SPECIAL ARTICLE

Green Surgical Practices for Health Care

Gifty Kwakye, MD, MPH; Gabriel A. Brat, MD, MPH; Martin A. Makary, MD, MPH

The objective of this study was to identify leading practices to promote environmentally friendly and efficient efforts in the provision of surgical health care. Health care is the second leading contributor to waste in the United States. Despite widespread enthusiasm for "going green" in the US economy, little substantive information is available to the medical community, to our knowledge. We explore safe and efficient strategies for hospitals and providers to protect the environment while delivering high-quality care. We performed a systematic review of the literature using relevant PubMed search terms and surveyed a panel of hospital managers and chief executive officers of health care organizations pursuing green initiatives. Recommendations were itemized and reviewed by a 7-member panel to generate a consensus agreement. We identified 43 published articles and used interview data from the panel. The following 5 green recommendations for surgical practices were identified: operating room waste reduction and segregation, reprocessing of single-use medical devices, environmentally preferable purchasing, energy consumption management, and pharmaceutical waste management. The medical community has a large opportunity to implement green practices in surgical units. These practices can provide significant benefits to the health care community and to the environment. Additional research and advocacy are needed to further explore green practices in health care.

Arch Surg. 2011;146(2):131-136

Health care facilities are the second leading contributor of waste in the United States, producing more than 6600 tons of waste per day and more than 4 billion pounds of waste annually.[1,2] Operating room and labor-delivery waste alone account for approximately 70% of hospital waste.[3] In the current era, hospitals routinely dispose of waste using costly autoclaves, microwave sterilization systems, and chemical disinfection. In addition, many hospitals use incineration and dumping of waste into landfills.[4] These disposal methods can be associated with several environmental and public health concerns.

Certain sectors of US industries, including some hospitals, have demonstrated leadership in creating eco-friendly sustainable development strategies. These include recycling, serving sustainable foods, reprocessing of devices, increasing energy efficiency, eliminating mercury products, managing pharmaceutical waste, and creating green buildings. When applied appropriately, these green (environmentally friendly) strategies can be associated with significant cost savings. The challenge in the health care setting is how to creatively find ways to support sustainability amidst handling large amounts of hazardous or infectious medical waste while ensuring patient safety.

The primary objective of this study was to review the published literature regarding green initiatives in health care. A secondary objective was to draw on the wisdom of leaders engaged in green efforts within and outside the medical commu-

Author Affiliations: Department of Surgery and Center for Green Health, School of Medicine (Drs Kwakye, Brat, and Makary), and Department of Health Policy and Management, Bloomberg School of Public Health (Drs Kwakye and Makary), The Johns Hopkins University, Baltimore, Maryland.

Table 1. Questionnaire Completed by Each Member of our Panel[a]

Question
1) How much medical waste is produced annually in the US? Of this, surgical waste constitutes what percentage or fraction?
2) Waste streams are usually classified into specific categories. Into which categories will you place surgical waste and what is the associated cost for disposing each identified stream?
3) There have been several reports on the impact of medical waste disposal techniques on the environment. Are you aware of any such effects? If yes, please provide examples and data to support or disprove these reports.
4) Please list and explain several surgical waste disposal techniques used by your institution or one that you are familiar with.
5) Are there any benefits or risks—to people, environment, and medical institutions—associated with these techniques?
6) There has been much hype in the media and even in medical centers on "going green." What are your thoughts on this?
7) Has the organization you work in adopted any such green practices? If yes, what steps did management take to implement them and how has employee acceptance been?
8) Have you noted any benefits or risks associated with these new green practices at your center? Please comment, if possible, on financial costs, safety, environmental cleanliness, waste volume, and employee/patient health. Any data to support points is appreciated.
9) Considering the subject of surgical waste production and disposal, what is one area of greatest concern to you and why?
10) Based on your experience, what are the five (5) main things surgical practices in particular can do to become more green? Please rank in order of greatest impact.

[a]The introductory paragraph was as follows: "We are interested in studying the impact, if any, of surgical medical waste on health and the environment. Please answer all the questions below and where suitable, provide data to support your statements. All data will be de-identified to protect patient and institutional rights. Thank you."

nity to generate a list of practical strategies that surgical units can implement.

METHODS

We conducted a literature search of PubMed and bibliographies of other relevant journals from January 1, 1980, through December 31, 2008. We used Medical Subject Headings search terms classified into the following 3 main categories: (1) problems (*waste management*, *medical waste disposal*, *public health concerns*, *environmental*, *incineration*, and *landfill*), (2) interventions (*surgery green initiatives*, *green in surgery*, *operating room green practices*, *recycling in operating room*, *recycling in surgery*, *reducing waste in surgery*, *surgical waste disposal*, and *hospital waste management*), and (3) results (*cost savings*, *staff response*, *environmental impact public impact*, and *protests*). Combinations of these terms from each category were performed to select relevant articles and abstracts.

A panel of subject matter experts was selected from leaders in the field of medical green practices. Panelists were interviewed between June 1 and December 31, 2008. Interviews were conducted and recorded in person or via telephone for at least 30 minutes each. Ten questions were asked of each expert (**Table 1**), and extra time was reserved for additional comments. Panelists were queried about current medical waste production, options for reducing or eliminating waste, and potential benefits to public and medical organizations from going green. At the end of each interview, they were also asked to identify an area of greatest concern to them and to list 5 action items for hospitals and providers. Hospital and participant data were de-identified. Consensus among panelists on surgical green initiatives was determined by ranking common responses, identifying the top 5 priorities from the resultant list, and discussing the pooled results to achieve unanimous agreement. Results from the literature review were used to support or closely examine information obtained from the panel. The panel approved the consensus recommendations without changes.

RESULTS

LITERATURE REVIEW

We identified 113 peer-reviewed US-based articles regarding the environment and regarding environmentally friendly practices. There were 98 full-text articles, of which 43 fulfilled inclusion criteria for the study. These articles were used to validate and expand on consensus recommendations by the panel.

PANEL OF EXPERTS

The panel was composed of 7 leaders in the field of medical green practices. Panelists included the clinical products specialist and the director of environmental sciences of a tertiary medical institution in the Northeast, the research director of the medical organization Health Care Without Harm, the chief executive officer of Ascent Healthcare Solutions, 2 board-certified general surgeons from hospitals with more than 500 beds, and a public health expert with 15 years' experience in the field.

All 7 panelists independently identified operating room waste reduction and segregation as the most effective and practical method for initiating green practices in surgical units. Three of 7 recommended the same 5 green initiatives, with varying order of preference. Only one panelist listed 3 items that varied significantly from the others obtained.

After tallying the results obtained from the survey and reviewing the data against the published literature, the following 5 strategies were agreed on by the group to be the highest-priority solutions for the surgical community: (1) operating room waste reduction and segregation, (2) reprocessing of single-use medical devices, (3) environmentally preferable purchasing, (4) energy consumption management, and (5) pharmaceutical waste management. We explore each of these strategies in light of the systematic literature review performed.

COMMENT

OPERATING ROOM WASTE REDUCTION AND SEGREGATION

Medical waste can be separated into the following 5 main categories that require different treatment and disposal

Table 2. Common Materials Used in Surgical Practices That Should Not Be Placed in Red-Bag Waste

Material	
Paper towels	Casts and splints
Vent tubing	Packaging materials
Suction tubes	Alcohol preps and wipes
Intravenous bags	Dressings and gauze
Foley bags	Cotton
Foley catheters	Tapes
Batteries	Diapers and incontinence pads
Masks	Bedpans
Gowns	Urinals
Drapes	Emesis basins
Linens	

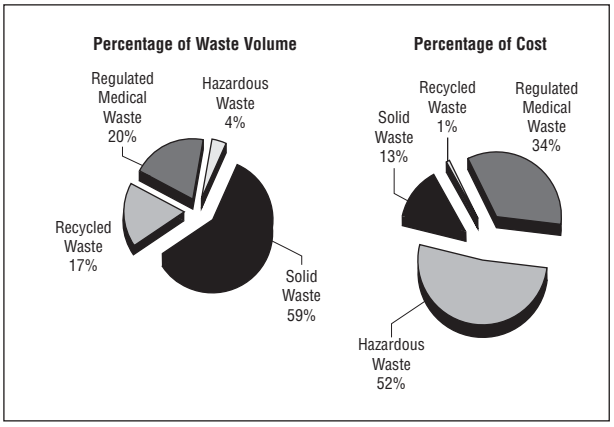

Figure 1. Comparison of waste volume and cost. Courtesy of Colleen Cusick, RN, The Johns Hopkins Go Green Initiative.

procedures based on federal guidelines: infectious and pathologic (eg, tissues and body fluids), sharps, pharmaceuticals, radioactive, and general waste (eg, paper and unsoiled linens).[5] Two kinds of disposal bags are used to separate waste, red bags for specific infectious and pathologic waste and clear bags for all noninfectious waste. Radioactive and sharp wastes are disposed of in preassigned containers depending on their level of contamination with infectious waste. The problem is that most waste in surgical units is misallocated at an individual level into red bags. In fact, as much as 90% of red-bag waste does not meet criteria for red-bag waste. This is believed to occur because of a misunderstanding of what criteria need to be used for waste segregation. For instance, although usually disposed of in red bags, items listed in **Table 2** should be placed in clear bags unless visibly soiled, dripping, or caked with blood or bodily fluids.[5]

The importance of careful diligent waste segregation becomes clear when the cost associated with disposal of each type is considered. **Figure 1** compares the relative cost of waste per volume of each category of waste with its cost. Although hazardous and regulated medical waste (equivalent to infectious waste) make up only 24% of medical waste, they account for 86% of costs.[6] Unfortunately, an estimated 40% of regulated medical waste from operating rooms is packaging material and another 40% is suction canister waste.[2,7] Therefore, if the quantities of these 2 items were reduced, the volume of regulated medical waste could be decreased by more than 30%.

To render waste segregation easier for staff, a medical center initiated a simple system of making clear bags more readily available during surgical preparation and then replacing them with red bags just before the patient is wheeled into the operating room, which marks the period when most waste requiring red bags is generated.[3] The medical center also began washing and reusing all surgical scrubs and jackets.[3] These 2 changes, in addition to several others, have amounted to a 50% reduction in medical waste volume over 7 years.[3] Another hospital reduced its waste by 50 000 pounds and saved $60 000 annually by switching to reusable surgical gowns. A different hospital reduced by 70% its use of the blue wrap used to store instruments by switching to hard cases, with estimated yearly savings of $26 000.[8]

REPROCESSING OF SINGLE-USE MEDICAL DEVICES

Under the Medical Device User Fee and Modernization Act of 2002, a reprocessed single-use device is any "original device that has previously been used on a patient and has been subjected to additional processing and manufacturing for the purpose of an additional single use on a patient."[9] Twenty-five percent of more than 6000 US hospitals and 2700 ambulatory surgery centers report using at least 1 type of reprocessed single-use device.[10] The cost savings and the appeal of an environmentally friendly alternative offered by the reprocessing industry make it an attractive investment for hospitals. For instance, Ascent Healthcare Solutions in 2008 alone reported a supply cost savings of $138 142 000 [1 950 447.2 kg] and 4 300 000 pounds (2150 tons [1950.5 metric tons]) of medical waste diverted from US landfills.[11] Given that more than 60% of medical devices on the US Food and Drug Administration's list of single-use devices known to be reprocessed or considered for reprocessing are used in surgical treatment, surgical practices stand to benefit significantly and should take greater interest in reprocessing efforts.[12] **Figure 2** shows cost savings across various surgical specialties from the reprocessing of commonly used devices.[13] Despite these data, concerns exist about the safety of these devices.[14] To date, the US Government Accountability Office has found no evidence indicating that the use of reprocessed devices increases health risk.[15,16]

ENVIRONMENTALLY PREFERABLE PURCHASING

Hospitals for a Healthy Environment, a collaboration between the US Environmental Protection Agency and the American Hospital Association, advocates for the use of environmentally preferable purchasing in all departments of hospitals. They define environmentally preferable purchasing as the "act of purchasing products/services whose environmental impacts have been considered and found to be less damaging to the environment and human health when compared to competing products/services."[17] Apart from cost savings, environmentally preferable purchasing creates a healthier hospital environment for patients and staff, which fur-

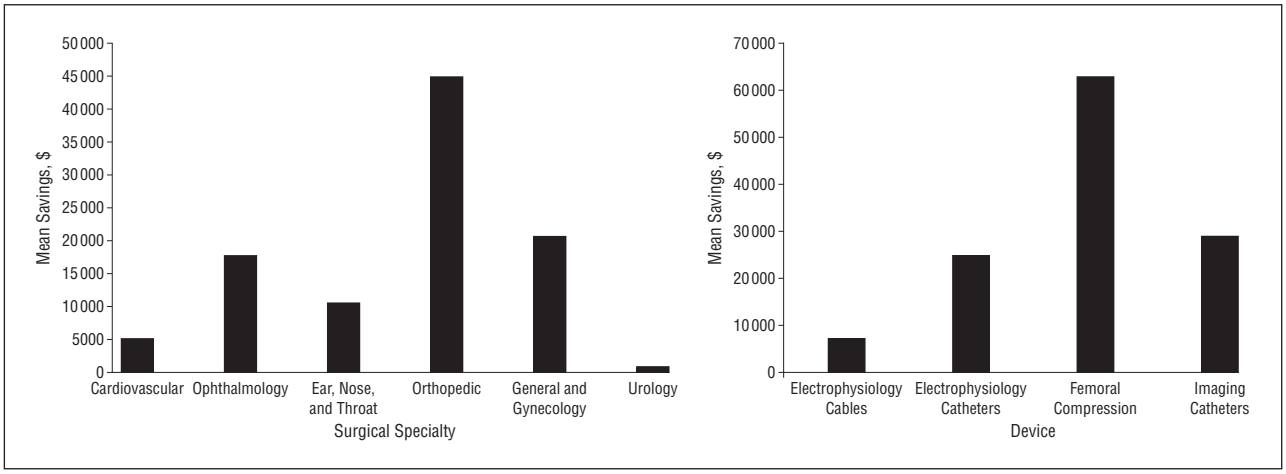

Figure 2. Comparison of mean savings associated with reprocessing of specific devices in various surgical specialties. A, Operating room reprocessing savings by surgical specialty. B, Mean distribution of $100 000 in device reprocessing savings across 20 facilities. Adapted from Flynn and Knishinsky.[13]

Table 3. Energy Efficiency Programs[a]

Program
Energy-efficient heating, venting, and air-conditioning system designs
Energy-efficient lighting system designs
Energy-efficient sterilization, gas, and water plants
Energy-efficient waste disposal systems
Energy-efficient housekeeping methods
Energy-efficient medical and nonmedical equipment
Thermal storage analysis systems and cooling analysis systems
Energy-efficient building infrastructure designs
Effective cogeneration feasibility analysis and design
Highly motivated and trained staff, including senior management, for initiating and implementing energy-saving protocols

[a] From data by Ruparel.[23]

ther reduces long-term expenditure. Material managers of surgical units can support environmentally preferable purchasing by obtaining supplies from vendors who use environmentally friendly raw materials or products. Hospitals should aim to eliminate all mercury products and to replace these with approved alternatives that are easily recycled or require no specialized disposal.

Other general practices that have been shown to improve the overall effect on the environment could be adopted by surgical units. For instance, surgical facilities can commit to using only unbleached recycled paper instead of chlorine-bleached white paper given that manufacturing of the latter releases dioxins into our waterways as a by-product.[18] By using 100% recycled paper, hospitals can reduce manufacturing energy use by 44%, decrease greenhouse gas emissions by 37%, and cut solid waste emissions and water use by 50%.[19] Other suggestions include reducing product packaging, switching to safer cleaning products, and purchasing products that are free of latex, polyvinyl chloride, and diethylhexylphthalate.[17] This could reduce the incidence of allergic reactions, asthma, eye damage, burns, and indirect contamination of hospital food and the water supply.[19]

Although significant, cost savings vary depending on types and amount of environmentally preferable purchasing used by various hospitals. However, it is estimated that a 1000-bed hospital could save, for example, $175 000 per year and reduce waste by 34 000 pounds if they use reusable sharps containers instead of disposable ones.[8] In addition, the direct environmental and public health impact of environmentally preferable purchasing is important, given studies[20,21] that have highlighted the effects of current waste disposal strategies.

ENERGY CONSUMPTION MANAGEMENT

The health care industry accounts for 9% of America's commercial energy use, driven by its dependence on energy-intensive medical equipment, special lighting, and a 24-hour operating schedule.[22] It is estimated that 25% of a hospital's operating cost goes toward meeting its energy needs, with distribution varying among departments.[22] Understandably, surgical units consume a large proportion of this energy not only in the operating rooms and postanesthesia care units but also in the clinics, waiting rooms, and nursing and physician stations, where energy is used to power monitors, computers, and coffee machines. By managing energy use, surgical practices could save between 25% and 45% in energy costs.[22] Monthly savings could be increased further by implementing energy efficiency programs (**Table 3**).[23] Given the high rate of energy waste, instituting simple energy efficiency program changes can result in significant savings, as experienced by New York–Presbyterian Hospital in New York City; by replacing older lighting, air conditioning, water chilling, and pumping systems with newer, more efficient models, the hospital expects annual savings of $1.77 million.[24]

As an additional incentive, hospitals can qualify for federal tax deductions under the Energy Policy Act of 2005 for new or renovated buildings that save 50% or more of their projected annual energy costs for heating, cooling, and lighting.[25,26] An investment tax credit can also be claimed if practices use combined heat and power systems or specific solar lighting and photovoltaic systems.[25,26]

Table 4. Resource Conservation and Recovery Act List of Hazardous and Toxic Pharmaceutical Agents

P-Listed Acutely Hazardous Waste	U-Listed Toxic Waste
Arsenic trioxide	Chloral hydrate[a]
Epinephrine[b]	Chlorambucil
Nicotine	Cyclophosphamide
Nitroglycerin	Daunomycin
Phentermine[a]	Dichlorodifluoromethane
Physostigmine	Diethylstilbestrol
Physostigmine salicylate	Hexachlorophene
Warfarin sodium ≥0.3%	Lindane
	Melphalan
	Mercury
	Mitomycin
	Paraldehyde[a]
	Phenol
	Reserpine
	Resorcinol
	Saccharin
	Selenium sulfide
	Streptozotocin
	Trichloromonofluoromethane
	Uracil mustard
	Warfarin sodium <0.3%

[a] Continuous intravenous infusion.
[b] Most common hazardous waste.

PHARMACEUTICAL WASTE MANAGEMENT

The environmental effect of pharmaceutical agents is a new and controversial issue. The US Geological Services confirmed evidence of contamination of surface, ground, and drinking water by pharmaceutical compounds, including antibiotics, corticosteroids, hormones, and other drugs.[27,28] The agency sampled 139 streams across the country and reported at least 1 pharmaceutical contaminant in 80% of samples.[28] The impact of these drugs on humans is not yet known, although effects of endocrine disruptors on reproduction have been shown in aquatic organisms.[29]

While much is yet to be discovered, many within the public health community have advocated for the use of the precautionary principle that "parties should take measures to protect public health and the environment, even in the absence of clear, scientific evidence of harm."[30(p.xxiii)] It is a subject worth the attention of the surgical community, given that we use and prescribe several of the more common drugs that end up as pharmaceutical waste contaminants in public waterways.

The federal Resource Conservation and Recovery Act classifies these drugs (listed in **Table 4**) as P-listed waste (acutely hazardous) or as U-listed waste (toxic). This Act and the Clean Water Act's general pretreatment regulations contain specific statements regarding disposal of P-listed and U-listed waste, which are summarized in a document by Hospitals for a Healthy Environment titled *Managing Pharmaceutical Waste: A 10-Step Blueprint for Health Care Facilities in the United States*.[31] Pharmacies and waste management services in hospitals can be good resources for guidelines regarding correct disposal of pharmaceutical waste and can provide needed education to surgical staff.

In conclusion, information obtained from the literature review and from the panel reveals a strong need for better and more widespread environmentally friendly initiatives in the medical community. The field of surgery represents a high-yield area for which green practices can be implemented, often with associated cost savings. These findings are consistent with those in other industries, in which sustainable practices are achievable, meaningful, and popular among consumers. As physicians, we share a common desire to deliver the highest possible quality care to our patients directly and indirectly. This goal should guide our efforts as we seek ways to improve public health and sustainability through green initiatives. While the proposed practices are based on the observations and experiences of leaders in the field, additional research is needed to further explore the effect of surgical care on the environment.

Accepted for Publication: June 17, 2009.
Correspondence: Martin A. Makary, MD, MPH, Department of Health Policy and Management, Bloomberg School of Public Health, The Johns Hopkins University, Clinical Research Building II, 1550 Orleans St, Ste 507, Baltimore, MD 21231 (mmakary1@jhmi.edu).
Author Contributions: *Study concept and design:* Kwakye and Makary. *Acquisition of data:* Kwakye. *Analysis and interpretation of data:* Kwakye and Brat. *Drafting of the manuscript:* Kwakye. *Critical revision of the manuscript for important intellectual content:* Kwakye, Brat, and Makary. *Administrative, technical, and material support:* Makary. *Study supervision:* Brat and Makary.
Financial Disclosure: None reported.
Funding/Support: This research was supported by philanthropy from Mr and Mrs Chad and Nissa Richison.
Additional Contributions: Colleen Cusick, RN, and Hugh Waters, PhD, contributed to the study.

REFERENCES

1. DiConsiglio J. Reprocessing SUDs reduces waste, costs. *Mater Manag Health Care.* 2008;17(9):40-42.
2. Gaskill M. Going green: RNs tackle hospital waste. April 24, 2006. NurseWeek Web site. http://www.h2e-online.org/docs/nurseweek42406.pdf. Accessed January 14, 2009.
3. Medical waste incinerator waste management plan: Malcolm Grow Medical Center, Building 1056, Andres Air Force Base, Maryland. June 2001. US Air Force Institute for Environment, Safety and Occupational Health Risk Analysis Web site. http://airforcemedicine.afms.mil/idc/groups/public/documents/afms/ctb_033957.pdf. Accessed January 14, 2009.
4. Lee BK, Ellenbecker MJ, Moure-Ersaso R. Alternatives for treatment and disposal cost reduction of regulated medical wastes. *Waste Manag.* 2004;24(2):143-151.
5. Yeshnowski M. Minimizing red-bag waste. http://www.powershow.com/view/2c796-YTBiO/Minimizing_Red_Bag_Waste_Marcy_Yeshnowski_Tetra_Tech_EM_Inc_402_4746228. Accessed November 25, 2010.
6. Wong KV, Narasimhan R, Kashyap R, Fu J. Medical waste characterization. *J Environ Health.* 1994;57(1):19-25.
7. "Blue Wrap." Infocycling, 2007. State of California Integrated Waste Management Board Web site. http://www.calrecycle.ca.gov/Publications/LocalAsst/Infocycling/34208001.pdf. Accessed December 12, 2010.
8. Health Care/Hospital Recycling and Waste Management for Blue Wrap. California Green Solutions Website. http://www.californiagreensolutions.com/cgi-bin/gt/tpl.h,content=2232. Accessed January 10, 2011.
9. Medical Device User Fee and Modernization Act of 2002 (MDUFMA), Pub L No. 107-250, 116 Stat 1588-1620. October 26, 2002. US Food and Drug Administration Web site. http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance

/Overview/MedicalDeviceUserFeeandModernizationActMDUFMA/ucm109133.htm. Accessed November 25, 2010.
10. Executive summary: survey on the reuse and reprocessing of single-use devices (SUDs) in US hospitals. April 30, 2009. US Food and Drug Administration Web site. http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/ReprocessingofSingle-UseDevices/ucm121678.htm. Accessed November 27, 2010.
11. Hospitals benefit from sustainability initiatives with more than $138 million in savings in 2008. January 12, 2009. Ascent Healthcare Solutions Web site. http://www.ascenths.com/docs/press/2008_year-end_011209.pdf. Accessed January 14, 2009.
12. List of single-use devices known to be reprocessed or considered for reprocessing (attachment 1). From September 29, 2005, *Federal Register* Notice. US Food and Drug Administration Web site. http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/ReprocessingofSingle-UseDevices/ucm121218.htm. Accessed November 27, 2010.
13. Flynn AB, Knishinsky R. A matter of reprocessing. *Mater Manag Health Care*. 2005;14(10):32-35.
14. Heeg P, Roth K, Reichl R, Cogdill CP, Bond WW. Decontaminated single-use devices: an oxymoron that may be placing patients at risk for cross-contamination. *Infect Control Hosp Epidemiol*. 2001;22(9):542-549.
15. Report to the Committee on Oversight and Government Reform, House of Representatives: reprocessed single-use medical devices: FDA oversight has increased, and available information does not indicate that use presents an elevated health risk. January 31, 2008. US Government Accountability Office Web site. http://www.gao.gov/new.items/d08147.pdf. Accessed November 27, 2010.
16. Health-care–associated infections in hospitals: number associated with medical devices unknown, but experts report provider practices as a significant factor. September 26, 2008. US Government Accountability Office Web site. http://www.gao.gov/products/GAO-08-1091R. Accessed November 27, 2010.
17. Environmentally preferable purchasing how-to guide. Health Care Without Harm Web site. http://www.noharm.org/lib/downloads/purchasing/EPP_How-To_Guide.pdf. Accessed December 12, 2010.
18. Ali M, Sreekrishnan TR. Aquatic toxicity from pulp and paper mill effluents: a review. *Adv Environ Res*. 2001;5(2):175-196.
19. The supply chain/green purchasing overview. August 2010. Rutgers, The State University of New Jersey, Web site. http://greenpurchasing.rutgers.edu/supply_chain.html. Accessed November 27, 2010.
20. Sang N, Li GK. Chromosomal aberrations induced in mouse bone marrow cells by municipal landfill leachate. *Environ Toxicol Pharmacol*. 2005;20(1):219-224.
21. Elliott P, Briggs D, Morris S, et al. Risk of adverse birth outcomes in populations living near landfill sites. *BMJ*. 2001;323(7309):363-368.
22. Healthcare facilities account for 9% of energy consumption. December 1, 2008. *Managed Healthcare Executive* Web site. http://managedhealthcareexecutive.modernmedicine.com/mhe/Exclusives/Healthcare-facilities-account-for-9-of-energy-cons/ArticleStandard/Article/detail/569619. Accessed November 27, 2010.
23. Ruparel M. Energy efficiency program for hospitals. *Express Healthcare Management* Web site. http://www.expresshealthcaremgmt.com/20030228/management.shtml. Accessed December 12, 2010.
24. ENERGY STAR success story: New York–Presbyterian Hospital. ENERGY STAR Web site. http://www.energystar.gov/index.cfm?c=healthcare.bus_healthcare_ny_presb_hospital. Accessed January 15, 2009.
25. Energy Policy Act of 2005, 42 USC §15801. August 8, 2005. US Environmental Protection Agency Web site. http://www.epa.gov/oust/fedlaws/publ_109-058.pdf. Accessed January 15, 2009.
26. IRS regulations. Tax Incentives Assistance Project Web site. http://www.energytaxincentives.org/general/irs_regs.php. Accessed January 15, 2009.
27. Jones OAH, Voulvoulis N, Lester JN. Human pharmaceuticals in the aquatic environment: a review. *Environ Technol*. 2001;22(12):1383-1394.
28. Kolpin DW, Furlong ET, Meyer MT, et al. Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000: a national reconnaissance. *Environ Sci Technol*. 2002;36(6):1202-1211.
29. Nash JP, Kime DE, Van der Ven LT, et al. Long-term exposure to environmental concentrations of the pharmaceutical ethynylestradiol causes reproductive failure in fish. *Environ Health Perspect*. 2004;112(17):1725-1733.
30. Raffensperger C, Tickner J, eds. *Protecting Public Health and the Environment: Implementing the Precautionary Principle*. Washington, DC: Island Press; 1999.
31. Managing pharmaceutical waste: a 10-step blueprint for health care facilities in the United States. April 15, 2006. Hospitals for a Healthy Environment Web site. http://www.h2e-online.org/docs/h2epharmablueprint41506.pdf. Accessed January 15, 2009.