But if we can reframe our approach to chemicals, reconsider the needs of our economy, and redesign the policies of our corporations and governments, we could be fashioning a new, twenty-first-century chemical industry and a safer, sounder, and more sustainable economy.

1.4 The Objectives of This Book

Can we create a truly safer chemicals market? Can we rid our economies of chemicals that endanger us? Can we develop and adopt new, safer, and more sustainable chemicals? Can we make chemicals without harm? This

book offers broad outlines for a strategy and identifies and examines many initiatives that are currently under way to provide answers to these questions.

There is no need to argue that we are better off because of the advances generated by the synthetic chemical revolution—we are. Nothing in this book should be interpreted to suggest that we do not need high-performing and cost-effective chemicals; we just need different ones. Nor will we argue here that there are too many dangerous chemicals on the market. That case has been made by many others.[15] Instead of focusing on the problems that hazardous chemicals cause, this book seeks to identify potential solutions. The central question is how to preserve and extend the tremendous gains made possible by synthetic chemicals while better protecting human health and the environment. If we are serious about building a sustainable economy, then we need to become more thoughtful, more responsible, and more creative about what chemicals we make and how we use them.

This book is about a broad, international quest for a safer, sounder, and more sustainable approach to chemicals management. The book offers a new narrative about the chemicals problem—a story focused on the systems of chemical production and consumption—and it identifies an emerging movement determined to more effectively address the problems raised by dangerous chemicals. There is a central and positive argument to the book:

We can develop and use safer alternatives to the chemicals that threaten our health and environment; however, this will require a new chemical strategy focused on broad changes in science, the chemical economy, and government policy.

This book is about policy—chemical policy. However, it is also about science, politics, and the economy. We will need government and corporate policies that not only seek to reduce the use of toxic and hazardous chemicals but also to promote the development and adoption of safer, cleaner, and "greener" chemicals. We will need to transform the chemical manufacturing industries and move from a dependence on finite supplies of petroleum to more biocompatible chemicals secured from renewable resources. We will need to restructure the downstream product industries that manufacture, distribute, and sell products and manage those products once they become wastes. We will need new approaches to science, both the environmental health sciences that provide information about chemical hazards and the molecular sciences that can develop new

chemicals and chemical processes that take into account environment and health effects.

The book considers all the chemicals on the chemicals market.[16] It makes no distinction among industrial chemicals, chemicals in commercial products, agricultural chemicals, pesticides, and food additives—these are all synthetic chemicals manufactured by the chemical industry. It makes sense to consider chemicals as a whole because they are all bound together in complex and inter-related chemical production and consumption systems.

The book largely focuses on the United States. This is quite arbitrary because the chemical market and the chemical industry are global. However, there needed to be some boundaries, and the United States has fallen so far behind international expectations that finding new directions for the United States offers a much needed contribution to international chemical policies.

The book argues for a broad and comprehensive strategy for converting the chemical economy by focusing on the chemical market, the chemical industry, and the transformation of chemistry. The argument begins with an examination of past government policies to control chemicals and argues that these policies were compromised by economic, procedural, political, and implementation issues. However, this history provides useful lessons on what worked and what failed. The text moves on to present an analysis of emerging government initiatives outside the United States that represent a new wave of chemical policies built on a new set of assumptions and capacities. Arguing that the solution to the chemicals problem lies in reframing the problem, a systems view of chemical production and consumption is used to identify general principles for a more comprehensive, hazard-based, and transformative policy framework. Following a brief overview of the chemical industry and its markets, the text moves on to examine three strategic fronts that are advancing the conversion of the current systems of chemical production and consumption toward safer chemicals. The chapters that follow develop a safer chemical policy framework that include processes for characterizing, classifying, and prioritizing chemicals; generating and using new chemical information; promoting transitions to safer chemicals; and developing safer chemicals. The book closes by considering the potential role for government in advancing these policies.

To convert the current outdated chemical control policies into safer chemical policies will require a significant transformation of laws, chemical, and product manufacturing and science. We can be respectful of the

generations of scientists, industrialists, and government officials who devoted their careers to creating the rich and diverse array of chemicals that today provide the material foundation of modern economies. However, the task ahead for this century is not more commercially viable chemicals but safer and more sustainable chemicals. Indeed, the directions ahead for developing safer chemicals through basic chemistry, biochemistry, biotechnology, and nanotechnology offer many exciting challenges and innovative opportunities.

If John Warner, Dara O'Rourke, Helen Holder, Charlotte Brody, Roger McFadden, and hundreds of other nonconventional thinkers have their way, the chemistry of the twenty-first century will be far safer, cleaner, and more sustainable than the chemistry of the past. We can have chemicals with less harm, but it will take a substantial transformation of our economy and our society, and that is what this book is about.

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