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The U.S. Experience in Promoting Sustainable Chemistry

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Abstract

Background, Aim and Scope. Recent developments in European chemicals policy, including the Registration, Evaluation and Authorization of Chemicals (REACH) proposal, provide a unique opportunity to examine the U.S. experience in promoting sustainable chemistry as well as the strengths and weaknesses of existing policies. Indeed, the problems of industrial chemicals and limitations in current regulatory approaches to address chemical risks are strikingly similar on both sides of the Atlantic. We provide an overview of the U.S. regulatory system for chemicals management and its relationship to efforts promoting sustainable chemistry. We examine federal and state initiatives and examine lessons learned from this system that can be applied to developing more integrated, sustainable approaches to chemicals management.

Main Features. There is truly no one U.S. chemicals policy, but rather a series of different un-integrated policies at the federal, regional, state and local levels. While centerpiece U.S. Chemicals Policy, the Toxic Substances Control Act of 1976, has resulted in the development of a comprehensive, efficient rapid screening process for new chemicals, agency action to manage existing chemicals has been very limited. The agency, however, has engaged in a number of successful, though highly underfunded, voluntary data collection, pollution prevention, and sustainable design programs that have been important motivators for sustainable chemistry. Policy innovation in the establishment of numerous state level initiatives on persistent and bioaccumulative toxics, chemical restrictions and toxics use reduction have resulted in pressure on the federal government to augment its efforts.

Results and Conclusions. It is clear that data collection on chemical risks and phase-outs of the most egregious chemicals alone will not achieve the goals of sustainable chemistry. These alone will also not internalize the cultural and institutional changes needed to ensure that design and implementation of safer chemicals, processes, and products are the focus of the future. Thus, a more holistic approach of 'carrots and sticks' – that involves not just chemical producers but those who use and purchase chemicals is necessary. Some important lessons of the US experience in chemicals management include: (1) the need for good information on chemicals flows, toxic risks, and safer substances.; (2) the need for comprehensive planning processes for chemical substitution and reduction to avoid risk trade-offs and ensure product quality; (3) the need for technical and research support to firms for innovation in safer chemistry; and (4) the need for rapid screening processes and tools for comparison of alternative chemicals, materials, and products.

Keywords: Chemicals policy; green chemistry, REACH (Registration, Evaluation and Authorization of Chemicals); sustainable chemistry; Toxic Substances Control Act (TSCA); U.S. experience in promoting sustainable chemistry; U.S. regulatory system for chemicals management

Introduction

Recent developments in European chemicals policy, including the proposal of a regulation concerning Registration, Evaluation and Authorization of Chemicals (REACH) (European Commission 2003), provide a unique opportunity to examine the U.S. experience in promoting sustainable chemistry as well as the strengths and weaknesses of existing policies. There are some unique features of the U.S. experience in chemicals management that could provide useful insight into emerging international discussions on sustainable chemicals management. In this commentary, we provide an overview of the U.S. regulatory system for chemicals management and its relationship to efforts promoting sustainable chemistry. We examine the federal system and policies implemented at the state and local levels in the U.S, and finally, we examine lessons learned from this system that can be applied to developing more integrated, sustainable approaches to chemicals management.

The problems and limitations of industrial chemicals and current approaches to their regulation are strikingly similar on both sides of the Atlantic. These include:

A lack of information on most chemicals in commerce. Studies in the late 1990s by the European Chemicals Bureau, the U.S. Environmental Protection Agency, and advocacy groups have clearly demonstrated the lack of basic screening level toxicity data on widely used chemicals: those deemed High Production Volume (EDF 1997, US EPA 1998). Even less well studied are particular toxicity endpoints, effects of and pathways to single and multiple exposures, and uses of chemicals within supply chains. These data gaps make effective assessment and management of risks difficult, at best.

A disconnect between regulatory concepts for new and existing chemicals. Under existing laws, chemicals in use before chemicals legislation came into force (1979 in the U.S.) are considered 'registered', essentially seen as safe until government agencies demonstrate they present an unreasonable risk, while new chemicals that have come on the market since legislation are subject to data requirements and government review. This situation provides an incentive to continue using unregulated existing chemicals while discouraging innovation in newer, potentially safer chemicals.

A slow and resource intensive risk assessment process for substances suspected to be harmful places the regulatory burden on authorities. Existing policies place a high burden on government agencies to act to restrict chemicals in commerce which must be taken on the basis of detailed, costly and time-consuming risk assessments. In such cases, uncertainty about chemical impacts tends to favor inaction, while additional data are sought.

A lack of incentives to substitute and innovate from problem chemicals to safer alternatives. Given the high hurdles for government agencies to take action on existing chemicals, there is little incentive to develop or implement safer substitutes. Further, government resources on chemicals tend to be disproportionately applied to data collection and risk assessment versus risk management and innovation activities.

While the problems are similar, clearly the solutions may not be exactly the same due to political, economic, legal and cultural differences between Europe and the United States. Nonetheless, understanding these problems provides an important framework for developing the solutions that would guide us towards more sustainable chemistry.

1 Chemicals Policy in the United States: Background and Drivers

Toward the end of the 1960s several notable incidents involving synthetic chemicals and heavy metals attracted the attention of the media and the American public (Randall et al. 1977, DeVito and Farris 1997). Following publication of a 1971 U.S. White House Council on Environmental Quality (CEQ) report on the lack of data and government oversight of chemical hazards, the U.S. Congress initiated several years of heated debate culminating in the Toxic Substances Control Act of 1976 or TSCA (Council on Environmental Quality 1971, see Tickner 2000). TSCA was designed as 'an early warning system' to identify potential dangers before chemicals are widely dispersed throughout commerce and damage has occurred. The law's drafters noted that "*the most effective and efficient time to prevent unreasonable risks to public health or the environment is prior to first manufacture. It is at this point that the costs of regulation in terms of human suffering, jobs lost, wasted capital expenditures, and other costs are lowest (United States Congress 1976: 161).*"

Since the passage of the Toxic Substances Control Act in 1976 (see section 1.1), there have been numerous drivers in the U.S. for actions to test and manage toxic substances and to promote safer chemicals and processes. These include: impacts of chemicals on health and ecosystems in the Great Lakes basin; concerns about the impacts of chemicals on children and other vulnerable sub-populations; chemical accident prevention and chemical security, particularly in the age of global terrorism; and waste management and pollution prevention where the costs of chemicals in waste streams are often borne by municipalities.

1.1 The Toxics Substances Control Act of 1976: Centerpiece of US chemicals regulation

TSCA "*established the principle of public interest in the marketing of chemicals* (Davies 1999)." The Congressional intent, described in section 2 of TSCA (15 U.S.C. 2601–2692), is for industry to have responsibility to understand chemical risks and government to have authority to control unreasonable risks in a way that does not hinder innovation. Under TSCA a "*new chemical substance*" is defined as "*any chemical substance which is not included in the chemical substance list compiled and published under [TSCA] section 8(b).*" This list, called the 'TSCA Inventory,' is a list of all chemical substances in commerce prior to December, 1979. All chemicals on the market prior to this date (about 60,000 substances, more than 99% by volume of what is on the market today, are considered existing chemical substances (see Inform, Inc. 1995).

TSCA contains a number of key provisions that address data collection and risk management for new and existing substances (see Brown et al. 1999 and Ashford and Caldart 1997). These include:

- **Section 5:** Prohibits the manufacture, processing, or import of a "*new chemical substance*" or "*significant new use*" of an existing substance unless a premanufacture notification (PMN) is submitted to EPA at least 90 days before the commencement of manufacture or processing. The PMN contains information on the chemical identity, physical characteristics, processing and use, and available toxicity data. During this 90-day period, EPA reviews the chemical's human and environmental risks and exposures, examining the data submitted in addition to other information. EPA can then request more data, prohibit or limit manufacture, or halt the review process.
- **Section 6:** Authorizes the EPA to issue regulations to address the risks of existing substances that present an unreasonable risk to health. Such regulations can be issued immediately when a threat of harm is imminent.
- **Section 4:** Compels the EPA Administrator to require the testing of chemical substances or mixtures, new or existing, if 1) there are insufficient data to make an unreasonable risk determination and testing is necessary; and 2) the chemical substance or mixture may present an unreasonable risk or the chemical will be produced in substantial quantities and either may enter the environment in substantial quantities or lead to significant or substantial human exposure.
- **Section 8:** Authorizes EPA to promulgate rules that require chemical manufacturers, processors, and distributors to maintain records and make reports on chemicals and mixtures. This includes requirements to submit health and safety studies, provide immediate notice of 'substantial risks,' and maintain records of adverse health effects for 30 years. This section allows EPA to issue rules to collect production and use information as well as information on disposal and byproducts.

1.2 Limitations of management of existing chemicals

Despite the years of debate over TSCA and great hopes that it would help eliminate substantial gaps in the regulation of toxic substances, its implementation has been less than successful, particularly for existing chemicals. In implementing restrictions on the manufacture or use of toxic chemicals, the EPA has an extremely high burden to act under TSCA, which results in few chemical restrictions. To restrict such chemicals EPA must prove that the chemical "*will present an unreasonable risk*", that it is choosing the least burdensome regulation to reduce risks to a reasonable level, and that the benefits of regulation outweigh the costs to industry. EPA must do this on a chemical-by-chemical basis. Following an unsuccessful effort to phase-out asbestos after a ten year regulatory process (see Percival et al. 1992), EPA has determined that the opportunity costs of restricting substances are more often than not, too high (see Goldman 2002, Tickner & Geiser 2003, Gottlieb 1995) A 1994 report by the U.S. Government Accounting Office (GAO) found that throughout its existence EPA has restricted only five chemicals (PCBs, chlorofluorocarbons, dioxin, asbestos, and hexavalent chronmium).[1] That number has only slightly increased in the past decade. EPA has in recent years undertaken consent agreements with individual companies to stop production of problem chemicals on a voluntary basis – such as with the penta- and octa-brominated diphenyl ethers (USEPA 2004). While important, overall the EPA's lack of power to regulate existing chemicals actually provides a disincentive to bringing safer chemicals to market.

1.3 New chemicals review – A bright and under-recognized light

Despite TSCA's limitations for existing chemicals, the new chemicals program has proven to be a successful example of a precautionary screening and review policy. The new chemicals provisions of TSCA apply at the premanufacture stage (before any marketing or major investment in the production of a chemical has occurred) and place a low initial threshold for agency action: "*may present an unreasonable risk to human health or the environment or substantial exposure throughout their production, use, and disposal*." In conducting the premanufacture reviews, the EPA uses a multidisciplinary lifecycle review approach involving long-standing agency scientists to rapidly assess the risks associated with new chemicals. Through *deterrence* from potentially harmful chemicals and *guidance* toward safer chemicals and production methods, the EPA provides strong signals to manufacturers as to types of chemicals that might present an unreasonable risk and types of chemicals and synthesis pathways that will reduce risks. EPA's tools include (see Tickner 2000):

- **Categories of chemicals**. The EPA has used its 'Chemical Categories' list to indicate the types of chemicals that pose risks of concern to the agency and the types of data needed to evaluate those risks. As a result, companies are more likely to present data and avoid the possibility of regulation.
- **Informal communication and negotiation with submitters**. If EPA staff express concern over a premanufacture notice, submitters are not likely to question those concerns and will either withdraw the chemical or come up with the data.
- **Pollution prevention initiatives.** EPA has set up voluntary programs to encourage the development of safer chemical products and production systems, including providing software to firms to understand chemical risks and safer syntheses. These help to internalize considerations of safety at the earliest points of the research and design phase of chemicals. Since it is difficult for the agency to regulate chemicals once they are on the market, having these tools can promote safer chemicals that can eventually replace problematic older ones. Under EPA's Sustainable Futures program, employees of participating firms undergo training on pollution prevention in exchange for some flexibility in the company's PMN submissions (USEPA 2004a).

An unexpected and important outcome of the EPA's New Chemicals Program has been the development of tools and processes to rapidly evaluate chemical lifecycle risks in a multidisciplinary manner and in the face of uncertain or missing data. Because notification occurs at the premanufacture stage, companies are only required to submit available data (and in some instances some testing). As such, only a small percentage of premanufacture notifications come into the agency with toxicity or even physiochemical data. Due to this lacking data, over the past twenty years, the Environmental Protection Agency has developed a number of methods and tools including quantitative structure activity relationship (QSAR), as well as exposure assessment and hazard assessment tools (e.g., EcoSAR, Oncologic, CHEMSTEER, EPISUITE, see Waugh 2004)). These tools are then updated as data come in on particular chemicals. Tools such as EPA's Pollution Prevention Framework (including the PBT profiler) are widely distributed to government agencies and industry (USEPA 2004b). While the new chemicals program could be strengthened through the addition of tiered testing requirements as production of new chemicals increases (to avoid repeating the current lack of information and power to regulate problem substances), the program has proven itself to be an efficient process. However, the new chemicals program applies to less than 1 percent by volume of the chemicals on the market today.

1.4 Data collection efforts on new and existing chemicals

EPA has had some modest successes obtaining data on chemical toxicity, use, and exposure under TSCA's section 4's testing and information provisions, and section 8's provision to disclose knowledge of substantial risks from chemicals, providing an early warning system. Section 8 also allows EPA to issue rules to collect production and use information as well as information on disposal and byproducts. This includes the Inventory Update Rule, which generates an inventory every four years of all of the non-polymer chemicals produced in or imported into the United States. The newest update will include supply chain and exposure data for chemicals (USEPA 2005). Nonetheless, it is interesting to note that some 25 years after the passage of TSCA, the very problem for which the Act was enacted, lack of data on chemicals, has not been solved. Although TSCA section 4 provides EPA with authority to require chemical testing, few test rules have been enacted. In part, this is because EPA

[1] PCBs were banned under TSCA in 1976 and the asbestos ban was overturned by the Fifth Circuit Court of Appeals.

must first have some data to demonstrate that the substance 'may present an unreasonable risk or substantial exposure' before requiring more data and must defend its requests for data usually on a chemical-by-chemical basis (Goldman 2002). Given these limitations, EPA has used voluntary initiatives such as the High Production Volume Challenge (see section 2.1) to achieve its goals.

2 Other Facets of U.S. Chemicals Policy

Due to its limitations to regulate existing chemicals, EPA has relied heavily on a range of voluntary initiatives to achieve chemicals testing and management goals. While many of these initiatives have been extremely successful and should form a part of a comprehensive chemicals management strategy, they also need the support of a regulatory program. These programs include:

2.1 Chemical right to know

The United States has a long history in promoting right to know. The 1986 Emergency Planning and Community Right to Know Act established the Toxics Release Inventory (TRI), a national, publicly-available inventory of emissions and waste generated from manufacturing facilities. In 1998, following studies on the lack of data on high production volume (HPV) chemicals – those used over one million pounds per year (about 500 metric tonnes) (see USEPA 1998), EPA initiated its Chemical Right to Know Initiative to better understand the hazards posed by HPVs, to improve reporting of persistent, bioaccumulative, or toxic substances (PBTs), and to facilitate public awareness of the dangers these chemicals may pose to children. Three programs were designed to facilitate the goals of the Initiative: (1) the HPV Challenge Program, (2) the Voluntary Children's Assistance Program, and (3) PBT Chemical Reporting (USEPA 2003). The HPV Challenge is described in more detail below.

The HPV program has perhaps been the most widely discussed of the Right to Know Initiative efforts. In 1998, the EPA entered into a voluntary 'challenge' with the American Chemistry Council and an environmental advocacy group for industry to provide basic screening level data (the Organization for Economic Cooperation and Development's Screening Information Data Set) on the 2800 HPV chemicals. To date, the program has been fairly successful, with industry consortia 'adopting' almost 99% by tonnage of the HPV chemicals and producing robust summaries of toxicity data. However, there are about 500 'orphan' chemicals which have not been adopted by industry consortia, and the program does not address chemicals that have achieved HPV status since 1998. Further, the program does not cover the more than 6,000 chemicals currently used annually in cumulative quantities between 10,000 and 1,000,000 pounds (about 2 metric tonnes to 500). Despite the program's somewhat limiting scope, the HPV challenge has shown that industry has substantial amounts of non-public data on chemical hazards (USEPA 2004c, ED 2004).

2.2 Pollution prevention

Emissions and waste data from the Toxics Release Inventory have proven remarkably important in promoting industry consciousness about the efficiency of toxics use. The Pollution Prevention Act of 1990 elevated pollution prevention as the fundamental goal of the environmental protection efforts in the US. While the Act did not prescribe any particular agency actions, it has led to the establishment of a number of successful EPA voluntary research and outreach efforts. Pollution prevention represents an important and indirect route to chemicals management – production process redesign and product design change can result in a substantial reduction or substitution of problem materials. EPA's efforts on pollution prevention have ranged from voluntary sector or use based initiatives to examine alternatives to problem substances, to procurement guidelines, to product labeling initiatives, to design challenges. Unfortunately, these innovative programs tend to be underfunded and understaffed as compared to more traditional risk assessment programs (Geiser 1997). Three of EPA's most successful pollution prevention programs include:

2.2.1 Design for environment (DfE)

The DfE program is a series of voluntary partnerships with stakeholders to prevent chemical exposures through educated business decisions (Graedel and Allenby 1996, USEPA 2004d). The DfE program identifies a range of technologies, products, and processes that can be used to prevent pollution; evaluates and compares the risk, performance, and cost tradeoffs of the alternatives; and disseminates information on the alternatives. DfE is comprised of 13 separate projects that involve industry by sector, such as the Environmentally Preferable Approaches for Achieving Furniture Fire Safety Standards initiative.

2.2.2 Green chemistry

To encourage the development and use of safer chemicals, the U.S. EPA has been a leader in promoting green chemistry, chemical processes and products that are safer throughout their production use and disposal (Anastas and Warner 1998, USEPA 2004e). EPA has established four green chemistry programs: (1) The Presidential Green Chemistry Challenge offers individuals, groups or organizations reward for innovations that help benefit human or environmental health. (2) Educational materials through EPA and American Chemical Society partnership to ensure that green chemistry innovations are being incorporated into students' education of chemistry; (3) Integration of green chemistry considerations into new chemicals design; and (4) the Green Chemistry Institute, born from a partnership between the American Chemical Society, is a non-profit entity that promotes environmentally friendly chemistry through research, education, and sharing of information between stakeholders.

Despite EPA's leadership in promoting green chemistry, its implementation in practice has suffered from a general lack funding (the Eventual passage of the Green Chemistry Research and Development Act now being debated in Congress will hopefully elevate the importance and funding for Green Chemistry efforts).

2.2.3 Persistent, bioaccumulative and toxics program

The EPA's Persistent and Bioaccumulative Toxics (PBT) program, emphasizes multi-media, cross-program management of PBT substances. Through the program the EPA has established precautionary guidelines for chemical manufacturers to avoid bringing new PBTs to market and developed Internet-based tools to assess chemicals for their potential persistence and capacity to bioaccumulate. The EPA is currently working on priority PBTs – in conjunction with the Binational Toxics Strategy (see section 3) – such as mercury and dioxins for reductions (USEPA 2004e).

3 State and Regional Policy: Drivers for Innovation in Chemicals Policy in the U.S.

Traditionally the states and regions have been the innovators in environmental policy in the United States and chemicals policy is no exception, particularly given limited federal oversight on existing chemicals. Over the past thirty years several regional and state initiatives have provided important signals to the federal government of the need for national policy. For example, regional efforts in the Great Lakes on persistent and bioaccumulative substances led to a national policy and several state level initiatives for the right to know ultimately resulted in federal legislation in this area. With increasing pressures from Europe and elsewhere to substitute problem chemicals in products, such as electronics, states are beginning to initiate their own restrictions on such substances. Some state and regional chemicals policy efforts include: *Please give numbers to the subchapters.*

3.1 Great Lakes

Much of the world's attention to the impacts of persistent and bioaccumulative toxics originated in the Great Lakes region. To address contamination of the Great Lakes region, the U.S. and Canada signed the Great Lakes Water Quality Agreement in 1977 to expresses a joint commitment to restore and maintain the chemical, physical and biological integrity of the Great Lakes Basin Ecosystem The Agreement calls for the virtual elimination of persistent and bioaccumulative pollution in the region and the subsequent Great Lakes Binational Toxics Strategy provides a mechanism for voluntary actions to reduce priority PBT chemicals (USEPA 2003a, 2004g).

3.2 Pollution Prevention

There are more than 30 state level pollution prevention initiatives in the US. Most focus primarily on education, outreach, research and demonstration projects on pollution prevention (Spektor and Roy 2003). However, several states, including Massachusetts and New Jersey, have mandatory requirements for firms to conduct analyses of pollution prevention options, which include chemical substitution.

3.2.1 The Massachusetts Toxics Use Reduction Act (TURA)

The Toxics Use Reduction Act (TURA) of 1989 is an example of how integrated state pollution prevention policies can foster innovation in more sustainable chemistry. The Act requires that manufacturing firms using specific quantities of some 900 industrial chemicals undergo a biyearly process to identify alternatives to reduce waste and the use of those chemicals. Through the toxics use reduction planning process firms understand why they use a specific chemical (what 'service' it provides), and how it is used in the production process. They also conduct a systematic search for and comprehensive financial, technical, environmental, and occupational health and safety analysis of viable alternatives.

In its broadest sense, The Toxics Use Reduction Act does not instruct industrial facilities to identify the 'safe' level of use, emissions or exposure to chemicals. The act instructs firms to identify ways to redesign production processes and products and provides six different methods that 'count' as toxics use reduction (including chemical substitution, for example replacement of a chlorinated solvent with an aqueous one; process change, for example use of high pressure paint applicators; product change, using a different plastic to avoid the use of phthalates; and improved management, for example, upgrading equipment and procedures to more effectively manage chemical flows). Several aspects of the toxics use reduction process make it a good example of a policy framework to support sustainable chemistry: (1) goal-setting for waste and toxic chemical reduction, (2) a commitment to avoid trade-off risks, (3) required analysis of alternative chemicals and process designs to reduce toxics use, and (4) required review of progress. Further, technical and research support are provided to firms by university and state government technical assistance providers to help identify, examine, and test potential options. Research grants are also provided to individual companies, communities, and other stakeholders to research, develop and implement alternative safer chemistries (Tickner and Geiser 2004).

Between 1990 and 2000, the Toxics Use Reduction Program can demonstrate that the some 550 firms that have continuously participated in the program have reduced the total amount of toxic and hazardous waste by 58 percent and the use of the targeted toxic chemicals by more than 40 percent while the state has seen a 90 percent drop in Toxics Release Inventory releases (MATURI 2004). Through 2004, use of one chemical, trichloroethylene used in degreasing operations, was reduced from 2.5 million pounds per year to 25,000 lbs per year as a result of an aggressive research, outreach, and testing program of alternative cleaning technologies. In 1997, the Massachusetts Toxics Use Reduction Institute (a research and technical support unit established by the law) conducted an analysis of the Act demonstrating that the Act saved Massachusetts industry some $15 million over a seven year period. This figure does not include the public health and environmental benefits gained through the program (MATURI 1997).

Emerging European and international regulations, such as the Directive on Restrictions on Hazardous Substances and

Waste from Electronic and Electrical Products have provided an incentive to extend the Toxics Use Reduction model to product design. The Massachusetts Toxics Use Reduction Institute at the University of Massachusetts Lowell is currently working with companies in the electronics supply chain to identify alternatives to problem materials in electronics production. Further the state legislature will in 2005 consider new legislation that would require the establishment and implementation of substitution action plans for ten priority substances.

While many states have passed legislation phasing out specific chemicals (such as mercury of brominated diphenyl ethers) or limiting their use or discharge, as a group these are too specific to single chemicals to affect any fundamental shift in regulatory paradigm. Despite this, it is likely that state level chemicals policy efforts will provide the impetus for future federal reform. One example is in the state of Washington which in 1998 implemented a state-wide phase out policy on persistent, bioaccumulative and toxic (PBT) chemicals. Under the policy, action plans for voluntary and mandatory industry actions on particular substances, such as mercury, are being developed (WADEQ 2004). Finally, in California, which plays an important role in national environmental policy due to its sheer size, the 1986 Safe Drinking Water and Toxic Enforcement Act (also known as Prop 65), prohibits businesses from discharging chemicals with carcinogenic or reproductive toxicity effects into sources of drinking water. Under the law the Governor is required to maintain a list of chemicals covered by the Act and Businesses must also provide clear warning to individuals exposed to these chemicals by activities of the business (COEHHA 1986).

4 Discussion – Lessons Learned for Sustainable Chemicals Management

As noted in the previous sections, the U.S. experience in chemicals management is highly diverse with successful and less successful components. Nonetheless, taken together, there are some important lessons that could serve to inform international dialogues on sustainable chemicals management. These are discussed below.

4.1 The important role of good information for sustainable chemistry

Information is critical for companies, authorities and the public to understand and act on risks and to stimulate safer and cleaner alternatives. While data are important for understanding chemical hazards, exposures, and risks, data on materials flows are equally important to understanding how chemicals are used, the efficiency with which they are used, their uses throughout a supply chain, and opportunities for preventive interventions. For example, industry research has demonstrated that chemical firms often know very little about the supply chain uses of their chemicals more than one or two steps down the supply chain (RPA 2002). It is virtually impossible to manage chemicals without this knowledge. Experience with toxics use reduction in Massachusetts and other places has found that many companies are extremely inefficient in chemicals management, with information on chemicals use being dispersed throughout the firm. When firms are required to conduct a materials accounting (how the chemical comes into the firm, is transformed, and leaves the firm), many recognize this inefficiency in materials management and are more apt institute programs to reduce risks. Materials accounting (combined with facility planning) has thus been of critical importance for stimulating toxics use reduction particularly in firms that are downstream users of chemicals – where chemicals provide a 'service' that can often be provided by less problematic substances (MATURI 1997). Similarly, the Toxic Release Inventory requirements of the 1986 US Emergency Planning and Community Right to Know Act have led many business leaders to institute production and product changes for pollution prevention.

Finally, it is virtually impossible to understand the impacts of policies or improve their implementation without data on costs and effects of reductions in chemical use or emissions. Thus, data such as that on chemicals flows and chemical exposure, plays an important role in providing metrics as to the efficacy of policies. While metrics as to the efficacy of chemicals policies are hard to define (for example reductions in disease), there are metrics, such as chemical use, which serve as surrogate measures. The Nordic Product registers provide an interesting data source for understanding reductions in chemical use in products. The various registers, which keep track of chemicals (type and quantities) used in products have been compiled into a database called SPIN (SPIN 2004). However, the data are in a form that makes analyses of trends difficult to conduct and as such few analyses of the database have been completed.. The lack of post-implementation data collection represents a critical gap in the European approach to chemicals management, and one that makes regulators and others in other countries, such as the United States, highly skeptical of the impacts of European policies. The lack of such data inhibits the ability to understand the efficacy of various policy tools, impacts of enforcement, and the overall impacts of policy on chemicals management culture and the economy.

Information serves no purpose if it is not used. Right to know efforts in the U.S. have demonstrated the power of public information for prevention (Greenwood and Sachdev 1999, Inform, Inc 1995). As such, provision of information needs to be an active requirement of firms. The use of an Internet database is important – for information on chemicals flows, risks and regulatory actions. Such public provision of information does need to be balanced with protection of legitimate confidential business information. However, trade information protections should not occur at the expense of public health protections and should not protect data that are readily available through other means such as the Chemical Economics Handbook. The experience with the overly liberal confidential business information under the Toxic Substances Control Act demonstrates that too much protection can lead to an unnecessary diversion of agency resources from protecting health to protecting data (Goldman 2002).

4.2 The need for comprehensive planning for sustainable substitution

Chemicals are used in production processes and products. Chemical substitution and phase-out policies often fail to consider the implications of substitution or chemical reduction on process and product design or health. Alternative chemicals and process changes may not only involve shifts in chemical risks (to workers and communities) but also in physical and psychosocial risks associated with changes in work patterns (Ashford 1996). Comprehensive consideration of alternatives may also help reduce exposures to other chemicals that may not be of high concern under regulatory programs (for example PBTs) but may be of concern due to their potential for safety or accident risks.

Thus, having clear and comprehensive planning processes – with clear guidance and training support from government – can help ensure more sustainable chemicals management. Planning is critical to: (1) understanding materials flows and supply chain linkages; (2) understanding production processes and product design – why and how chemicals are being used; (3) understanding options for reducing problem chemical use in either production or process design, while maintaining the desired function of the chemical; (4) understanding the performance, health safety and environmental, and economic trade-offs involved; and (5) establishing priorities, performance targets and measuring progress towards more sustainable process and product design.

As described above (see section 4.1), planning plays a central role in the Massachusetts Toxics Use Reduction program. Support for planning in chemicals policy efforts can help ensure that manufacturers, downstream users, and retailers consider the potential trade-off risks involved in chemical substitution and to consider other options for reduction in hazardous chemicals use (e.g., process efficiency or design change). An important part of the planning process is considering technological feasibility. Alternative substances may not provide the same level of product quality or characteristics as the original substance or a substance with multiple functions may require multiple substitutes. A great concern for companies is product quality, and if product quality will be reduced as a result of substitution, managers may be hesitant to move forward. While feasibility concerns should not stop the quest to seek substitutes, they are important. Technical support to firms in substitution could play an important role in ensuring safer and technically feasible alternatives.

4.3 The need for technical, research, and financial support for innovation

Analysts of technology change note that innovation requires a series of conditions to be successful, which can be termed 'willingness and capacity' or 'motivation and facilitation' (Ashford 1999). Legislation and market forces can institute willingness by forcing data collection and action on particular chemicals and by instituting a culture of sustainable chemicals management. However, capacity or facilitation often times is as important or a more important factor for stimulating innovation, and the lack of technical and research support can hinder sustainable chemistry efforts. Industry is not always that innovative on its own, particularly small- and medium-sized companies. Thus, support for innovation through technical assistance, information, and research support on process design, chemical synthesis, and green chemistry should play an important role in the implementation of any sustainable chemistry. Some ways in which governments can support innovation in sustainable chemistry (which could be funded in part by fees on problem chemicals) include:

- Education, training, and outreach on substitution methods and development of tools for assessment. Such efforts can provide the skills to industry and others to examine options, ensure minimization of risk trade-offs and internalize sustainable chemistry within the firms decision-making structures. Tools to assess and compare alternative chemicals – such as those being developed by the U.S. EPA – can assist firms in guiding them towards safer substances in materials development and procurement.
- Research and development funding for safer substances. Public or privately funded technical assistance could be effectively applied to development of safer alternatives to problem substances. Such research, development and assessment projects could be done on a particular substance basis or use basis (such as chlorinated solvents or brominated flame retardants).
- Direct technical support to firms for substitution. Often firms may have a desire to substitute a particular substance but do not have the technical resources to evaluate or implement alternatives. In some cases, firms may be reluctant to try a new technology that has not been proven in their particular use. Government agencies and academic institutions can provide important technical support to firms in evaluating alternative technologies, undertaking demonstration projects to show their use in practice, and networking firms working on similar problems. In the state of Massachusetts, for example, work of the Surface Solutions Laboratory at the University of Massachusetts Lowell has been critical to the substitution of chlorinated solvents (see <www.cleanersolutions.org>). The lab evaluates and tests alternative cleaning systems for firms using their own materials and substrates, thus virtually eliminating the technological risk to firms and facilitating substitution.
- Finally, recognition of leading companies and research is critical to supporting innovation. The U.S. government and several states have undertaken awards for innovation in green chemistry and toxics use reduction that serve to provide an impetus for innovation efforts.

4.4 The need for rapid assessment tools for chemicals

One of the key concerns about present chemicals management programs is their emphasis on costly, slow, chemical by chemical risk assessments. This is a potential pitfall of data intensive policies such as the European Commission's proposed REACH policy. There is a need for tools to more rapidly assess chemicals on the basis of uncertain data and structural analogs that can be validated and improved when actual data arrive. Such rapid processes can ensure more effective and rapid decisions on chemicals (providing signals of which chemicals could be problematic or safer), thus helping firms make more health protective design decisions. Rapid assessment and screening tools – such as those developed by U.S. EPA for new chemicals – can help firms and government agencies:

- More rapidly characterize chemical hazards and exposures,
- Prioritize chemicals for substitution and other risk management actions,
- Identify structural attributes that can make chemicals problematic,
- Identify safer chemicals and structures,
- Allow for comparisons between substances,
- Build expertise and databases of accumulated knowledge on substances.

5 Conclusions

The Need for Multiple Tools and An Integrated Approach to Achieving Sustainable Chemicals Management

There is truly no one U.S. chemicals policy, but rather a series of different non-integrated policies at the federal, regional, state and local levels that provide some important lessons to guide future discussions on sustainable chemistry. Most important, a truly integrated chemicals policy to support sustainable chemistry should consist of voluntary and mandatory tools (including regulatory powers to act on uncertain information), research on chemical risks and alternatives, and a consideration of lifecycles of substances and their use in products. It would also integrate protection of consumer and environmental health with occupational health. It would integrate a multi-media approach and a multi-agency approach to chemicals management to avoid piecemeal, uncoordinated, and often opposing efforts. This is no simple challenge.

It is clear that data collection on chemical risks and phaseouts of the most egregious chemicals alone will not achieve the goals of sustainable chemistry. These alone will also not internalize the cultural and institutional changes needed to ensure that design and implementation of safer chemicals, processes, and products are the focus of the future. Thus, a more holistic approach of 'carrots and sticks' – that involves not just chemical producers but those who use and purchase chemicals – is necessary. Some of these multiple tools include: procurement policies; government and industry lists of problem chemicals; requirements for chemical reduction and substitution planning; technical and research support for designing and implementing safer chemicals; tax and liability incentives for firms; demonstration projects, and product labeling and producer responsibility. It is necessary to integrate chemicals policy efforts with other efforts on cleaner production, integrated product policy, and sustainability as chemicals play a critical role in both making our lives easier and healthier but also potentially more dangerous.

Ultimately, achieving sustainable chemistry requires shifting our regulatory emphasis from one on reacting to risks, to one focused on solutions and innovation in safer chemistry – that achieves the important functions that chemicals provide while minimizing their impacts on society. Such a transition represents a major cultural shift in policy and funding resources, but would be critical in achieving the win-win conditions that underscore sustainable chemistry.

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