

Environmental Implications of the Health Care Service Sector

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Abstract

This report analyzes the environmental effects associated with activities undertaken and influenced by the health care service sector. It is one part of a larger study to better understand the environmental effects of service sector activities and the implications for management strategies. Considerable analysis has documented the service sector's contribution to domestic economic conditions, yet little analysis has been performed on the broad impacts service firms have on environmental quality.

For this study we developed a framework to examine the nature of service sector industries' influence on environmental quality. Three primary types of influence were identified: direct impacts, upstream impacts, and downstream impacts. In addition, indirect impacts induced by service sector activities include their influence over settlement patterns and indirect influences over other sectors of the economy. In our initial analysis, we noted that many functions performed in the service sector also are commonly found in other sectors. We have analyzed the impacts of these activities separately from those unique to the health care sector, as they present different challenges.

Health care is one of the largest U.S. industries, employing one in nine workers and costing one in seven dollars generated in the economy. Functions performed in the industry that are common in other sectors include: transportation; laundry; food services; facility cleaning; heating and cooling; and photographic processing. Activities unique to the health care industry include: infectious waste generation and disposal; medical waste incineration; equipment sterilization; dental fillings; ritual mercury usage; x-ray diagnosis; nuclear medicine; pharmaceutical usage and disposal; and drinking water fluoridation. The industry has considerable leverage upstream on its suppliers, which is important to managing risks from the use of goods commonly used in the industry, including: mercury-containing products, polyvinyl chloride plastics, latex gloves, and syringe needles.

We identified a number of areas for potential environmental management initiatives: controlling emissions from on-site "production" type functions; mercury use; the environmental consequences of infection control measures; pollution prevention through substitution of alternative health care services; and research and data collection.

Key Words: health care; medical services; service sector; environmental impact analysis; sector environmental profile; sector-based strategies

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PREFACE

This report is an attempt to analyze and estimate the environmental effects associated with activities undertaken and influenced by the health care service sector. It is a scoping study of this sector and we relied upon a wide variety of sources to compile the information. The two most fruitful sources were trade press articles and government studies. Publications tailored towards professionals working in the field, such as *Health Facilities Management* and *Infectious Waste News* regularly devote space to environmentally relevant topics. Government studies of mercury emissions and ionizing radiation provide information regarding the relative contribution of health care activities to exposure levels. Materials produced by industry associations and advocacy organizations were also consulted. Some documents were found in the academic literature and obtained from individual firms. Some phone interviews were conducted, though not in any structured way, to learn about the industry and to find further information sources. The Lexis/Nexis service and the Internet were invaluable tools for accessing articles and publications from these various sources.

A small workshop was held at Resources for the Future in January 1999 to discuss broadly the environmental implications of the service sector. The diverse attendees, including representatives of government, industry, environmental groups, and academia, provided a variety of perspectives on our research. A small breakout group devoted its attention to the health care sector, and identified a number of important issues confronting the industry. We are grateful to all the participants in the workshop, and to the numerous people who reviewed and provided constructive comments on a preliminary draft of this report.

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SUMMARY

Overview of the Health Care Services Sector

The U.S. health care system encompasses a wide variety of practices and activities, ranging from traditional healing methods to innovative application of high-technology treatments. One in seven dollars generated in the U.S. economy are spent on health care (HCFA, 1998). One in nine workers in the United States (10 million people) are employed in health care facilities, which include nearly 200,000 physicians' offices, over 100,000 dentists' offices, over 20,000 long-term care facilities, 10,000 home health care companies, 8,000 health clinics, and 7,000 hospitals. There are also numerous specialty facilities and practices, such as chiropractor and osteopath offices, MRI facilities, dialysis clinics, blood banks, and HMO clinics (Bureau of the Census, 1994). Less than 20% of U.S. health care expenditures are paid for "out-of-pocket" by consumers. Almost half is paid for by government programs such as Medicaid and Medicare, while private insurers and companies footed the bill for the other third (HCFA, 1998).

Environmental Impacts

Resource and Material Consumption

Mercury. The most common filling used in tooth repair, dental amalgam, accounts for over 10% of the mercury consumed domestically, the third largest use (Reese, 1997). Other mercury-containing products common in health care settings include thermometers, blood-pressure units, dental amalgam, saline solutions, a variety of medical tubes that use mercury as a flexible weight, batteries used to power medical equipment, and in a variety of mercury compounds used as reagents, stains, and fixatives in clinical laboratories.

Silver. The large volume of silver-based photographic films used in medical x-ray imaging accounts for over 15% of the domestic silver consumption (Hilliard, 1996 and Silver Institute, 1998). Another 2% of domestic silver consumption is used in manufacturing dental amalgam (Silver Council, 1999).

Energy. Total energy use in the health care sector represents approximately one percent of total domestic energy consumption. Health care buildings are, however, intensive energy consumers. The average health care facility consumes 240,000 thousand Btu (British Thermal Units) per square foot--the second highest among commercial building types. This consumption rate is twice as high as office buildings, and follows only food service facilities.

A number of factors contribute to high energy costs, including high electricity usage by medical equipment and high air exchange rates to minimize airborne infections. Hospitals and long-term care facilities are operated 24 hours a day, 7 days a week, year-round; often have cafeterias with cooking equipment; consume fuel oil for emergency electricity generation; and have high volume laundering facilities (EIA, 1998 and Quayle, 1998).

Health care services also consume a variety of other common resources in considerable quantities, including rubber, plastics, and paper products. Disposable medical supplies are commonly used in the industry, to prevent disease transmission between and among patients and health care employees. Unique materials consumed in significant quantities during health care service provision include pharmaceuticals and radioisotopes.

Pollution and Waste Outputs

Waste Management. Medical practices generate over three million tons of solid waste per year, less than two percent of all municipal solid waste. The majority of solid waste from health care facilities, approximately 85%, is typical of commercial solid waste streams--such as office paper, cardboard, plastics, metals, glass, and food wastes. The other 15% (approximately five-hundred thousand tons per year) is handled as potentially infectious, often referred to as "red bag" or "regulated medical waste (RMW)" (U.S. EPA, 1994).

Radiological and chemical wastes are also generated in the medical sector. Since most radioisotopes used in medical applications have short half-lives lasting hours, days, or weeks, the preferred method of radioactive waste management is on-site storage until they have decayed to safe levels. As a result, only one percent of the radioactive waste disposed of in low-level radioactive waste facilities is from medical or research uses (Hamilton, 1993). A number of chemically hazardous wastes are generated in medical settings, including: chemotherapy wastes, spent formaldehyde from dialysis membrane disinfection, waste anesthetic gases, photographic processing chemicals, and waste pharmaceuticals (U.S. EPA, 1990). In addition, health care practices generate some uniquely complex and difficult to dispose wastes. These include multi-hazard wastes that have some combination of infectious, radiological, chemical, or physical hazards.

Air Emissions. Incineration is the predominant disposal method for regulated medical wastes. There are approximately 2,400 hospital/medical/infectious waste incinerators (HMIWIs) in the United States, most of them owned by and located at hospitals (U.S. EPA 1997a and Malloy, 1997). As many as two-thirds of HMIWIs have no pollution control devices installed (EWG, 1997). EPA's latest estimate of nationwide air emissions of dioxin-like compounds identifies medical waste incinerators as the third largest source, representing 17% of total toxic equivalent concentrations (TEQ) (U.S. EPA, 1998). Medical waste incinerators are also estimated to be responsible for over 10% of nationwide air emissions of mercury (U.S. EPA, 1997b). Medical facilities are also the source of some air toxics--ethylene oxide (EtO) sterilizing units are often vented from the rooftops of hospitals. EtO emissions from hospitals are largely unregulated, except in certain states such as California.

Water Discharges. POTW pretreatment programs in many cities have been successful in eliminating pollutants entering their systems from large industrial sources. Increasingly, attention has been drawn to the cumulative impacts of small sources. San Francisco's Regional Water Quality Control Board identified wastewater discharges of silver from spent photographic processing chemicals as one of the major sources of silver in San Francisco Bay (Interagency Workgroup, 1998). The vast majority of these discharges are from small medical offices, such as dentists, chiropractors, and orthopedists. A number of studies of mercury loadings at wastewater utilities have identified discharges of dental amalgam waste from dentists' offices as a large mercury source. Other medical facilities are sources of mercury-containing wastewater--clinical laboratories use a variety of mercury-containing chemicals, mercury spills from equipment often end up in the sewage system, and water discharges from medical waste incinerators and autoclaves are high in mercury content.

Patient and Occupational Exposures

Nosocomial Infections. Patients visiting medical facilities are at risk of gaining an infection during their stay, referred to as nosocomial infections. In hospitals alone, 5-10% of patients contract an infection while under medical care. This results in 1.75 to 3.5 million hospital-acquired infections annually, 88,000 of which are estimated to contribute to the cause of death. While the infection rate per hospital admission has remained fairly stable of the last twenty years, the rate per patient day has grown 36% due to shorter patient stays (Weinstein, 1998). Residents of nursing homes and other long-term care facilities are also prone to gaining infections while under care, though less surprising due to the residential nature of these facilities. An estimated 1.6 to 3.8 million patients acquire infections in nursing homes each year (Strausbaugh, 1999). Seven hundred cases of tuberculosis (TB) were contracted in long-term care facilities in 1997, 3.6% of the nationwide TB cases (Centers for Disease Control, 1998). Infection control remains an important challenge to the health care industry. Many infection control measures have environmental ramifications, such as natural rubber latex gloves and gaseous and liquid chemical sterilants.

Occupationally-Acquired Infections. Health care employees are also at risk for infectious disease transmission in the workplace. Over 550 cases of tuberculosis were contracted by health care workers in 1997, 2.9% of nationwide cases (Centers for Disease Control, 1998). Each year, health care workers report an estimated 600,000 needlesticks--accidental injuries occurring from syringes and other sharp objects. A number of these result in infections of bloodborne diseases, including Hepatitis B and C and Human Immunodeficiency Virus (HIV) (OSHA, 1997). While HIV transmission in the workplace is remarkably low and Hepatitis B transmission rates have dropped in the last decade, the fear of contracting such diseases remains a large concern for health care employees. Infectious disease transmission is not limited to doctors and nurses who come in direct contact with patients. Janitorial staff, laundry employees, and sanitation workers also contend with potentially infectious materials and needles. Last year, three cases of tuberculosis (TB)

among workers at a medical waste processing facility in Washington State were believed to have been caused by exposure to infectious waste ("Stericycle," *Medical Waste News*, 1998).

Materials Allergies and Chemical Exposures. Infection control measures drive a number of health care practices which pose occupational risks of their own. The use of latex gloves as a barrier against bloodborne pathogens has increased dramatically over the last decade. Some 5-20% of health care workers have allergic reactions to natural rubber latex, including asthma attacks and other respiratory problems (NIOSH, 1997). Large amounts of liquid and gaseous sterilants and disinfectants are used to clean surfaces and equipment throughout medical facilities. Even some pharmaceuticals, such as cytotoxic compounds used in chemotherapy, pose acute occupational risk to employees. In addition to the direct exposures workers face, health care employees contend with chronic low-level exposures. Combined with leaked anesthetic gases and laboratory chemicals such as formaldehyde, the total burden of chemical use in health care facilities can contribute to poor indoor air quality.

Ionizing Radiation. X-ray imaging, or radiography, is used to assist diagnosis in a wide variety of health care professions, such as chiropractic, oncology, dentistry, orthopedics, and surgery. Nuclear medicine refers to the use of radioisotopes in diagnostic and therapeutic medical procedures. When averaged across the entire U.S. population, medical x-ray imaging and nuclear medicine procedures are the source of 84% of anthropogenic radiation doses. This represents 15% of the total ionizing radiation received by U.S. residents (NRC, 1990). Few acute radiation harms have occurred in these two fields in recent years, but the total dose received is of some concern as radiation effects are cumulative.

Policy Implications

Governmental interventions to address environmental and safety hazards of health care practices are often fragmented programs housed in multiple agencies. These efforts address hazards at different life-cycle stages: product safety and effectiveness; facility operations and employee behavior; and pollution control and waste management.

A number of areas stand out as potential future environmental management initiatives: controlling emissions from on-site "production" type functions; mercury use; the environmental consequences of infection control measures; pollution prevention through substitution of alternative health care services; and research and data collection.

Some health care service providers perform "production" type functions on-site to process materials for use in certain procedures. Examples of these functions include bulk dental amalgamation, photoprocessing, and radiopharmaceuticals. These production functions can result in unsafe occupational exposures and generate wastes in the health care setting. There are already some environmental management initiatives and industry changes underway that will likely reduce the magnitude of the impacts from these activities. Other efforts should be made to accelerate the transition away from high exposure on-site production wherever possible.

Mercury usage is commonplace in products throughout the health care industry, although considerable achievements in material substitution have been made in other consumer products (batteries, thermostats, paints, and fluorescent lights). National commitments for further reduction in mercury use and emissions in the Binational Toxics Strategy with Canada and the Draft Mercury Action Plan are likely to increase attention to health care mercury use and emissions.

Despite the adoption of a number of infection control measures with environmentally damaging side effects in recent years, hospital-acquired infection rates per patient have remained fairly stable. Now that these practices generally have peaked in their ability to control infections, opportunities should be identified to achieve similar performance at lower environmental costs.

Disease prevention, finding non-surgical procedures for treating problems that have usually been treated with surgery, and other such advances have both medical and environmental benefits by reducing consumption of high-impact services.

Alternative approaches to preserving or improving personal health and quality of life may also be effective pollution prevention techniques. Shifting from a health care system based upon resource-intensive invasive treatment techniques to a system that stresses preventive care is promising for achieving environmental gains. Switching to health care practices with lower environmental impacts will achieve environmental goals as surely as end of pipe controls on dentists' wastewater pipes or scrubbers on medical waste incinerators.

Though not unique to the health care sector, the quality and quantity of information about health care environmental practices and consequences is poor in a number of instances. For instance, lack of data about health care waste management practices has hindered regulatory development, and little scientific research has been performed on the effects of pharmaceuticals in the environment--an area with potentially widespread impact.

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ENVIRONMENTAL IMPLICATIONS OF THE HEALTH CARE SERVICE SECTOR

Terry Davies and Adam I. Lowe*

I. INTRODUCTION

Traditional pollution control and environmental protection systems have been centered on primary production industries, such as manufacturing, mining, and agriculture. The Toxics Release Inventory, for instance, originally applied solely to manufacturing firms. In recent years, many efforts have promoted the role of the consumer in influencing environmental outcomes. This is exemplified by the proliferation of curbside recycling programs, as individuals have begun to take responsibility for the impacts of their behavior. Increasingly, attention has been drawn to a third aspect of the economy – the service sector. As the United States continues its trend towards a post-industrial society, the service sector will increase its influence on economic output and employment. Already, service industries account for three-quarters of the gross domestic product. Employment in the service sector has been steadily growing in the U.S. for the last four decades, and is projected to account for nearly all net job creation over the next decade. Little analysis has been performed on the broad impacts service firms have on environmental quality, despite their enormous economic impact of such firms.

Which industries comprise the service sector varies depending on the purposes of the classification. Broadly speaking, *services* can be defined as "activity (work) done for others," in contrast to the creation of tangible commodities - *products* (Goedkoop, 1998). A practical definition of a service is "anything you can sell that is not capable of falling onto your toes" (Goedkoop, 1998). Service industries thus fill a myriad of roles in society, generally including such industries as: finance, insurance, and real estate; retail and wholesale trade; transportation, communications, and utilities; health care; business and legal services; and government services (Guile, 1997).

A small, but growing, body of literature has begun to discuss the environmental aspects of service sector activity (Allenby, 1997; Ellger, 1997; Graedel, 1997; Guile, 1997; and Rejeski, 1997). Emerging from these discussions are three primary types of influence that service industries have on environmental quality:

1. direct impacts, caused by the provision of the service;
2. upstream impacts, resulting from the service provider's influence over its suppliers' product specifications or environmental performance; and
3. downstream impacts, where the service provider influences its customers' behavioral or consumption patterns.

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In addition, indirect impacts induced by service sector activities include their influence over settlement patterns and indirect influences over other sectors of the economy. Another important insight from the literature on the service sector and on industrial ecology is the importance of getting beyond the traditional focus on end-of-the-pipe waste treatment. The most important environmental advances of the future are likely to be accomplished by preventing pollution. Preventing pollution leads to asking questions about the function or purpose of a particular activity and how that function can be performed with less waste.

Brad Allenby (personal communication, 4/28/99) has applied this perspective to the medical sector. "The issue," he says, "is not just how to reduce end-of-pipe production of waste in offering medical services, but identifying ways in which quality of life (health) can be enhanced by options causing less environmental impact. So, for example, the question is not just how much waste each hospital produces, but how to reduce the demand for hospitals as a whole." Disease prevention, finding non-surgical procedures for treating problems that have usually been treated with surgery, and other such advances have both medical and environmental benefits. Restructuring within the industry may help in achieving these goals – efforts to expand health insurance coverage and increased managed care have already resulted in dramatic reductions in hospital visits. Whether this indicates greater use of preventive care, or merely shifting health care activities out of centralized hospital locations to clinics and outpatient facilities is still under debate.

In our initial analysis of service sector industries, we have also found many functions performed in the medical sector that also are commonly found in other sectors – such as facility heating/cooling, transportation, laundering, etc. We have analyzed these activities separately from those unique to the health care sector, as they present different challenges.

We selected the health care sector as our initial study area because it is a clear example where a service provider can play a large role in environmental quality – it has numerous direct impacts on the environment, leverage "upstream" on the firms that produce the products used by the sector, and considerable influence "downstream" over the behavior of consumers who utilize its services. To the extent possible, we have identified both direct impacts caused by health care activities and indirect effects as a result of its influence. However, this paper should be considered a reconnaissance of the health care sector's overall influence on environmental quality, not a definitive evaluation.

Nature of The Health Care Service Sector

Health care services are pervasive in modern American life – one in seven dollars generated in the U.S. economy are spent on health care (HCFA, 1998a). The U.S. health care system is known for its innovative use of medical technology, research into the cause of disease, and development of new treatments. It is also known for its complexity, cost, emphasis on treatment over prevention, and lack of universal coverage (National Health Care Task Force, 1993). The health care system encompasses a wide variety of practices and activities, and is supported by a number of industries devoted to providing resources to the medical community. For the purposes of this paper, we define the health care sector to

include those organizations that provide health care *services* to consumers. The production of health care equipment and supplies (i.e. the manufacturing of pharmaceuticals, radioisotopes, or intravenous bags) is not included – though we assess the influence that health care service providers have over these industries. Similarly, direct consumption of health care products by individuals (over-the-counter pharmaceuticals, attending fitness centers, etc.) is included only where health care service providers influence such behavior.

One in nine workers in the United States are employed in health care facilities, which include nearly 200,000 physicians' offices, over 100,000 dentists' offices, over 20,000 long-term care facilities, 10,000 home health care companies, 8,000 health clinics, and 7,000 hospitals. There are also numerous specialty facilities and practices, such as chiropractor and osteopath offices, MRI facilities, dialysis clinics, blood banks, and HMO clinics (Bureau of the Census, 1994). Over three-quarters of health care costs are paid for by government programs or private insurance (HCFA, 1998a). Health care expenditures are expected to double over the next ten years due to factors such as increased real per capita income, an aging population that is living longer, and increased pharmaceutical consumption (HCFA, 1998b).

Interactions

Relationship with Suppliers

Health care services rely on a number of specialized products produced solely for consumption by the health care industry, including medical equipment and devices; pharmaceuticals; radioisotopes for use in nuclear medicine; and disposable medical supplies. Many of these products are unique to the health care industry, produced by specialty health care manufacturers. Health care professionals often have a direct role in product development, providing manufacturers with design consulting and clinical testing. Health care manufacturers rely upon the assistance of medical professionals to navigate the regulatory approval process for new products and to capture market share.

Relationship with Payee

Less than 20% of U.S. health care expenditures are paid for "out-of-pocket" by consumers. Almost half is paid for by government programs such as Medicaid and Medicare, while private insurers and companies footed the bill for the other third (HCFA, 1998). Government agencies and private insurance companies influence health care provision through their reimbursement policies and standards of care. Cost pressures from health care funding organizations has forced a dramatic organizational restructuring of the health care sector in recent years. The traditional roles of physician practices, non-profit and municipal hospitals, and nursing homes are shifting with the increase in home health care services, free-standing specialty clinics, assisted living centers, and general industry consolidation. A variety of new organizational entities have emerged, including: managed care plans which assume responsibility for a patient's treatment through preferred service providers; health care networks formed through mergers or strategic alliances between hospitals and other health

service providers; physician-controlled organizations; and large, multi-hospital private corporations. Competition and cost-cutting within the industry will continue to change the nature of the health care sector.

Regulation and Certification of Industry Activities

Health care activities are heavily regulated. A number of federal, state, and local agencies have regulatory authority over safety in health care settings. On the federal level, the Food and Drug Administration (FDA) is the primary federal agency with influence over health care safety matters, through its regulation of the manufacturing, marketing, and use of pharmaceuticals, medical equipment, medical devices, medical supplies, sterilants, and biological products. Voluntary workplace infection control guidelines published by the Centers for Disease Control (CDC) form the basis of many health care facilities' infection control practices. The federal Occupational Safety and Health Administration (OSHA) has a number of standards covering occupational exposure to physical, chemical, radiological, and infectious hazards in health care facilities. The Nuclear Regulatory Commission (NRC) regulates the medical use of reactor-produced materials, including radiopharmaceuticals. The Environmental Protection Agency (EPA) regulates low-level disinfectants, hazardous materials handling and disposal, and incinerator emissions. The Department of Transportation regulates infectious and other hazardous waste transportation. Health care funding agencies, such as the Health Care Financing Administration (HCFA), ensure that participating health care organizations meet all applicable federal health, safety, and program standards.

State agencies also have considerable regulatory authority over the operations of health care facilities. States are the primary regulators of x-ray facilities and infectious waste management, treatment, and disposal. Many federal programs are delegated to states or provide them with considerable implementation authority. States often also have professional certification, facility licensing, and quality of care requirements. State and local governments regulate wastewater discharges to publicly-owned treatment works, enforcing compliance with pretreatment standards and discharge limits.

A number of activities in the health care industry are also regulated by industry certification bodies. The nonprofit Joint Commission on Accreditation of Healthcare Organizations sets standards and certifies the activities of hospitals, health care networks, managed care organizations, home health care organizations, long term care facilities, behavioral health care services, pathological and clinical laboratories, and ambulatory care facilities. Similarly, the American College of Radiography provides certification services for mammography facilities. Physicians, nurses, and a variety of other health care professionals undergo professional certification.

The remainder of this paper is organized as follows. Section II explores the environmental impacts of activities that occur in the health care sector that are also commonly found in other industries, such as laundry services. Section III focuses on the environmental impacts of activities that are unique to the health care sector. An example of this is infectious waste, which requires an industry-specific management approach. Section IV describes the

influence that product choice has on the sector's impacts. It discusses the roles of materials management departments and Group Purchasing Organizations, and their influence on medical supply manufacturers. Section V addresses the influence that the health care industry has on other economic sectors, including its influence on land development. Section VI concludes the paper by examining the environmental policy implications of health care activities. It focuses on existing initiatives already underway in the industry and governmental programs, and on areas that could use further attention.

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II. FUNCTIONS COMMONLY FOUND IN OTHER INDUSTRY SECTORS

The health care sector performs a number of functions that are common to other sectors, including transportation, laundry, food services, building cleaning, heating/cooling, and photographic processing. Many of these support services have traditionally been performed by health care organizations, but increasingly are being contracted out to service firms. The environmental impacts of these types of activities are generally well characterized.

Transportation Services

A variety of municipal, non-profit, and private organizations provide medical transportation services, primarily emergency medical response. The largest private medical transportation provider, American Medical Response (AMR), has a fleet of over 5,000 ambulances nationwide that transports 6 million people per year to emergency care facilities. AMR estimates that it responds to 15 percent of all emergency calls made nationwide (American Medical Response, 1999). Fleet operations and maintenance have environmental impacts such as gasoline consumption, air emissions, and wastes such as used oil, antifreeze, batteries, and tires. The engines used in ambulances generally are required to meet EPA's "Heavy-Duty Engine Emission Standards," which also apply to cargo vans, trucks, and buses. Emergency vehicles are, however, exempt from alternative fuel purchasing requirements under the Clean Air Act "Clean Fuel Fleet" program and the Energy Policy Act, which apply to other large fleets of vehicles (U.S. EPA, 1998).

Laundries

Hospitals launder an estimated 5 billion pounds of soiled linen each year (Electric Power Research Institute, 1996), including bed sheets, pillow cases, baby blankets, gowns, and scrubs. Hospitals have historically run their own laundries on-site, though they increasingly rely upon outside contract laundry services. In 1994, over 50% of hospitals reported using an outside laundry service or full-service textile rental and laundering firm. Almost half of the hospitals that do run their own laundries accept outside linens, from affiliated clinics and physician practices or other hospitals (Weller, 1996).

Laundry volume per patient day has been increasing, from 15 pounds in 1970 to over 20 pounds in 1995. This increase is attributed to shorter patient stays and wasteful practices, such as laundering unused linen (Phillips, 1996). Hospital laundries are large consumers of water, natural gas, and electricity, though they are estimated to be twice as efficient as home washing machines (Shepherd, 1998). A study of 44 hospitals and medical centers found that natural gas consumption per square foot was 25% higher in facilities with on-site laundries than those without (Butkus, 1998). Large quantities of disinfectants are used in hospital laundries for infection control and some items are sterilized afterwards for use in surgical settings (Electric Power Research Institute, 1996 and Shepherd, 1998). Long-term care facilities also process large volumes of laundry.

Food Services

Long term care facilities and hospitals serve millions of meals daily to residents, patients, employees, and visitors. Together, long term care facilities and hospitals served \$9.4 billion dollars worth of food in 1997 – over three percent of the food eaten outside of the home. Health care food sales have been gradually declining since 1990 in absolute terms and as a percentage of total food service (U.S. Department of Agriculture, 1998). The decline in hospital food service sales is perhaps caused by shorter hospital stays, down to an average of 2.5 meals per visit (Bilchik, 1998). One study has reported that food quality influenced patients' overall satisfaction with their hospital stay ("Hospital Finds Food," *Report on Quality Management*, 1998). Health care food service wastes are handled as solid waste, not part of the regulated medical waste stream. However, the large volume of waste generated in food preparation can contribute significantly to waste management costs. Much of this waste can be composted, as over half of the waste generated by food services operations is food scraps. Some facilities grind food wastes for disposal through sewers, though some POTWs forbid such practices due to high biological oxygen demand. Other components of the food service waste stream are fairly easily recycled, including cardboard, steel and aluminum cans, plastic containers, and glass bottles (Bisson, 1993 and Byers, 1997). Cooking and refrigeration facilities also contribute to the high energy needs of health care facilities (U.S. Department of Energy, 1998).

Facility Cleaning

Cleaning surfaces in patient rooms and elsewhere throughout health care facilities is important for infection control and basic sanitation. Though the Centers for Disease Control's infection control guidelines point out that "surfaces rarely are associated with transmission of infections to patients or personnel," it recommends routine cleaning with disinfectants in patient care areas (Centers for Disease Control, 1998). Most health care facilities use cleaning supplies containing low-level disinfectants for this task, which often have anti-bacterial, anti-fungal, and anti-viral properties. In certain instances, specific cleaning compounds are necessary - for instance, phenol compounds are the only cleaners effective at killing tuberculosis bacteria. Despite employee and patient safety concerns, some facilities use phenols for cleaning all patient surfaces (Pierce, 1997). Some disinfectants can pose acute or chronic occupational risks, varying widely among differing compounds. Disinfectants and anti-microbial soaps used for hand-washing must be registered with EPA under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). The Food and Drug Administration (FDA) licenses high-level disinfectants and liquid chemical sterilants, which are generally used only to clean medical devices, not surfaces, (see Section 3) under Federal Food, Drug, and Cosmetic Act (FFDCA) authority. These regulatory programs evaluate both the safety and effectiveness of these anti-microbial compounds. OSHA sets permissible exposure limits for all disinfectants and sterilants. (National Antimicrobial Information

Network, 1998). In addition to exposure concerns, a number of standard cleansers contain significant amounts of mercury (MASCO, 1995).

Heating, Ventilation, and Air Conditioning

Heating, ventilation, and air conditioning (HVAC) systems in health care facilities are important to maintaining the comfort of the patients and employees, as well as controlling the spread of airborne infectious diseases. Hospitals, nursing homes, and long-term care facilities must provide fresh air to people harboring infections and also to people with weak immune systems. To reduce the spread of airborne microorganisms, HVAC systems in health care facilities are designed to have high exchange rates and extra filtration. This increases the amount of air that the system must heat and cool. Isolation rooms for patients with tuberculosis are designed to have negative air pressure and separate exhaust vents. In addition, most hospitals and many clinics are open 24 hours a day year round, adding to their heating and cooling needs (Quayle, 1998). Hospital HVAC systems contribute significantly to high energy consumption – hospitals consume more than twice as much energy per square foot as commercial office buildings (U.S. Department of Energy, 1998). Well-maintained HVAC systems are also important to indoor air quality in all buildings, but especially health care facilities due to the presence of people with weak immune systems.

Photographic Processing

X-ray imaging, or radiography, is used to assist diagnosis of a wide variety of health care professions, such as chiropractic, oncology, dentistry, orthopedics, and surgery. The vast majority of medical x-rays are recorded on silver-based radiographic films, similar to black and white photographic film. Most radiographic films are used in the medical professions, with a few small consumers in scientific, law enforcement, and industrial settings. Manufacturing radiographic films accounts for 10% of the world's consumption of commercial-grade silver, 15% in the United States (Hilliard, 1996 and Silver Institute, 1998). Population growth and aging are expected to drive continued growth of radiographic film use, despite the introduction of digital systems (Saxe, 1997 and Silver Institute, 1998).

Spent black and white photographic chemicals are commonly disposed in the wastewater system, including silver-containing fixer and rinse water. Silver recovery systems are widely available, but are generally economical only for facilities that process large volumes of x-rays, such as hospitals. Silver scrap recovery has been increasing in recent years, and currently represents almost half of domestic production. Three-quarters of domestic recycled silver is derived from photographic wastes. The majority of this is recovered from spent photochemicals, along with some from film scrap (Silver Institute, 1998). Many radiographic film manufacturers have return programs to recycle the lead foil used as protective packaging. One study found that only one quarter of dentists who developed x-rays recovered silver from their photochemicals, while three quarters recycled lead foil (Welland, 1991). The photo processing industry, in collaboration with EPA, has

developed a voluntary *Code of Management Practice for Silver Discharge*, which contains recommendations for silver recovery technologies and management practices for small photographic processors, including medical x-ray facilities (U.S. EPA, 1999).

The chemicals used to process radiographic film can cause acute occupational hazards, as developing agents are very alkaline and stop baths are quite acidic. Severe poisonings and even fatalities have occurred from improper handling of concentrated solutions or powdered forms of photochemicals. Improper mixing, decomposition, and evaporation can cause unhealthy vapor buildup if the processing facility is not properly vented.

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III. IMPACTS FROM ACTIVITIES UNIQUE TO THE HEALTH CARE SECTOR

A number of health care activities present hazards that are infrequently found or never present in other industries. Infection control measures in health care facilities, while necessary to reduce the spread of disease, include a number of practices with serious environmental ramifications. Due to concerns about potentially infectious medical waste, the majority of medical wastes are incinerated. As a result, medical waste incinerators are one of the largest sources of air emissions of dioxin and mercury. Some liquid and gaseous chemicals used in medical equipment sterilization pose considerable occupational hazards due to their toxicity.

Dental amalgam used in fillings has become one of the largest remaining uses of mercury in the U.S., and disposal of mercury containing wastes generated from their installation and removal remains a significant challenge. Ritualistic use of mercury in selected immigrant populations is an emerging threat to individuals. Occupational and individual exposure to mercury, a known neurotoxin, remains a concern in these settings.

Nuclear medicine and x-ray diagnosis (radiography) play important roles in the detection and treatment of disease in our modern health care system. Yet these two activities represent the largest source of exposure to anthropogenic ionizing radiation, when all sources are averaged across the entire population. Other environmentally-relevant health care practices with potentially widespread impacts include fluoridation of drinking water supplies and the effects of pharmaceuticals on water bodies.

Infectious Waste Generation and Disposal

The health care sector generates a unique type of waste – that which has the potential to transmit disease. In the summers of 1987 and 1988, reports of syringes, blood vials, and other medical wastes washing up on U.S. beaches were featured in the national media. Public concern about aesthetic impacts and the risk of infection and injury from improperly disposed medical wastes drew national attention to medical waste management practices (Medical Waste Policy Committee, 1989 and U.S. General Accounting Office, 1990). Medical waste continues to draw intense media attention – medical waste violations were highlighted during a recent highly-publicized investigation into interstate shipping of municipal solid waste on the East Coast (Timberg, 1999).

Potentially infectious waste is generated during patient examination or treatment, and is often referred to as "regulated medical waste (RMW)" or "red-bag waste," due to the commonly used receptacle color to distinguish it from non-infectious solid wastes. There is no national, standardized definition of what wastes should be "red-bagged," thus RMW refers to wastes handled according to requirements in a wide variety of federal and state regulatory programs. Generally, such programs define RMW to include medical wastes such as: cultures and stocks of infectious agents, pathological wastes, human blood and blood products, sharps, animal wastes, and isolation wastes. RMW represents only 15% of all wastes generated in health care facilities; approximately five-hundred thousand tons of RMW are generated each

year (U.S. EPA, 1994a). Some health care facilities include other solid wastes in their red-bag waste streams, resulting in higher disposal costs. Facilities that have embarked upon infectious waste management programs have found that better segregation can result in significant cost savings and reduced reliance on incineration and/or sterilization (EWG, 1997). The medical waste treatment and disposal market has grown to over \$1 billion annually (Malloy, 1997). The total costs borne by the sector for medical waste disposal is even higher if the cost of operating on-site hospital waste incinerators is included.

The calculated risk of a member of the public getting an infection from improperly disposed RMW is quite low (Rutala, 1992). Sanitation workers and medical waste industry employees are at higher risk from infectious wastes than the general public, as they handle large volumes of potentially infectious waste prior to treatment. Last year, three cases of tuberculosis (TB) among workers at a medical waste processing facility in Washington State were believed to have been caused by exposure to infectious waste. Industrial hygienists believe that the TB bacteria became airborne during treatment and infected employees who were not wearing respiratory masks during a failure of an air filtration system. Fifteen other workers at the facility received treatment for latent TB infections, though it is unclear if any were caused by occupational exposure ("Stericycle," *Medical Waste News*, 1998).

The most common medical waste disposal method is incineration, though no federal or state program requires it. Other common treatment technologies include autoclave (high temperature steam sterilization) and low-frequency radio wave sterilization. Some states allow untreated medical wastes to be disposed of in landfills, while others require medical wastes to be destroyed beyond recognition (NaQuin, 1998).

Medical Waste Incinerators

There are approximately 2,400 hospital/medical/infectious waste incinerators (HMIWIs) in the United States, most of them owned by and located at hospitals (U.S. EPA 1997 and Malloy, 1997). Small medical waste generators and hospitals without on-site facilities often send wastes to commercial medical waste incinerators or municipal solid waste combustors (U.S. EPA, 1996 and Malloy, 1997). HMIWIs were not brought under federal Clean Air Act jurisdiction until 1990. Final regulations were not approved until 1997 and a court recently sent the rule back to EPA for further clarification (Zacaroli, 1999). The regulations remain in place while the agency justifies its standards to the court, and states are currently developing State Implementation Plans based upon the promulgated standards. Only a few states have existing HMIWI air emissions regulations (NaQuin, 1998). As a result, as many as two-thirds of existing HMIWIs have no pollution control devices installed (EWG, 1997).

EPA's latest estimate of nationwide air emissions of dioxin-like compounds identifies medical waste incinerators as the third largest source, representing 17% of total toxic equivalent concentrations (TEQ) (U.S. EPA, 1998). On-site hospital incinerators produce high levels of dioxins primarily due to batch processing, lack of pollution control devices, and age – newer, continuous feed commercial medical waste incinerators generally have much

lower emissions (U.S. EPA, 1997; EWG, 1997; and NaQuinn, 1998). There are some claims that the high chlorine content of medical wastes (twice as much plastic as municipal waste, much of it polyvinyl chloride) aids in the creation of dioxin (EWG, 1997 and Malloy 1997), though the latest industry-sponsored study found no correlation between vinyl content and dioxin emissions (American Society of Mechanical Engineers, 1995). Medical waste incinerators are also estimated to be responsible for over 10% of nationwide air emissions of mercury (U.S. EPA, 1997). This is attributed to the large numbers of medical supplies that contain mercury, such as thermometers and certain blood pressure measuring devices.

EPA estimates that the 1997 regulations will reduce annual mercury and dioxin releases from HMIWIs by 95% in five years. A large portion of the reduction is attributed to an expected shift in medical waste disposal practices – EPA expects that 50-80% of existing incinerators will shut down as a result of the regulations. Air emissions will be reduced as more regulated medical waste is handled by commercial incinerators with advanced pollution control systems, on-site or commercial autoclaves, and/or alternative treatment technologies (U.S. EPA, 1997).

Medical Equipment Sterilization

Once medical equipment, especially surgical equipment, has come in contact with a patient, it needs to be sterilized prior to reuse. Autoclaves, high temperature steam sterilizers, are commonly used for equipment made of metal and some plastics. Some medical instruments, however, are steam or heat sensitive, particularly rubber surgical tubes, flexible scopes, electrical equipment, and fiber optics. This equipment has typically been sterilized using ethylene oxide (EtO) gas, a highly-effective sterilant. Since EtO is highly flammable and explosive, historically it was mixed with chlorofluorocarbons in a 12% EtO and 88% CFC combination. Following the phase-out of CFCs, 100% EtO systems have become the dominant technology ("Ozone," *Biomedical Market Newsletter*, 1997).

EtO is flammable, explosive, and acute doses effect the central nervous system and irritate eyes and mucous membranes in humans. There is some evidence that long-term human exposure to EtO can also cause miscarriages and certain cancers (ATSDR, 1990 and U.S. EPA, 1994b). OSHA estimates that 68,000 health care workers work with EtO annually (U.S. Occupational Safety and Health Administration, 1995). OSHA rules set permissible exposure limits for employees, and are largely credited with increasing monitoring and driving technological improvements to reduce exposure. Hospital EtO sterilizer emissions are usually vented to the roof, and are estimated to be the source of 45% of national EtO air emissions (U.S. EPA, 1999). Though hospital EtO emissions are not currently regulated by EPA, the agency's recent Integrated Urban Air Toxics Strategy targets hospital sterilizers for future regulation (Kennedy, 1999). Some states already regulate hospital EtO emissions.

A number of alternative sterilization technologies are under development, but ethylene oxide remains the primary sterilant used in both medical equipment manufacturing and on-site hospital settings. ("Ozone," *Biomedical Market Newsletter*, 1997).

Dental Fillings

Dental amalgam, often known as "silver fillings," has been used for over 150 years to fill cavities (American Dental Association, 1996). Amalgam is created by mixing a silver alloy with liquid mercury, resulting in a substance that hardens quickly into a durable filling. Dentists place approximately 100 million amalgam fillings per year in the U.S., approximately half of all tooth restorations (U.S. PHS, 1997). Since amalgam is long-lasting (average of 10 years) and cheaper than alternative materials, 80-95% of dentists use it to repair posterior teeth where strength and durability are most important (Michigan, 1996). Dental amalgams account for over 10% of domestic mercury consumption, the third largest use (Reese, 1997) and represent 2% of domestic silver consumption (Silver Council, 1998).

Historically, dentists have mixed their own amalgam using bulk mercury and silver alloy. Mercury poisoning from long-term occupational exposure has been documented in dentists, but measured mercury levels in dentists has been dropping in recent years (American Dental Association, 1996 and U.S. Public Health Service, 1993). Today, 85-90% of dentists use pre-measured capsules that minimize mercury vapor generation and the likelihood of spills (Michigan, 1996 and Wisconsin, 1998). Occupational exposures are expected to decline further as more dentists adopt pre-measured capsules. After mixing the amalgam and placing the filling in the patient's tooth, an estimated fifteen to fifty percent is leftover (Florida, 1997), known as "non-contact" amalgam waste. Dentists also generate "contact" amalgam waste when they polish new fillings, drill or remove old fillings, or extract teeth with amalgam fillings. Suction devices placed in patients' mouths remove amalgam particles, which then passes through a particle trap before being discharged into the sewer system. Large particles are caught in the trap, but smaller particles and dissolved mercury are discharged into the sewers. A number of wastewater utilities have discovered that discharges from dental facilities are one of the largest sources of mercury in their systems. Estimates of dental contributions to wastewater mercury loadings are 8-14% in San Francisco (Massachusetts, 1997); 14% in Seattle (Welland, 1991); 13-79% in Boston (Massachusetts, 1997); 26% in Milwaukee (Obenauf, 1997) and Duluth (Massachusetts, 1997); and 76-80% in Minneapolis/St. Paul (Berglund, 1997). Amalgam wastes are considered hazardous wastes in many states – RCRA rules generally require mercury recovery from high mercury content wastes such as amalgam. In some states contact amalgam is also classified as an infectious waste – suggested handling practices include storage under weak bleach until disposal. The few existing surveys of dental waste management practices show that many dentists are recycling amalgam wastes, though a large portion of dental wastes also enters the municipal and infectious waste streams, contributing to the high levels of mercury emissions from municipal and medical waste incinerators (Berglund, 1997 and Florida, 1997).

Controversy over mercury exposure to patients from amalgam fillings has prompted amalgam safety studies by FDA and the U.S. Public Health Service (PHS). Over time, small amounts of mercury vapors and particles are released from fillings due to regular wear, and can be absorbed by the body (U.S. PHS, 1993). Public health studies have not found convincing evidence that this low-level chronic mercury exposure is harmful, yet the most

recent national inquiry conducted by PHS concluded that the "risks cannot be totally ruled out." The PHS recommended that no restrictions on the use of dental amalgam were appropriate based upon existing scientific knowledge and has embarked upon an ongoing research program to study the biological effects of dental amalgam. (U.S. PHS, 1993).

Ritual Use of Mercury

A shiny liquid at room temperature, elemental mercury has held mystical significance in many cultures throughout history. Greater awareness of mercury's health hazards over the last half-century has largely eliminated public contact with elemental mercury in most Western societies. However, over the last ten years public health officials have noted widespread spiritual and medicinal uses of elemental mercury in Caribbean and Latin American immigrant communities in the United States. It is promoted by spiritual healers practicing Santeria (a religion originating in Cuba) and Esperitismo (a belief system originating in Puerto Rico), who believe that mercury (azogue in Spanish) wards off evil spirits and attracts good luck. Some Mexican-Americans also swallow small doses of mercury to relieve indigestion and other stomach ailments. People adhering to such customs keep mercury in the home and workplace, or carry mercury capsules around in amulets or purses. Others sprinkle mercury throughout a room, mix it with bath water or perfume, burn it in candles, or leave it in open containers underneath their bed (ATSDR, 1997; Levinson, 1997; Rauch, 1991; and Wendroff, 1990).

Mercury volatilizes at room temperature, causing a gradual buildup of mercury vapors in unventilated rooms. Ritual activities that spread mercury throughout a room or cause spills can leave persistent mercury contamination that is difficult to cleanup. One study concluded that twenty-seven thousand people could potentially be exposed to harmful levels of mercury vapors in their homes in New York City each year from such rituals. This same study found that 40% of people of Caribbean descent and over 25% of Hispanics acknowledged using mercury for a wide variety of practices (Ojito, 1997). Preliminary results of a Chicago study found that 20% of Hispanics surveyed used mercury in rituals (Rittner, 1997). Almost every botanica visited by researchers in New York and Chicago sells vials of mercury, further evidence that the practices are commonplace.

X-Ray Diagnosis

X-ray imaging, or radiography, is used to assist diagnosis in a wide variety of health care settings, such as chiropractic, oncology, dentistry, orthopedics, and surgery. X-rays are high-frequency electromagnetic energy produced when fast-moving electrons crash into a metal target. As an x-ray travels through the body, it is absorbed or scattered by atoms – more effectively by atoms such as calcium in the bones and teeth. Photographic films or digital imaging systems are used to record the x-rays that pass through the body, producing an image that contrasts the density of tissue or bone. Computed Tomography (CT) scans produce three dimensional x-ray images, using computers to extrapolate information from

multiple x-ray exposures. The high resolution of CT scans can reveal structures not apparent in two dimensional x-rays (American College of Radiology, 1993 and U.S. Nuclear Regulatory Commission, 1998a).

The American College of Radiology estimates that 260-330 million radiological procedures were performed in 1990, at a cost of \$19-22 billion (Sunshine, 1991). While this includes a wide variety of diagnostic and therapeutic procedures, such as MRI and ultrasounds, traditional x-ray diagnostic examinations constitute the majority of spending on radiology services (Sunshine, 1991). The Food and Drug Administration (FDA) estimates that up to one third of all diagnostic x-ray examinations are not medically necessary, but instead are performed due to administrative requirements such as hospital admissions rules (Massachusetts, 1997).

Ionizing radiation, such as x-rays, can cause cellular disruption by disrupting chemical bonds or damaging chromosomes. High doses of radiation can cause adverse health effects, such as cancer. Since a number of different body parts are examined in radiology, exposure from medical x-rays varies widely depending on the intensity of the beam and the total area exposed. Small exposures over time may have a detrimental effect similar to receiving a single large exposure, since radiation doses are cumulative. When averaged across the entire U.S. population, exposures to x-rays from medical imaging procedures are the source of 62% of anthropogenic ionizing radiation doses. This represents 11% of the average ionizing radiation, including natural sources, received by the average U.S. resident (National Research Council, 1990). There is no federal regulatory program governing x-ray machine operations, with the exception of mammography facilities. State radiation protection programs regulate x-ray machine and facility operations, performing activities such as safety and shielding plan review, facility and operator licensing, and facility inspections.

Nuclear Medicine

Nuclear medicine refers to the use of radioisotopes in diagnostic and therapeutic medical procedures. Nuclear diagnostic imaging allows physicians to examine the structure and functioning of internal systems, using radiopharmaceuticals designed to migrate to the particular organ of interest – the emitted gamma rays can then be detected by cameras. Cancer can be treated using radiation therapy techniques by administering high levels of radiation to kill or damage cancerous cells.

About 10-12 million nuclear diagnostic procedures are performed annually along with 60-70,000 radiation therapy procedures. The therapeutic market is expected to grow rapidly in the near future, as new radiopharmaceuticals are developed. Currently radiation therapy is used in half of all cancer treatments (U.S. Nuclear Regulatory Commission, 1996). The materials and technologies used in nuclear medicine have the potential to do great harm to the human body. Risk management is institutionalized in nuclear medicine – radioactive substances release energy in predictable ways that are calculated to determine dosage. The risk of complications resulting in death from radiation therapy is approximately 1%, similar to chemotherapy (1%) but lower than most invasive surgery (1-23% depending on the type of

cancer and type of surgery). No deaths or significant injuries from misadministration of a nuclear medicine procedure have been recorded in over twenty years (American College of Nuclear Physicians, 1997). Nuclear medicine accounts for 22% of cumulative anthropogenic exposure to ionizing radiation averaged across the U.S. population, or 4% of the total including natural sources (National Research Council, 1990).

To supply the nuclear medicine industry, approximately 1 million shipments of radioactive substances occur annually, representing 40%-60% of all radioactive material shipments (U.S. Department of Energy, 1995). The safety record of radioactive material shipments is quite good; in one year only 24 accidents were reported out of over 2 million shipments and less than 1% of the standard shipping containers have released their contents during an accident (Hamilton, 1993 and U.S. Nuclear Regulatory Commission, 1998b).

Historically, nuclear medicine technologists have formulated the radiopharmaceuticals used in radiation therapy on-site, facing long-term low-level occupational exposures to radioactive substances. In recent years commercial nuclear pharmacies have cropped up to supply the market, formulating radiopharmaceuticals in batches for multiple hospitals and nuclear medicine clinics. Nuclear pharmacies are better equipped to reduce occupational risks, inadvertent spills, and waste generation – economies of scale suggest that they have access to better equipment and training (American College of Nuclear Physicians, 1997 and Hamilton, 1993).

Radioactive waste management often begins with extended on-site storage, as most radioisotopes used in medical applications have half-lives lasting hours, days, or weeks. After the material has decayed to safe levels, the waste can be disposed of in either the solid or infectious waste streams, depending on its characteristics. As a result, only one percent of the radioactive waste disposed of in low-level radioactive waste facilities is from medical or research uses (Hamilton, 1993).

In addition to nuclear medicine procedures, radioisotopes are used "behind the scenes" to diagnose and prevent disease. Blood products are sometimes irradiated for transfusions involving people with severe immunodeficiencies, to kill the donor's lymphocytes. Clinical laboratories perform 10 million radioimmunoassay tests annually on blood and other body fluids by tagging compounds with radioactive labels (American College of Nuclear Physicians, 1997).

Pharmaceuticals

Recent studies, primarily in Europe, have detected the widespread presence of pharmaceuticals in surface water bodies, groundwater, and drinking water supplies. These studies have measured low concentrations of a number of drugs, including cholesterol-lowering compounds, analgesics, chemotherapy formulations, and antibiotics (Raloff, 1998). The patterns detected suggest that the primary source of these pharmaceuticals is human excretions (Buser, 1998). Though most pharmaceuticals are designed to be absorbed by the human body, in some cases 50-90% may pass through the human system (Raloff, 1998). For many years scientists have studied the prevalence and effects caused by the introduction of

pesticides and industrial chemicals into the environment, but comparatively little attention has been devoted to the impacts of widespread pharmaceutical pollution. Initial concerns that have been raised include furthering the development of antibiotic resistant organisms and the alteration of hormonal balances of wildlife and human populations.

As part of its pharmaceutical approval process, the Food and Drug Administration requires drug manufacturers to perform environmental assessments, including a rough calculation of potential pharmaceutical concentrations in POTW's after eventual excretion by consumers (U.S. Food and Drug Administration, 1998). FDA recently raised the reporting thresholds, reducing the number of applicants that are required to complete an environmental assessment. The agency determined that few calculations indicated significant concentrations, though there has been no monitoring to verify the manufacturers' estimates (Raloff, 1998). Recent EPA regulations of air and water discharges from the pharmaceutical manufacturing industry focus solely on traditional pollutants. RCRA and state hazardous waste programs include a few particularly toxic pharmaceuticals, such as chemotherapy agents, in their definitions of hazardous waste. Only 2-4% of all waste pharmaceuticals (residual, expired, or damaged) are handled as hazardous wastes (California, 1996). European scientists have begun to set an agenda for further research on the environmental implications of pharmaceuticals (Raloff, 1998).

Drinking Water Fluoridation

Dentists are at the center of a five-decade long international public debate over the benefits and risks of adding fluoride to public drinking water supplies. Fluoride is known to reduce the incidence of dental cavities, and fluoridation of water supplies is considered to be one of the most effective ways of treating the teeth of large populations. A 1991 Public Health Service meta-analysis of a number of studies credits water supply fluoridation with reducing dental cavities by 20-40% compared to nonfluoridated areas (U.S. Public Health Service, 1991). Fluoride risks have also been studied extensively, but have generated a large amount of controversy. On one side, some argue that some studies of fluoride exposure indicate that it can cause cancer, bone brittleness, and other detrimental health effects (Environmental Health Perspectives, 1997 and Citizens for Safe Drinking Water, 1997). Neither of the last two national scientific examinations of the issue found an association between fluoride and cancer (National Research Council, 1993 and U.S. Public Health Service, 1991). Limited data and conflicting results led both to conclude that more research is necessary into fluoride's relationship to bone brittleness. Both studies generally concluded that there was no sign that current levels of fluoride in drinking water supplies posed health risks.

Both also noted that cumulative exposure to fluoride has been rising due to other sources of fluoride, such as toothpaste and beverages. This raises the concern that more individuals could be receiving higher cumulative doses than estimated when drinking water standards were set.

In the United States, approximately half of the population is served by water supplies that have fluoride added to it and another ten percent are served by systems with naturally

occurring levels above the minimum level considered protective for reducing dental cavities (American Dental Association, 1998 and Environmental Health Perspectives, 1997). The Public Health Service published an optimal range for fluoride in drinking water in the 1960s. This range represents the minimum level that achieves reduction in dental cavities, yet the upper bound should still result in minimal adverse tooth mottling (fluorosis). The Environmental Protection Agency's drinking water program treats fluorosis as a cosmetic effect. Its maximum contaminant level is based upon other potential adverse health effects, and thus is higher than the PHS's. The National Research Council study mentioned above determined that EPA's maximum level was protective of human health based upon current scientific knowledge.

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IV. SUPPLY CHAIN ENVIRONMENTAL MANAGEMENT

The environmental impacts of health care activities are significantly influenced by the characteristics of the products used in the industry. The use and disposal of medical supplies, such as gloves, thermometers, and syringes, can pose environmental and occupational hazards. High mercury emissions from medical waste incinerators can be traced to the many mercury-containing products used in health care delivery. Purchasing organizations thus play an important role in determining the environmental impacts of health care activities, through their control over product availability and characteristics.

Medical supplies account for \$180 billion in hospital and nursing home expenditures each year ("Anti-GPO," *Hospital Materials Management*, 1998). Demand for disposable medical supplies has been growing, representing \$30 billion of this market ("Disposables," *Medical Waste News*, 1994).

Procurement functions are highly centralized in the health care industry, especially in hospitals and managed care networks. Most hospitals have a materials management department, responsible for purchasing, storage, and distribution of medical supplies and equipment. A Florida study found that 94% of hospitals have a centralized purchasing department (Florida, 1997). Materials management is essential for effective hospital operations, as ample medical supplies are crucial for patient care and account for 20-30% of hospital costs ("Outsourcing," *Hospital Materials Management*, 1995). To reduce costs, most nonprofit hospitals obtain medical supplies through purchasing cooperatives, known as group purchasing organizations (GPOs). Almost all nonprofit hospitals purchase their supplies through the six hundred GPOs ("Anti-GPO," *Hospital Materials Management*, 1998), as do some public and for-profit hospitals and smaller health care providers. GPOs contract for large volumes of supplies, negotiating more favorable price rates with medical supply manufacturers and distributors than individual facilities could achieve alone. As the intermediaries between the health care providers and the medical supply manufacturers, wholesalers, and distributors, GPOs and materials managers have considerable influence over product specifications and availability.

A number of factors influence medical supply purchasing decisions, including: physician and nurse preferences, clinical effectiveness, regulatory requirements, safety and infection control concerns, and, of course, cost. When bringing new products to market, medical supply manufacturers also must contend with regulatory approval and product liability concerns. Efforts to achieve environmental benefits through product substitutions must contend with these other factors that drive medical supply consumption.

Four examples of health care products with environmental and safety concerns are profiled below to illustrate their potential impacts. Three topics were selected due to the hazards associated with the materials they are made from: mercury-containing products; polyvinyl chloride plastics; and latex gloves. In addition, a discussion of needles and syringes was included due to their physical hazards and potential to transmit infectious diseases.

Mercury-Containing Products

A number of commonly used medical supplies contain mercury, and a variety of other mercury-containing products can be found in health care facilities. Mercury-containing medical supplies include thermometers, blood-pressure units, dental amalgam, saline solutions, and a variety of medical tubes that use mercury as a flexible weight. Mercury can also be found in common electrical materials, such as thermostats, fluorescent lamps, and batteries used to power medical equipment. Clinical laboratories use a variety of mercury compounds as reagents, stains, and fixatives. A twelve-hospital inventory of clinical and research laboratories found over 800 stains, fixatives, and other chemical products that contained mercury (MASCO, 1995).

Medical waste incinerators are believed to be the source of over 10% of nationwide anthropogenic air emissions of mercury. Discarded consumer, electrical, and medical products are the main contributors to these emissions. A large amount of health care wastes, sometimes including mercury products, enters the municipal waste stream. Municipal waste combustors release large amounts of mercury, estimated at nearly 20% of nationwide air emissions (U.S. EPA, 1997b). EPA has recently promulgated air pollution control standards for both medical and municipal waste incinerators. These regulations are expected to shift some waste from incinerators to other waste disposal methods and force many incinerators to install pollution control devices. Under both of these scenarios, mercury products will be disposed in other media (land or water). To achieve greater environmental benefits at lower cost, a number of mercury pollution abatement strategies have focused on reducing the intentional uses of mercury. *The Great Lakes Binational Toxics Strategy*, adopted by Environment Canada and U.S. EPA in 1997, commits the U.S. to a 50% reduction of mercury use by 2006 from 1991 levels (Environment Canada, 1997). The voluntary partnership between the American Hospital Association and EPA commits the partners to working towards the virtual elimination of mercury wastes from hospitals by 2005 (AHA, 1998). These strategies rely upon the widespread adoption of alternatives to mercury-containing products.

For many medical supplies that contain mercury, there are non-mercury based alternatives available. For instance, EPA estimates that digital thermometers are gaining 1-2% market share each year and that the amount of mercury from thermometers discarded in municipal solid waste dropped 50% from 1985-1995 (U.S. EPA, 1997b). Blood pressure gauges that contain no mercury are commercially available and are generally recognized as accurate and effective (Florida, 1997 and Wisconsin, 1998). A number of hospitals have already embarked upon projects to eliminate or reduce their consumption of mercury-containing products (CHW, 1998; EWG, 1998; and Williams, 1997). These efforts, along with a number of state-sponsored pollution prevention programs, have begun to identify product substitutes for most mercury-containing items.

Polyvinyl Chloride Plastics

The U.S. health care industry consumes almost 3 million pounds of plastic medical products each year. Polyvinyl chloride (PVC) is a primary component in 25% of all medical products--over 750 million pounds are used annually ("Selecting," *Medical Device & Diagnostic Industry*, 1996 and Chlorine Chemistry Council, 1999). PVC plastics came into medical use beginning with blood transfusions during World War II, and have been used widely since then due to their low cost, versatility, and durability. PVC is the primary material used for many medical products, such as intravenous bags, blood bags, tubing, and disposable mattress covers. It is also widely used in packaging and numerous building materials. PVC products have been the focus of numerous environmental campaigns, often due to concerns over the environmental and health impacts of toxic chemical usage in the PVC production process.

Hospital wastes have been estimated to have twice as much chlorine content as municipal waste streams, primarily due to the large amounts of PVC products. EPA's latest estimate of nationwide air emissions of dioxin-like compounds identifies medical waste incinerators as the third largest source, accounting for 17% of total toxic equivalent concentrations (TEQ) (U.S. EPA, 1998). The high levels of dioxins and hydrochloric acid (HCL) created in medical waste incinerators are primarily associated with batch processing, lack of pollution control devices, and incinerator age (U.S. EPA, 1997a). There are some claims that PVC products are precursors of dioxin and HCL emissions when burned in incinerators (EWG, 1998; HCWH, 1997; Malloy 1997), though the latest industry-sponsored study found no correlation between vinyl content and dioxin emissions (American Society of Mechanical Engineers, 1995).

There is also a growing concern over potential carcinogenic and other toxic properties of the plasticizers used to make the PVC flexible. Two recent reviews of the scientific literature regarding the safety of such compounds, known as phthalates, came to opposite conclusions (Koop, 1999 and Tickner, 1999). If phthalates are determined to be toxic, intravenous (IV) bags, blood bags, and pharmaceutical containers are of particular concern as they provide fluids directly to patients' bloodstreams (Health Care Without Harm, 1999). Research on newly developed plastics has found some with favorable characteristics that could replace existing PVC products (Lipsitt, 1997). Some manufacturers have begun to market IV products made from non-vinyl plastics, especially in Europe due to substantial consumer and government pressure (Baxter, 1999; Health Care Without Harm, 1999). A few hospitals have begun to inventory their PVC use and, when possible, to purchase products that do not contain PVC (EWG, 1998; Health Care Without Harm, 1999).

Latex Gloves

Surgical gloves have been in use for over a century (FDA, 1997), but surgical glove use has dramatically increased over the last decade in patient examination and dental settings. Latex gloves are a protective barrier against bloodborne pathogens, and increased use has

largely been driven by fears surrounding the HIV epidemic and adaptation of universal precautions against infectious agents, required under OSHA's 1991 Bloodborne Pathogens Standard. In 1996, 90% of all medical gloves were made of natural latex rubber (NRL). Since NRL gloves are tacky, three-quarters of NRL gloves are lubricated with a cornstarch powder. Powder-free gloves are manufactured by chlorinating the surface to reduce the tackiness (FDA, 1997). A wide variety of other medical supplies are manufactured with natural rubber latex, but disposable gloves are by far the most common product.

NRL products can cause skin irritation, from contact with rubber and/or chemicals used during the manufacturing process. In addition, between 1-6% of the population is susceptible to a more serious allergic reaction to proteins found in NRL (FDA, 1997; NIOSH, 1997). Respiratory problems and asthma like attacks are the most common symptoms, believed to be triggered when allergens attached to the cornstarch powder become airborne. Once airborne, the powder can become lodged throughout health care facilities, including in HVAC systems. NRL allergy is now prevalent in 5-20% of health care workers--from 500,000 to 2 million people, as they are sensitized through repeated contact with NRL products (FDA, 1997; Moore, 1999; NIOSH, 1997).

Alternative products on the market include powder-free NRL, synthetic latex, vinyl, and other synthetic products. Chlorinated powder-free NRL gloves are generally 50-100% more expensive than the powdered variety, and currently fill one-quarter of the NRL market (FDA, 1997; "Hospitals," *Hospital Materials Management*, 1997). They also are less durable and have shorter shelf-lives, and may cause a higher prevalence of skin irritation. Vinyl gloves are less effective as a barrier to infectious agents, but are commonly used for routine patient examinations where the risk of disease transmission is low. FDA and OSHA have both considered a range of regulatory actions to reduce NRL allergy. To date, their actions have addressed safety management and product labeling. Few health care facilities have switched entirely to powder-free or non-NRL gloves, citing cost and performance issues as hindrances. Most, however, use such products for procedures involving a known NRL allergenic patient or employee ("Hospitals," 1997; Moore, 1999; NIOSH, 1997).

Needles and Syringes

Puncture wounds caused by infected needles can transmit bloodborne pathogens, such as HIV and Hepatitis. Hospital-based health care workers report approximately 600,000 needlestick injuries occur annually, potentially exposing them to bloodborne diseases (OSHA, 1998). CDC's *Universal Precautions for Prevention of Transmission of HIV and Other Bloodborne Infections* (1987-1989) and OSHA's standard for *Occupational Exposure to Bloodborne Pathogens* (1991) set standards for health care infection control practices, including guidelines for the safe use, handling, and disposal of needles. Needlestick injuries account for 80% of health care workers' exposure to potentially infectious blood. Hepatitis B infections in health care workers declined from 12,000 new cases in 1985 to 800 in 1995, largely as a result of safety measures implemented due to these standards. During this time period, an estimated 100-200 health care employees have died annually from occupationally-

acquired Hepatitis B infections (OSHA, 1997; CDC, 1998). In addition, 500-1,000 cases of Hepatitis C are contracted by health care workers each year. There have been only 45 documented cases of HIV transmission by needlestick, yet this remains a particularly vivid concern among health care workers (OSHA, 1997). But the continued high frequency of needlestick injuries despite increased attention to safety by health care employees has led OSHA to re-examine needlestick prevention strategies. Increasingly, attention is focused on "safer needle devices" that reduce the risk of needlestick injuries. A number of safety needles and needleless devices have entered the marketplace in the last few years, but are generally still two to four times as expensive as regular needles (Levenson, 1998).

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V. INFLUENCE OVER OTHER SECTORS

Waste Disposal Industries

The health care sector has considerable influence over the activities of the waste management industries serving the regulated medical waste and radioactive waste streams. Over the last ten years, medical waste treatment and disposal has grown into a \$1 billion industry (Malloy, 1997). It has a separate network of transportation systems and treatment facilities to destroy pathogens, including on-site hospital incinerators, commercial incinerators devoted solely to medical waste, and a number of facilities using alternative treatment technologies such as autoclaves (high temperature steam) and low-frequency radio waves. EPA predicts that new regulations published in 1997 will cause 50-80% of existing medical waste incinerators to shut down rather than install pollution control devices (U.S. EPA, 1997). It is not yet clear how the market will respond to the influx of waste from health care facilities that close down their incinerators. Some larger health care facilities may build on-site autoclaves to replace their incinerators. Off-site operations will likely expand, including commercial medical and municipal waste incinerators, autoclaves, and low-frequency radio wave treatment facilities. Browning-Ferris Industries, the nation's largest medical waste incinerator operator, announced that it will replace its incinerators with autoclaves (Allen, 1998).

Radioactive wastes generated from nuclear medicine procedures comprise only one percent of the waste disposed of in low-level radioactive waste facilities (Hamilton, 1993). Despite the small contribution, ensuring adequate disposal capacity for nuclear medicine wastes has played a large role in debates over siting low-level radioactive waste disposal facilities. The public generally views nuclear medicine as an important and appropriate application of nuclear technology. Public interest in the nuclear medicine industry aids the nuclear power and government-sponsored nuclear research communities by providing support for radioactive waste disposal facilities.

Technology Transfer with Other Sectors

A number of environmentally-preferable technologies developed for use in health care sectors can be adopted for use in other industries, and visa versa. Advanced compact electron accelerators used in nuclear medicine applications are also used for food irradiation, medical equipment sterilization, pulp treatment, and plastic polymerization. Some of these procedures are currently heavily reliant on hazardous chemicals, which could be reduced with the successful introduction of accelerator technology. Accelerator produced beams can sometimes substitute for reactor-produced radioisotope sources, minimizing the amount of radioactive waste generated.

Similarly, x-ray producing equipment is also used in a handful of industrial and other commercial applications, such as non-destructive testing and airport baggage inspection. X-ray diagnostic facilities could greatly benefit from the technology seen in small, automatic, self-contained consumer photographic processing systems that are increasingly common in

photography stores. Automatic processing machines use less water, less photographic chemicals, and significantly reduce operator exposure to photographic chemicals.

Impacts on Regional Land Use Patterns

Geographical studies of medical services tend to focus on residents' access to healthcare to determine populations underserved (or overserved) by medical services. Recent attention has been drawn to regional growth patterns and "sprawl." The role of medical facilities in influencing land use patterns is varied, but not likely to be a significant driver in regional land use patterns.

Small physicians' and dentists' offices tend to locate near the residential populations that they serve – gerontologists in older, established communities with aging populations and pediatricians in new, high-growth suburbs where young couples tend to settle. While the services they provide these communities may be important factors for subsequent residents, doctors and dentists clearly follow the locational decisions made by residents. Most nursing homes or other specialized medical facilities (diagnostic centers, etc.) are too small to have an effect on development patterns.

The same cannot be said for hospitals. A major hospital facility can trigger a range of related developments – doctors' offices, laboratories, outpatient clinics, etc. Hospitals can be transportation management challenges – new hospitals are likely to locate near highway interchanges, ensuring highway access from a number of highway-dependent communities. Old hospitals in urban residential areas may be limited in growth by the capacity of local feeder roads, parking facilities, and noise tolerance of nearby residents. Older, urban and rural community hospitals are stabilizing influences in the communities they are located in. They often serve as the primary means of access to medical service in communities neglected by other health care services, and can be a major employment center for skilled and unskilled urban and rural residents.

There is at least one example, the Mayo Clinic in Rochester, MN, where a medical facility is the major economic activity in the community and where most development is oriented to the hospital. There are more common examples of hospitals spurring development in their immediate vicinity. For example, in the Washington, D.C. area, the National Institutes of Health campus in Bethesda, MD has spurred a variety of related development, and in the Shady Grove area a hospital and a county medical facility have catalyzed some development.

While there are examples of medical facilities having locational effects, such facilities generally are not a major influence on land use or development patterns, at least when compared with other service sectors such as retail trade or universities. If the goal were to influence growth or limit sprawl, medical facilities would not be the most fruitful focus of attention.

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VI. POLICY IMPLICATIONS

Sector and Hazard-Based Strategies

Government interventions in the health care sector for environmental and safety reasons address three distinct life-cycle stages:

1. product safety and effectiveness;
2. facility operations and employee behavior; and
3. pollution control and waste management.

Broadly speaking, among federal agencies the Food and Drug Administration (FDA) is responsible for ensuring the safety and effectiveness of products used in health care; the Occupational Safety and Health Administration (OSHA), and the Centers for Disease Control and Prevention (CDC, a non-regulatory body) oversee safety practices in the health care workplace; and the Environmental Protection Agency (EPA) regulates pollution and waste management. The Nuclear Regulatory Commission (NRC) regulates the formulation, use, and disposal of radiopharmaceuticals used in nuclear medicine.

There is, of course, considerable overlap. EPA and FDA jointly share regulatory authority over the safety and effectiveness of anti-microbial sterilants and disinfectants. CDC has recommendations regarding waste disposal methods, FDA regulates sharps disposal containers, the Department of Transportation (DOT) regulates waste transportation on public highways, and EPA has promulgated regulations for medical waste incinerators. FDA's responsibilities include certification of mammography facilities and EPA's EnergyStar program provides technical assistance to health care facilities managers. The involvement of state health and environment departments, federal financing agencies, and industry certification programs adds to the numerous oversight authorities. Effective regulatory oversight of such a large and complex industry, especially one subject to so many regulatory authorities, is an enormous task.

With overlapping jurisdictions and fragmentation, the goals of one program can sometimes be detrimental to achieving the goals of another program. EPA's successful phase-out of chlorofluorocarbons caused a shift from gaseous sterilants containing only 10% ethylene oxide to 100% ethylene oxide, which increases occupational risks. The agency now is planning to regulate ethylene oxide emissions from hospital sterilizers as part of its urban air toxics strategy. Manufacturers seeking to substitute new, potentially less hazardous materials to address occupational or environmental hazards must navigate FDA's premarket approval program – a potentially lengthy process for materials being reviewed for the first time. Products already on the market, or similar to existing products, are not subject to the same level of scrutiny. State infectious waste regulatory programs, liability fears, and public concern (along with a short-lived pilot federal EPA medical waste regulatory program) drove many health care facilities to incinerate wastes to ensure complete destruction. As a result,

medical waste incinerators are now facing increased regulation due to their large contribution to air emissions of dioxins, mercury, and other pollutants.

Fragmentation of programs also hinders the ability of agencies to take a comprehensive look at the hazards of a practice throughout all stages of its life-cycle. Governmental interest in mercury-containing dental amalgam illustrates the extent of this fragmentation. The FDA approves all amalgam formulations prior to their release on the market and reviews safety information related to amalgam products. Since 1991, the Public Health Service has had a committee to study the health risks of dental amalgam, recommend policy options, and coordinate federal research. Almost every EPA program regulates mercury wastes – RCRA prohibits most land disposal; CAA regulations address mercury emissions from municipal and medical waste incinerators, where solid amalgam wastes are often disposed; and the CWA aims to eliminate mercury discharges from publicly-owned treatment works, which work with individual facilities emptying into their systems to reduce mercury loadings. EPA has provided funding to state governments and local wastewater authorities, primarily in the Great Lakes region, to estimate mercury pollution sources and undertake pollution prevention activities.

There are ways that program fragmentation can be surmounted to develop a comprehensive strategy for a particular hazard. The Hospital Infection Program (HIP) at the Centers for Disease Control and Prevention (CDC) stands out among governmental programs for its comprehensive approach to infectious disease control in health care settings. HIP is not a regulatory program, rather it undertakes surveillance and monitoring, studies the efficacy of control practices, develops management guidelines, and provides technical assistance. The broad view of the HIP program is evident in its 1985 *Guideline for Handwashing and Hospital Environmental Control* (CDC, 1985). The *Guideline* recommends infection control measures throughout hospitals, covering a wide range of activities including: handwashing; cleaning, disinfecting, and sterilizing medical equipment; infectious waste management; housekeeping; and laundry. The original document has been updated twice and has been supplemented by additional guides over the years, and remains the foundation for health care infection control programs.

Many of the environmental concerns of health care activities are unique to the industry, involve multi-media impacts, result in multi-hazard wastes, and/or require a balance with infection control or other priorities. Integrated sector-based strategies may be able to overcome the challenges inherent in developing programs to address such concerns. Many existing governmental initiatives that address environmental and safety concerns within the health care industry are either focused solely on health care activities, or are distinct health care initiatives within larger programs. EPA's program to review the safety and effectiveness of anti-microbial disinfectants, for instance, is housed within its pesticide review program.

NIOSH's 1988 *Guidelines for Protecting the Safety and Health of Health Care Workers* (NIOSH, 1988) is a good example of a sector-based strategy that examines hazards resulting from numerous activities within the health care sector. The *Guidelines* identify the wide variety of occupational hazards present in health care facilities, including physical,

chemical, radiological, infectious, and psychological hazards. The *Guidelines* document the magnitude of the hazards, but do not proscribe specific management strategies – instead it refers to existing rules and standards. Although the occurrence data, hazard information, and regulatory standards referenced are now out of date, the NIOSH *Guidelines* provide a good overview of the myriad risks encountered in the health care workplace. An update to the report was planned, (Federal Register, 1996) but the effort has since been abandoned. While 11-year-old voluntary guidelines are probably not a very effective tool for employers to follow when designing safety programs, they are a good model for integrated sector-based strategies. Efforts such as this, that approach a problem (occupational health) across multiple health care activities and multiple governmental programs may be necessary to achieve the goals of individual programs.

The recent agreement between EPA and the American Hospital Association (AHA, 1998) has the potential to develop more integrated approaches to environmental protection in hospital settings. The primary two goals set by the partnership are the virtual elimination of hospital mercury waste and a reduction in overall hospital waste volume by 50%. Strategies will be developed for each of these targets, and other materials will be identified for possible future pollution prevention initiatives. Sector-level reports such as these, as well as corporate environmental reports developed for individual facilities or companies, can be used for management systems, serve as effective communication tools, and increase the amount of data available on the sector. To date, there seems to be only one health care service company, Catholic Healthcare West, that has produced a corporate environmental report (Catholic Healthcare West, 1999).

Priorities

The environmental effects of the medical sector involve some activities that are unique to the sector and other activities that are common to many sectors. The areas that are most important for future action represent a similar mix. Areas that stand out as important future environmental management initiatives are:

1. controlling emissions from on-site "production" type functions;
2. mercury use;
3. the environmental consequences of infection control measures;
4. pollution prevention through substitution of alternative health care services; and
5. research and data collection.

On-Site Production

Some health care service providers perform "production" type functions on-site to process materials for use in certain procedures, including dental amalgam, photoprocessing, and radiopharmaceuticals. These production functions can result in unsafe occupational exposures and generate wastes in the health care setting. In the case of dental amalgam, 10-

15% of dentists mix their own bulk liquid mercury with silver alloy on-site. The majority, however, use small capsules of pre-measured amalgam that eliminate direct contact with mercury, minimize mercury vapor generation, and reduce the likelihood of spills. Since 1984, various American Dental Association guidelines and resolutions have recommended that dentists shift to pre-measured capsules to minimize occupational exposure to mercury, reduce the chance for spills, and reduce waste mercury (Michigan, 1996 and Wisconsin, 1998).

The vast majority of medical x-rays are recorded on silver-based radiographic films, similar to black and white photographic film, and processed immediately on-site. Direct exposure can cause acute occupational hazards, as developing agents are very alkaline and stop baths are quite acidic. Wastewater discharges of silver from spent x-ray processing chemicals have been cited as one of the major sources of silver in San Francisco Bay (Interagency Workgroup, 1998). Facilities that process large volumes of x-rays, such as hospitals, can afford self-contained processing systems that minimize worker exposure to photoprocessing chemicals. Silver recovery systems are also widely available, but generally are not economical for small facilities such as dentists or chiropractor offices.

A number of radiopharmaceuticals used in nuclear medicine are often formulated on-site in hospitals and nuclear medicine clinics, due to the short lifespan of the isotopes. The radioisotope used in 90% of all nuclear imaging procedures, Technetium-99m, has a half-life of only 6 hours, preventing it from being shipped over large distances. Nuclear medicine technologists have traditionally formulated these radiopharmaceuticals on-site, but increasingly rely upon the 250 commercial nuclear pharmacies that have appeared in major cities around the country. Nuclear pharmacies formulate radiopharmaceuticals in batches for multiple sites. Economies of scale suggest that they will have access to better equipment and training than individual hospitals and nuclear medicine clinics, thus can reduce occupational risks, inadvertent spills, and waste generation.

Efforts should be made to accelerate these transitions away from high exposure on-site processing wherever possible. Manufacturing firms and service providers can alleviate the problems that result from on-site production activities. Additional education and outreach may be all that is necessary to convince the remaining dentists to switch from on-site bulk amalgam mixing to pre-measured capsules. Centralized silver recovery plants that accept spent photochemicals could eliminate silver discharges to wastewater systems from small offices that process x-rays. Increased availability of nuclear pharmacies throughout the country will likely provide nuclear medicine departments with the ability to eliminate the facilities necessary for radiopharmaceutical production.

Mercury Use

Mercury, a naturally occurring metal, is a well-known neurotoxin that can arrest children's early brain development (ATSDR, 1990). It is considered a persistent, bioaccumulative toxic (PBT) pollutant – one that is long-lasting and builds up in animals at the top of the food chain. Mercury can easily migrate between media – air emissions can be deposited in water bodies and mercury buried in landfills often migrates to groundwater

and/or vaporizes into the air. Forty states have fish consumption advisories for at least one water body warning people not to eat its fish because of mercury contamination.

Regulatory pressure from state and federal agencies has been successful in largely eliminating or reducing mercury in a number of products, such as batteries, paints, and fluorescent lights. The national commitments for further reduction in mercury use and emissions in the Binational Toxics Strategy (Environment Canada, 1997) and the Draft Mercury Action Plan (U.S. EPA, 1998) will increase attention to health care mercury use and emissions. The recent commitment by the American Hospital Association to work towards eliminating mercury waste, and other initiatives should lead to hospital adoption of product substitutes that do not contain mercury. Many of these products are already available on the market, and have similar performance characteristics. Assuming success in that area, further efforts are warranted with non-hospital health care services – long-term care facilities; home health care organizations; doctors; veterinarians; and ordinary consumers all use mercury-based thermometers, certain blood pressure units, and other mercury-containing medical supplies.

The national commitment under the Binational Toxics Strategy to reduce mercury use to 218 tons by 2006 will also put pressure on dentists to reduce mercury consumption from dental amalgam. Dental amalgams represent over 10% (40 tons) of U.S. mercury consumption, the third largest use (Reese, 1997). The volume of mercury used to manufacture dental amalgam has remained fairly constant over the last ten years, while the two largest remaining mercury users, the chlorine manufacturing and electric switch industries, have both significantly reduced their mercury consumption in recent years. The chlorine industry has voluntarily committed to further reducing its consumption by 50% (U.S. EPA, 1998). Dental amalgam manufacturers and users will likely be called upon to help reach the 2006 goals, or perhaps subsequent lower goals. This could be achieved through a voluntary commitment or perhaps through a mercury use allowance system, where the national limit on mercury consumption is fixed and use permits are allocated or auctioned off (Swift, 1999).

While the FDA and the Public Health Service currently do not recommend the removal of mercury amalgam from the market due to health concerns, there is increasing pressure on dental amalgam users due to environmental concerns. In areas where mercury air emissions or water discharges are a large concern, efforts to reduce mercury emissions from wastewater systems, municipal waste combustors, and medical waste incinerators will likely pressure dentists to keep mercury out of their waste streams. Education, outreach, and improved recycling services will be necessary to increase dentists' waste amalgam collection and recycling. Good waste management practices involve fairly simple measures to keep particles out of the wastewater and scrap out of trash cans and "red bags".

Environmental Consequences of Infection Control Measures

The chance that a patient leaves a hospital with a hospital-acquired (nosocomial) infection has remained fairly stable for the last twenty years (Weinstein, 1998). Over this time period, a number of infection control measures with environmentally damaging side

effects have been adopted widely. These include activities which are essential for basic patient safety, such as medical equipment sterilization with hazardous liquid or gaseous chemicals. Wearing disposable latex gloves during patient examination is intended to reduce healthcare worker exposure to potentially infectious blood and other fluids and cross-infections between patients. Many infection control measures are not directly related to patient care, rather they are adjustments to facilities operations such as: laundry, surface cleaning, ventilation systems, and waste management and disposal. These activities are sometimes referred to as 'environment of care.' These activities remain important infection control measures, yet despite their widespread adoption nosocomial infections persist. Current recommendations for future nosocomial infection control efforts do not suggest increased vigilance for any of these activities (Weinstein, 1999). Now that these practices generally have peaked in their ability to control infections, opportunities should be identified to achieve similar performance at lower environmental costs. For instance, the shift to non-allergenic substitutes for natural rubber latex gloves should be encouraged. Better data on health care facility cleaning and sterilization practices could help identify areas where excess exposure to hazardous materials occurs.

Alternative Approaches to Health Promotion

Another area that future initiatives may find fruitful is pollution prevention through alternative approaches to preserving or achieving health. As we noted in the introduction, advances in preventing illness and in less resource intensive therapies are at least as promising in improving the environment as any end-of-the-pipe waste treatment. The new medical approaches may not be the responsibility of any government agency, and almost certainly are not EPA's responsibility. But their important environmental implications should not be ignored, and EPA may want to establish communications with the Department of Health and Human Services and with private medical organizations so that the environmental implications are adequately considered.

Research and Data Collection

The need for better data is a chronic problem that affects almost all environmental programs, and it is certainly applicable to the medical sector. There are some problems for which the data is very inadequate, for instance poor monitoring of medical waste disposal trends has hindered effective policy-making. There are some important problems for which there are almost no data at all, most notably the lack of research on the effects of pharmaceuticals on environmental conditions. While these two areas are the most visible data gaps, lack of data makes it difficult to track trends in many activities in the health care sector.

Studies of medical waste management going back 10 years have focused on the paucity of data on medical waste production, characterization, and disposal (Medical Waste Policy Committee, 1989 and U.S. General Accounting Office, 1990). Despite EPA's decision by inaction to not regulate medical waste management under RCRA, the Office of Solid

Waste should take the lead on research and data collection. Data collected under the Medical Waste Tracking Act, a demonstration regulatory program, is out of date and largely unavailable due to the agency's failure to publish a final report on the program. The lack of data on medical waste incinerators has led to major regulatory problems. An inaccurate count of the types of medical waste incinerators in operation led to an inflated initial estimate of national dioxin emissions. This has caused unnecessary controversy and contributed to the delay in completing the dioxin reassessment. A recent court ruling found that regulatory development models based upon limited emissions testing data on medical waste incinerators were inaccurate enough to send the regulation back to EPA for further clarification (Zacaroli, 1999). The EPA partnership with the American Hospital Association could be a good opportunity to improve data collection and quality. This will not be the sole answer to data problems, as its scope is limited to hospitals – omitting the rest of the health care sector.

A few recent efforts to measure the presence of pharmaceuticals in water bodies has been spearheaded by European scientists. Very little research has occurred on the ultimate impacts of pharmaceuticals on environmental conditions. Speculative concerns include the development of antibiotic resistant organisms and the alteration of hormonal balances of wildlife and human populations. EPA and FDA should begin to fund basic scientific research in this area – to determine the extent of such pollution and the impacts of pharmaceutical pollution on human and ecological health.

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