Applying Environmental Product Design to Biomedical Products Research

James Messelbeck[1] and Lara Sutherland[2]

[1]Applied Biosystems, Foster City, California, USA; [2]INFORM, Inc., Somerville, Massachusetts, USA

The principal themes for the Biomedical Research and the Environment Conference Committee on Environmental Economics in Biomedical Research include the following: healthcare delivery companies and biomedical research organizations, both nonprofit and for-profit, need to improve their environmental performance; suppliers of healthcare products will be called upon to support this need; and improving the environmental profile of healthcare products begins in research and development (R&D). The committee report begins with requirements from regulatory authorities (e.g., U.S. Environmental Protection Agency [EPA], the U.S. Food and Drug Administration), and the healthcare delivery sector). The 1998 American Hospital Association and EPA Memorandum of Understanding to reduce solid waste and mercury from healthcare facilities is emblematic of these requirements. The dominant message from the requirements discussion is to ensure that R&D organizations do not ignore customer, environmental, and regulatory requirements in the early stages of product development. Several representatives from healthcare products manufacturers presented their companies' approaches to meeting these requirements. They reported on efforts to ensure that their R&D processes are sensitive to the environmental consequences from manufacturing, distributing, using, and disposing of healthcare products. These reports describe representatives' awareness of requirements and the unique approaches their R&D organizations have taken to meet these requirements. All representatives reported that their R&D organizations have embraced environmental product design because it avoids the potential of returning products to R&D to improve the environmental profile. Additionally, several reports detailed cost savings, sustainability benefits, and improvements in environmental manufacturing or redesign, and increased customer satisfaction. Many companies in healthcare delivery are working to improve environmental performance. Fundamental to these efforts is the necessity of motivating suppliers to improve the environmental profile of new products used in the healthcare delivery sector. *Key words:* biomedical research, environmental economics, environmentally preferable purchasing, environmental product design, green chemistry, pharmaceutical industry, pollution prevention, research and development, U.S. Food and Drug Administration, waste reduction. — *Environ Health Perspect* 108(suppl 6):997–1002 (2000).
http://ehpnet1.niehs.nih.gov/docs/2000/suppl-6/997-1002messelbeck/abstract.html

This report highlights presentations made at the Biomedical Research and the Environment Conference held 1–2 November 1999 at the Natcher Conference Center, National Institutes of Health, Bethesda, Maryland, by the Committee on Environmental Economics in Biomedical Research and Products Development and Applying Environmental Product Design to Biomedical Research.

The need to improve environmental performance of the healthcare delivery system has implications for attention at both the local and national levels. For example, in 1998 the American Hospital Association (AHA) and the U.S. Environmental Protection Agency (EPA) signed a Memorandum of Understanding, an agreement to work together to dramatically reduce solid waste and mercury from hospitals and their allied healthcare facilities. To support this agreement, the suppliers of medical products will be called upon to provide products with improved environmental profiles. Thus, medical product manufacturers will need to consider environmental aspects in their research and development (R&D) processes, as well as in their manufacturing processes.

This report discusses how some forward-thinking R&D organizations in the medical products industry have embraced this environmental challenge to ensure that their products meet numerous regulatory and customer requirements while providing safe, efficacious, and cost-effective medical products. A specific goal of the committee was to present methods that several R&D organizations use to meet customer and regulatory requirements.

These methods are referred to as environmental product design (EPD). EPD is not unique to the medical products field. It has been used successfully in the electronics and automobile industries to improve environmental performance. This model, "pulling" environmental attributes through the supply chain and the manufacturing system, can be applied in the healthcare delivery system.

The Healthcare Sector and the Environment

The environmental effects of the healthcare industry came into public consciousness dramatically in 1987 when reports of medical waste washing up on public beaches was reported by national news. Since that time, attention to the medical sector by grassroots environmentalists and environmental regulators has increased considerably. In addition, EPA has named medical waste incinerators the fourth largest source of mercury in the environment (*1*) and also a major source of dioxin (*2*). In 1999 EPA promulgated new and controversial emissions standards for medical waste incinerators (*3*).

With this activity has come increased attention to mercury in general, which has been a focus of the Great Lakes U.S.–Canada Binational Toxics Strategy (*4*), the 1998 EPA "Action Plan for Mercury" (*5*), and the EPA "Persistent, Bioaccumulative, and Toxic Chemicals Initiative" (*6*). New England governors and eastern Canadian premiers have agreed to aggressively reduce mercury use and emissions in that region (*7*), and many New England states are considering ambitious legislation to require the labeling of mercury products and reduction of mercury use (*8*).

At the same time, various grassroots efforts have evolved to push for implementation of the regulations and other environmental improvements.

Hospitals have also been facing increasing financial pressures and escalating waste disposal bills. Many hospitals have found they could save money through waste reduction and have used this opportunity to create excellent environmental programs that reduce or eliminate mercury use, institute recycling programs, and strictly segregate infectious waste to reduce its volume.

A major outcome of this interest in environmental effects of the healthcare industry is the current partnership between the AHA and EPA. In 1998 the AHA and EPA signed a Memorandum of Understanding agreeing to work together to virtually eliminate mercury waste and to dramatically reduce solid waste coming from healthcare facilities. Activities resulting from the Memorandum of Understanding , now called Hospitals for a Healthy Environment, include planned seminars to bring pollution prevention and waste

This paper is based on a presentation at the Leadership Conference: Biomedical Research and the Environment held 1–2 November 1999 in Bethesda, Maryland, USA.

Address correspondence to J. Messelbeck, URS Corporation, 7 Hutton Centre Dr., Suite 700, Santa Ana, CA 92707 USA. Telephone: (650) 554-2274 Fax: (650) 638-5884. E-mail: messeljr@appliedbiosystems.com

Received 3 May 2000; accepted 27 October 2000.

minimization technology and knowledge to hospitals across the country. The AHA plans to collect information from their member hospitals on the implementation of these techniques and is developing an awards program to honor hospitals that excel in environmental programs.

Environmentally Preferable Purchasing

Hospitals continuously reviewing business expenses have discovered savings opportunities in waste management costs. In addition, the Federal government and many state agencies have been mandated to study environmental issues in purchasing practices of hospitals. Environment-conscious healthcare organizations are looking for products that reduce their environmental and waste disposal costs, products without toxic or otherwise problematic components or ingredients, and suppliers that show a corporate environmental commitment beyond meeting compliance and performance standards. Consequently, medical product producers are responding by improving the environmental profile of their products.

Some healthcare purchasers are also looking for suppliers who share their environmental commitment and vision. This commitment can be demonstrated by having a strong environmental record both here and abroad, continually improving the environmental performance of the product and its packaging, and responding to environmental needs of the customers. Products that help the facility reduce environmental and waste disposal costs include those with reduced packaging or fewer toxic constituents and products that conserve energy and water. Products with mercury, other persistent bioaccumulative toxins, or, in some cases, polyvinyl chloride (PVC) cannot meet the needs of an environmentally conscious purchaser.

Many healthcare delivery organizations have begun to look at environmental attributes in their purchasing, especially in terms of energy efficiency. Some organizations have made environmental excellence part of their mission and have translated this into their purchasing policies. Catholic Healthcare West (CHW), for instance, has committed itself to the principles of the Coalition for Environmentally Responsible Economies (CERES) (*9*). This commitment has been extended to its suppliers. CHW included environmental values into its written agreement with Premier, a group-purchasing organization. Premier has agreed, as part of its relationship with CHW, to support CERES, the Health Care Without Harm campaign, (*10*) and reduction of the volume and toxicity of the medical waste stream. Premier has also agreed to assist CHW in identifying products containing mercury and PVC, to consider the environmental impact of a product or service for which it contracts, and to communicate the desire for environmentally favorable products to manufacturers (*11*).

Kaiser Permanente has also made a commitment to improving its environmental bottom line. Kaiser states in its requests for proposals that it will be

> demonstrating a preference for products that cause the least amount of environmental harm during manufacturing, use, and disposal in partnering with suppliers who demonstrate a commitment to environmental quality through their business practices. (*12*)

Kaiser determined that latex gloves often caused allergies in its employees and that the environmental attributes of latex were worse than those of nitrile (*13*).

The Boston area hospitals served by the Massachusetts Water Resource Authority water treatment facility have been under much regulatory pressure to reduce mercury in their wastewater discharge. These hospitals have stopped buying certain products and brands that tested positive for mercury. This list is available as a public database to help hospitals identify products containing mercury (*14*).

These efforts form the beginning of environmental purchasing for healthcare organizations. As environmental demands on hospitals increase and more public awareness encourages hospitals to be proactive in their environmental programs, healthcare environmental purchasing will mature. Expectations of the environmental value of products will increase, and suppliers and manufacturers will need to look for efficient ways to determine the environmental needs and values of their customers and incorporate these features into the products they offer. Incorporating customer needs at the R&D level is crucial to the success of ultimately bringing environmental attributes to the product because it is most efficient to consider production changes at this stage. Manufacturers able to position themselves to meet the environmental specifications of healthcare purchasers will be at an advantage in the marketplace.

Regulation of the Pharmaceutical Industry

EPA has worked with the pharmaceutical industry to encourage and implement pollution prevention measures through waste minimization, identification of waste streams, optimization of process trains, and solvent reuse and recovery. A variety of pollution prevention measures are available to pharmaceutical manufacturers, including material substitution in tablet coating and equipment cleaning methods, process modifications in transfer operations and batch or continuous operations, and process optimization. Pharmaceutical manufacturers can also implement in-process recycling or other recovery and reuse methods to reduce the quantity of hazardous waste. Additionally, under the pharmaceutical MACT standard (*15*), EPA rewards pollution prevention in some cases by allowing it as an alternative to the more traditional end-of-pipe controls. Many of these techniques have been documented in the EPA Office of Compliance publication "Profile of the Pharmaceutical Industry" (*16*).

EPA also regulates the pharmaceutical industry through a number of Federal laws, including the Clean Air Act (*17*), the Clean Water Act (*18*), the Resource Conservation and Recovery Act (*19*), the Safe Drinking Water Act (*20*), the Underground Storage Tank regulations (*21*), the Emergency Planning and Community Right-to-Know Act (*22*), and the Toxic Substances Control Act (*23*). The pharmaceutical industry is unique when compared to most EPA-regulated industries because of its low ratio of finished product to raw material input, the quantities of residual waste created, and the generation of particular wastes including equipment cleaning residues, reaction residues, and spent solvents and reactants.

The U.S. Food and Drug Administration (FDA) regulates the pharmaceutical industry through the Federal Food, Drug, and Cosmetic Act (*24*). Five centers within the FDA deal with FDA-regulated products: the Center for Drug Evaluation and Research (CDER), the Center for Biologics Evaluation and Research, the Center for Veterinary Medicine, the Center for Devices and Radiological Health, and the Center for Food Safety and Applied Nutrition. Marketing a new drug entails an involved application process, including preclinical trials, an Investigational New Drug application to the FDA, three phases of clinical trials, a New Drug application, and postapproval testing. Supporting materials must accompany the applications, and companies spend millions of dollars and many years on this process on each drug before it is finally marketed to the public (*25*).

The mission of the CDER of the FDA is to ensure that safe and effective drugs are available to the American public. CDER has integrated the consideration of the environmental impacts of approving drug product applications into its regulatory process in accordance with the National Environmental Policy Act of 1969 (*26*), which requires all Federal agencies to assess the environmental impacts of their actions. This environmental review focuses on the environmental impacts of consumer use and disposal of drugs for human use.

After the FDA approves a drug product application, an applicant may wish to make changes in the manufacture, processing, or packing of the drug substance or drug product for technical, economic, or environmental reasons. An applicant is required to notify the FDA about each change in each condition established in an approved application beyond the variations already provided for in the application. Depending on the type of change, the applicant notifies the FDA by *a*) a supplement requiring FDA approval before the change is made; *b*) a supplement submitted at least 30 days prior to distribution of the product made with the change; *c*) a supplement for changes that may be put into effect immediately upon FDA receipt of the supplement, or *d*) an annual report. Changes in solvent, formulation, sources of plants/animals for drugs, and packaging are a few examples of the types of changes that may be contemplated for environmental reasons. These changes will likely result in supplement applications to the FDA for approval before implementation.

The extensive requirements of the FDA to report and provide data to support changes should be considered in the R&D of the drug, because postapproval changes can be costly in both the time and money. Most healthcare product R&D organizations are future oriented and are not inclined to review products already in the marketplace. Through careful consideration of the environmental implications of the manufacturing, processing, and packing of a drug in the R&D product stage, costly postapproval changes can be avoided.

How R&D Organizations of Medical Products Companies Have Responded

The R&D units of medical product companies have been focused on providing safe and efficacious products to meet the healthcare needs of the public. This imperative remains the foremost mission for pharmaceutical and medical device companies. The requirements for new products entering the healthcare delivery system, however, are more complex than the need for safety and efficacy. Medical products companies understand that to remain competitive they must respond comprehensively to the needs of their customers. Cost and environmental attributes have surfaced as new, unmet requirements of the healthcare delivery system. The cost of healthcare products is outside the scope of this committee. However, it is widely understood that waste reduction, including environmental waste, results in expense reduction benefits.

Many concerned medical product manufacturing companies are responding to the changing environmental requirements of their customers while they remain focused on their original (safe and efficacious) mission and regulatory requirements. Presented below are various models used successfully by organizations to meet regulatory and client expectations and to improve the environmental profile of their products.

a) Baxter International, Inc. develops, distributes, and manufactures a variety of products, systems, and services used in the healthcare field. Hospitals, clinical and medical research laboratories, blood and dialysis centers, and doctors' offices in over 100 countries use these products for a wide range of clinical procedures. Baxter has manufacturing facilities in 28 countries.

The company routinely reports their progress toward achieving sustainability targets, in large measure focused on the environmental impact of their products in the healthcare system. Baxter reports that it has reduced its packaging by 4% since 1995 and still hopes to reach its goal of 20% reduction by 2005 (*27*).

Baxter has worked on customer-oriented environmental issues since 1992, employing a checklist and life-cycle approach in their new product development process. The company's EPD reviews choice of product materials, supplier issues, packaging, environmental impact of manufacturing, and customer use and disposal of the product.

b) Bristol-Myers Squibb (BMS) is a health and personal-care company manufacturing medicines, medical devices, nutritionals, and beauty care items. BMS has facilities in over 60 countries and had revenues of over $18 billion in 1998. BMS applies the principles of product life cycle (PLC) to ensure that new products include environmental qualities while minimizing waste throughout the product's manufacture, use, and disposal. PLC at BMS employs cross-functional, multidisciplinary teams who review the product as it moves through R&D to commercialization. The company considers PLC a business tool that results in environmentally optimal products and reduces cost. Additionally, the company recognizes that the market, especially BMS customers, is demanding products with improved environmental profiles. In considering environmental features in the R&D stage, the cost of changing products in the market is avoided.

The PLC process at BMS begins with identifying critical environmental health and safety issues at each stage of the product life cycle. These issues include the environmental impacts of the product (including manufacturing, distribution, use, and disposal) on the air, water, and land through waste disposal. Opportunities to minimize these effects are prioritized using a cost-benefit approach. This produces a set of recommendations considered for product ingredients, manufacturing processes, packaging, and best disposal practices. (Table 1).

Current strategies at BMS include waste minimization and pollution prevention programs, toxic solvent reduction, and optimization of emerging environmentally acceptable technologies. For package designers this means reducing packaging to lower costs; using recyclable or environmentally benign packaging; considering alternative packaging that offers environmental advantages of the standard options; using soy- or vegetable-based inks; and educating customers on recycling and disposal options. In manufacturing, PLC requires consideration of the environmental health and safety impact of raw materials, manufacturing processes, and regulatory impacts at the facility. For the marketing

Table 1. Enhancing products through product life-cycle analysis.

Environmental product profiling	Research and product development	Marketing	Manufacturing	Packaging	Sales, distribution, transportation	Consumer use	Final disposition
Research and development	•	•	•	•	•		•
Marketing and sales	•	•	•	•	•	•	•
Engineering	•		•	•	•		•
Production planning	•	•	•		•		
Purchasing	•	•	•	•	•		
Production			•	•	•		
Plant management	•	•	•	•			
Quality assurance	•	•	•	•	•	•	
Maintenance	•		•	•	•		
Environmental health and safety	•	•	•	•	•	•	•
Public relations	•	•	•	•	•	•	•
Finance and accounting	•	•	•	•	•		•

department the consideration of shelf space and product appearance is balanced with the resultant environmental impact.

c) At SmithKline Beecham (SKB), a pharmaceutical and healthcare company with 47,000 employees in 160 countries, EPD has focused on improving chemical synthesis efficiencies to reduce waste and solvent use and optimize energy requirements. SKB has characterized this work as "green chemistry." Most of its pharmaceutical products are chemically synthesized. The environmental challenges for chemically synthesized, bulk drug manufacturing processes are complex molecules, complex synthetic routes, complex processes and wastes, strong regulation by the FDA, costly route and process changes post-FDA approval, and the need for early and rapid route definition.

To understand the environmental opportunities for improving chemical synthesis processes, SKB developed a phased approach. In Phase I the company identified mature chemistries. These chemistries were broken out into individual reaction steps. Each step was categorized according to chemical reaction types (e.g., oxidation, reduction). A chemistries database was then established. Tables 2 and 3 identify "greenness" metrics for mass and energy as a means to characterize chemistry efficiencies.

In Phase II the company developed a sustainability-driven assessment system and applied it to the chemistries database. The result was a database of chemistries ranked and prioritized according to sustainability qualities. Table 4 describes a comparison of various chemistries based on these priorities.

The company concluded that mass and energy terms appeared to be good leading indicators of overall environmental impact. Additionally, explicit tracking of solvent use is highly indicative of overall environmental impact. The evaluation using their sustainability metrics clearly differentiates between chemistries and chemical processes.

d) Allergan is a pharmaceutical company specializing in opthamological and dermatalogical products sold in over 100 countries. As a result of customer feedback indicating a preference for products with less packaging and minimal hazards, Allergan embarked on an EPD project establishing evaluation criteria to be integrated into the product development process. Allergan assembled an implementation team including internal Allergan representatives from marketing, R&D, packaging, environmental health and safety, manufacturing, legal, and purchasing departments, as well as external consultants who had experience with design for the environment and life cycle approaches to product development. The team developed the environmental evaluation criteria, the criteria use instructions, an accountability structure, and a process model for integration. The resulting system enables product designers to investigate the potential environmental impacts of different design options simply by inputting values into the computer. Implementation and training began in 1994 and was completed in 1995.

The quantitative method included two aspects: product formulation and manufacture based on materials, and packaging considerations. A chemical list is included in the method for evaluating the material environmental impacts. The chemical list includes references to threshold limit values, reportable quantities, threshold planning quantities, hazardous waste generation, Allergan-restricted materials, carcinogenic materials, and government reporting requirements. The packaging considerations include evaluations against

Table 2. Greenness assessment—example of mass metrics.

Category: Mass	Units
$\frac{\text{Mass of product (kg)} \times 100}{\Sigma \text{ total mass (kg)}}$	% kg/kg
$\frac{\text{Mass of product (kg)} \times 100}{\Sigma \text{ total mass (kg)} - \text{mass recyled (solvent + other) (kg)}}$	% kg/kg
$\frac{\Sigma \text{ total mass (kg)} - \text{mass recyled (solvent + other) (kg)}}{\text{Mass of product (kg)}}$	kg/kg
$\frac{\Sigma \text{ total mass (kg)}}{\text{Mass of product (kg)}}$	kg/kg
$\frac{\text{Mass of product (kg)}}{\Sigma \text{ (mass solvent in) (kg)}}$	kg/kg
$\frac{\Sigma \text{ (mass solvent in) (kg)}}{\text{Mass of product (kg)}}$	kg/kg

Σ, summation.

Table 3. Greenness assessment—example of energy metrics.

Category: Energy
$\frac{\Sigma \text{ Process energy (MJ)}}{\Sigma \text{ mass of product (kg)}}$
$\frac{\Sigma \text{ waste treatment energy (MJ)}}{\Sigma \text{ mass of product (kg)}}$
$\frac{\Sigma \text{ solvent recovery energy (M}}{\Sigma \text{ mass of product (kg)}}$

MJ, megajoule.

Table 4. Comparing chemistries.

	Units	Knoevenagel	Grignard	Ether	*N*-Acylation	*N*-Alkylation	Resolution	Lithal
$\frac{\Sigma \text{ total mass in excluding water (kg)}}{\text{Mass of product (kg)}}$	kg/kg	6.4	12.7	16.0	18.9	20.8	24	30.1
$\frac{\Sigma \text{ mass water (kg)}}{\text{Mass of product (kg)}}$	kg/kg	1.0	6.1	14.4	11.3	14.3	23.5	6.4
$\frac{\Sigma \text{ process energy (MJ)}}{\Sigma \text{ mass of product (kg)}}$	MJ/kg	4.0	6.3	8	8.6	23	11.7	30.9
$\frac{\Sigma \text{ total energy (MJ)}}{\Sigma \text{ mass of product (kg)}}$	MJ/kg	9.0	16.7	14	24.4	39	50	62.1
Number of different solvents	No	1.1	1.3	1.9	1.5	1.6	1	2.3
Overall estimated recovery efficiency	%	86%	75%	32%	65%	68	68	58%
Solvent mass factor (gross mass solvent/mass product)	kg/kg	4.7	10.6	11.8	16.5	16.5	20.4	25.9
Mass of solvent waste	kg/kg	0.6	2.65	8	5.8	5.3	6.5	11
All atom efficiency	%	78%	78	69%	N/A	64%	30	59%

Allergan-restricted materials, packaging weight reductions, packaging levels reduction, packaging recycled-content materials use, packaging component recyclability, biodegradability of packaging, and whether packaging components are reusable by Allergan.

The criteria have been used in the development of three new products, and the principles have been used in many other product redesigns. The potential product, including manufacturing component and packaging component analysis, has a possible quantitative score of 100. Table 5 exemplifies the analysis of three products whose scores ranged from 67 to 70 out of a possible 100. Areas that scored low or not at all include reductions in packaging weights per unit, use of recycled-content materials, reuse of packaging materials by Allergan, and elimination of levels of packaging.

Allergan has taken steps to integrate environmental criteria into the product design process. The initial completion of worksheets for three new products indicates that product improvement from an environmental perspective can and will occur. Raising the awareness of the product designers at Allergan has not only improved the environmental profile of new products but has also been useful in improving existing products, which consistently rank 20–40 points higher than older products.

Table 5. Criteria scores for newly designed Allergan products.

	Product no. 1	Product no. 2	Product no. 3	Potential high score
Product formulation and manufacture				
Threshold limit value	10.0	8.0	10.0	10.0
Threshold planning quantity	5.0	5.0	5.0	5.0
Reportable quantity	5.0	4.0	5.0	5.0
Use of restricted materials	10.0	10.0	10.0	10.0
Generation of hazardous wastes	7.5	7.5	7.5	7.5
Use of carcinogens	7.5	7.5	7.5	7.5
Government reporting requirements	5.0	5.0	5.0	5.0
Subtotal	50.0	47.0	50.0	50.0
Packaging				
Use of restricted materials	10.0	10.0	10.0	10.0
Weight reduction	0.0	0.0	0.0	10.0
Recycled content use	0.0	0.0	0.0	10.0
Allergan reusable packaging	0.0	0.0	0.0	5.0
Material recyclability	10.0	10.0	10.0	10.0
Packaging level elimination	0.0	0.0	0.0	5.0
Subtotal	20.0	20.0	20.0	50.0
Total	70.0	67.0	70.0	100.0

Conclusion

Many pharmaceutical companies are already incorporating environmental issues into R&D processes in varied and creative ways. The committee believes it is possible to create a program (toolbox) that can assist all pharmaceutical companies find the best method of incorporating these ideas into their processes. This program could guide a company from the beginning of the R&D phase through final FDA approval, facilitating decisions on environmental questions and options. It could also assist companies in partnering with their customers to provide products with the environmental attributes most crucial to healthcare facilities. Working together, the pharmaceutical industry can lead the healthcare supply chain in bringing environmental excellence to the entire healthcare delivery system.

Appendix.

Committee Members
James Messelbeck (Chair)
Applied Biosystems
850 Lincoln Centre Drive
Foster City, California 94404
Telephone: (800) 345-5224
Fax: (650) 554-2274
E-mail: messeljr@pebio.com

Lara Sutherland (Co-Chair)
INFORM, Inc.
17 Beacon Place
Somerville, Massachusetts 02143-4305
Telephone: (617) 864-3730
Fax: (617) 864-4277
E-mail: sutherland@inform.org

Members
Pat Batholomew
Baxter Healthcare Corporation
PO Box 490
Round Lake, Illinois 60073
Telephone: (847) 270-4504
Fax: (847) 270-4545
E-mail: bartho@baxter.com

Virginia L. Cunningham
SmithKline Beecham
2200 Renaissance Boulevard, Suite 105
King of Prussia, Pennsylvania 19406
Telephone: (610) 239-5262
Fax: (610) 239-5250
E-mail: virginia.l.cunningham@sb.co

Marcia Mia
Office of Compliance
U.S. Environmental Protection Agency
401 M Street, SW (2224A)
Washington, DC 20460
Telephone: (202) 564-7042
Fax: (202) 564-0009
E-mail: mia.marcia@epa.gov

Nancy Sager
U.S. Food and Drug Administration, HFD –357
5600 Fishers Lane
Rockville, Maryland 20857
Telephone: (301) 594-5633
Fax: (202) 827-2772
E-mail: sagern@cder.fda.gov

Chen Wen
Office of Pollution Prevention and Toxics
U.S. Environmental Protection Agency
401 M Street, SW (7409)
Washington, DC 20460
Telephone: (202) 260-4109
Fax: (202) 260-0178
E-mail: wen.chen@epa.gov

Michael Whaley
Allergan
PO Box 19534
Irvine, California 92623
Telephone: (714) 246-5492
Fax: (714) 246-4359
E-mail: whaley_michael@allergan.com

Craig R. Woodard
Bristol-Myers Squibb Company
PO Box 4000, D23-09
Princeton, New Jersey 08543
Telephone: (609) 252-6958
Fax: (609) 252-6062
E-mail: craig.woodard@bms.com

References and Notes

1. U.S. EPA. Mercury Study - Report to Congress. EPA-452/R-97-003. Washington, DC:U.S. Environmental Protection Agency, 1997. Available: *http://www.epa.gov/oar/mercury.html* [cited 6 December 2000].
2. U.S. EPA. The Inventory of Sources of Dioxin in the United States (External Review Draft). EPA 600-P-98-002Aa. Washington, DC:U.S. Environmental Protection Agency, 1998.
3. Federal Plan Requirements for Hospital/Medical/Infectious Waste Incinerators Constructed on or before June 20, 1996. Proposed Rules. 64 FR 36426, 6 July 1999.
4. U.S. EPA. Binational Toxics Strategy. Available: *http://www.epa.gov/grtlakes/bns* [cited 11 November 2000].
5. U.S. EPA. EPA Action Plan for Mercury. Available: *http://www.epa.gov/pbt/hgaction.htm* [cited 15 January 2000].
6. U.S. EPA Office of Pollution Prevention and Toxics. Persistent, Bioaccumulative, and Toxic (PBT) Chemicals Initiative. Washington, DC:U.S. Environmental Protection Agency. Available: *http://www.epa.gov/opptintr/pbt* [cited 15 January 2000].
7. Conference of New England Governors and Eastern Canadian Premiers. Resolution Concerning Mercury and Its Impact on the Environment. Resolution 23-2. Adopted at the 23rd Conference of New England Governors and Eastern Canadian Premiers, 7-9 June 1998. Available: *http://www.cmp.ca/neg/newse.htm#mercury* [cited 15 January 1999].
8. Northeast Waste Management Officials' Association. Discussion Document: Draft Model Act to Reduce Mercury-Containing Waste. Available: *http://www.newmoa.org/prevention/hottopics/model-act.html* [cited 15 January 2000].
9. CERES (Coalition for Environmentally Responsible Economies) is a nonprofit coalition of investors, public pension funds,

foundations, labor unions, and environmental, and religious and public interest groups, working in partnership with companies toward the common goal of corporate environmental responsibility worldwide. 11 Arlington Street, 6th floor, Boston, MA 02116-3411.

10. Health Care Without Harm is a coalition of more than 200 organizations dedicated to environmental improvements in the healthcare field. Contact: Charlotte Brody, Organizing Coordinator, PO Box 6806, Falls Church, VA 22040 (cbrody@essential.org).
11. Massachusetts Office of Technical Assistance. Health Care Purchasing Success Story. Health Care EPP Network Information Exchange. Vol 1, No 1. Boston:Massachusetts Office of Technical Assistance, 1999. Available: *http://www.state.ma.us/ota/otapubs.htm#eppnet* [cited 11 November 2000]
12. Gerwig K. Personal communication.
13. Gerwig K. Personal communication.
14. Medical Academic Scientific Community Organization. MWRA/MASCO Mercury Workgroup. Available: *http://www.masco.org/mercury* [cited 11 November 2000].
15. National Emissions Standards for Pharmaceutical Production. 40 CFR 63.1250-60 Subpart GGG.
16. U.S. EPA. EPA Office of Compliance Sector Notebook Project: Profile of the Pharmaceutical Manufacturing Industry. EPA/310-R-97-005. Washington, DC:U.S. Environmental Protection Agency, September 1997. Available: *http://es.epa.gov/oeca/sector/* [cited 6 December 2000].
17. Clean Air Act. 42 U.S.C. 7401.
18. Clean Water Act of 1977. 33 U.S.C. 1251.
19. Resource Conservation and Recovery Act of 1976. 42 U.S.C. 321.
20. Safe Drinking Water Act of 1974. U.S.C. 300f.
21. Technical Standards and Corrective Action Requriements for Owners and Operators of Underground Storage Tanks (USTs). 40 CFR 280.22. Available: *http://www.epa.gov/swerust1/fedlaws/cfr.htm* [cited 11 November 2000].
22. Emergency Planning and Community Right-To-Know Act of 1986 (EPCRA). 42 U.S.C. 11011.
23. Toxic Substances Control Act of 1976 (TSCA). 15 U.S.C. 2601.
24. Federal Food, Drug, and Cosmetic Act. 21 U.S.C. 301.
25. Spilker BA. The Drug Development and Approval Process. The Pharmaceutical Research and Manufacturers of America., 2000. Available: *http://www.phrma.org/searchcures/newmeds/devapprovprocess.phtml* [cited 6 December 2000].
26. National Environmental Policy Act of 1969, P.L. 91-190.
27. Baxter Corporation. 1999 EHS Sustainability Report. Available: *http://www.baxter.com/investors/citizenship/environmental/index.html* [cited 6 December 2000].