A Research Agenda for Advancing Patient, Worker and Environmental Health and Safety in the Health Care Sector

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Health Care Without Harm has initiated a research collaborative coordinated by faculty of the University of Illinois at Chicago School of Public Health, with support from the Pioneer Portfolio of the Robert Wood Johnson Foundation, aimed at stimulating collaborative research around health and safety improvements in health care. This collaborative is designed to increase the evidence base concerning the human health and environmental impacts of materials, products and practices within health care. In partnership with the Global Health and Safety Initiative (GHSI), the Research Collaborative is engaged in research directed at the intersection of environmental, patient, and worker safety issues related to building and operating health care institutions.

This paper is the fourth in a series of papers in which the Collaborative provides research and analysis of factors influencing patient, worker and environmental safety and sustainability in the healthcare sector. The editors of this series are Peter Orris, MD, MPH and Susan Kaplan, JD.

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EXECUTIVE SUMMARY

This paper focuses on research within the health care sector in the U.S. centering on patient, worker and environmental health and safety ("the three safeties"). It describes the Health Care Without Harm / Global Safety and Health Initiative (HCWH/GHSI) Research Collaborative, from whose work this Research Agenda was developed. It identifies research priorities in the near- and long-term at the intersection of the three safeties.

This research agenda has been developed based on a series of in-person interviews conducted during the past year by Health Care Without Harm / Global Health and Safety Initiative Research Collaborative staff with executives of health care systems as well as staff of federal agencies that work on these issues. It is also based on a series of four white papers contracted for by the Research Collaborative in order to provide an overview of the background literature and data reviews and to identify research needs for several of the pressing issues before GHSI and HCWH.

The research priorities that are discussed in detail in this paper have been organized into the following four major categories:

- The Business Case for Sustainability and Improved Patient/Worker Safety and Health in Hospitals and Health Care Facilities
- The Impact of Hospital and Health Care Building Design, Construction, Renovation and Materials on Patients, Workers and the Environment
- The Collateral Health Impacts of Pharmaceuticals and Other Chemicals Used in Hospitals and Health Care Facilities
- The Impact of Hospital and Health Care Institutional Organization and Operations on Patients, Workers and the Environment

Many of the issues and research priorities described in this paper fall under more than one of the above categories. Where this is the case, the issue has been placed in the category that seems to reflect its primary focus.

The consultation process of this report has led to the emergence of the following as the highest priority research questions to be addressed:

- **Business case for Sustainability in Hospitals/ Health Care.** A key research priority is to conduct and publish cases which identify the fiscal impact of sustainability measures in health care settings on costs associated with patient care, workers compensation, waste disposal, and premature aging of the built environment. These should examine a wide range of potential sustainability measures, as well as the fullest possible range of upfront and life-cycle costs and benefits leading to cost savings.
- **Post- / Pre- and Post-Occupancy Evaluations.** Many health systems have incorporated, or are considering incorporating, sustainability measures into their facilities ranging from energy and water retrofits to waste programs and chemical and sustainable food policies. A series of post-occupancy evaluation studies could be published to highlight new innovations and evaluate them for efficacy, cost-benefit and impact on patient, worker and environmental health and safety.
- **Creation of a Materials Evaluation Template.** Many new materials have been introduced over the last several years. While these materials have documented benefits for one of the safeties, there is little to no data on impacts on the others. As more new technologies and materials are brought to the health care market, an efficient and thorough evaluation tool would benefit health systems in making the most informed decisions.
- **Assessment of installation and performance challenges and benefits of alternative flooring materials.** The Research Collaborative white paper, "Resilient Flooring & Chemical Hazards: A Comparative Analysis of Vinyl and Other Alternatives for Health Care," evaluates the potential health and environmental impacts of vinyl flooring and several leading alternatives. The analysis should be extended to additional flooring product types, including newer synthetic polyethylene-based materials and traditional materials such as terrazzo and cork, and

should explore various attributes of alternative flooring materials.

- **Evaluation of both existing and new greener cleaning and disinfection products, practices and systems on patient infection control and human health.** Green cleaning questions were one of the top research priorities cited by hospital, health care and agency interviewees. Key questions that research could help to answer include: How well do greener cleaners clean? What is their efficacy in regard to patient infection control in comparison with conventional cleaning products? What is their effect on worker health? When do disinfectants need to be used? Perhaps most fundamentally, what cleaning products should hospitals and health care facilities use, where, and for what purpose?
- **Worker and patient exposure to hazardous drugs and chemicals.** Beyond cleaning agents, there are questions as to which chemicals in the healthcare setting are associated with adverse health effects among healthcare workers and patients — and which may also have community environmental effects. It would be helpful to measure current exposure levels by various types of healthcare workers, as well as develop a mechanism for pre-evaluation of health and environmental impacts of new chemical-containing products and equipment.
- **Musculoskeletal injuries in patients and health care workers.** Central research questions include: What is the relationship between work organization factors, job demands, workload, and physical factors, and the risk of musculoskeletal injuries in patients and health care workers? What is the effectiveness of best practices for safe patient handling and movement in hospitals and other health care settings? Additionally, a business model could be developed to demonstrate the cost-effectiveness of safe patient handling, and work organization models should be developed and tested with respect to the recruitment, retention, and injury rates of nursing staff.

I. INTRODUCTION

Over the next decade, United States health care institutions will invest $200 billion in new and renovated infrastructure.[1] The country's health care leadership has identified the safety of patients, health care providers, and the environment as priorities in making decisions about these expenditures.

Yet as environmental health and safety considerations emerge as priorities in the health care sector, the need for information on best practices, post-occupancy evaluation, and fundamental research has become more apparent. Hospitals, and their design teams, want reliable examples of "best practices" and evidence to justify their implementation. At the same time, important sustainable strategies — such as alternative ventilation systems and the use of safer cleaners — may be resisted due to perceived limitations in efficacy. Information on "green materials" — in the realm of both medical products and construction materials — is often confusing and lacks sufficient data to ascertain performance with regard to human health goals.

Where this data does exist, it speaks powerfully to the impact that the built hospital environment can have on workers and patients, as well as the community at large. For example, a recent study that was published in *The Lancet*[2] confirmed what analysts at HCWH have suspected for many years: nurses are at much greater risk of developing chronic respiratory illnesses than other working professionals, and have the highest rate of adult-onset asthma of all major occupation groups (more than twice the average rate, and even greater than that of professional cleaners). These findings confirmed that frequent exposure to cleaning chemicals, bio-aerosols, and latex are significant hazards in the health care setting, and pointed to the broader danger of poor indoor air quality in hospitals.

Across the U.S. — and globally — there is increasing interest in access to reliable information, and in objective research that will improve understanding regarding the health implications of sustainable building and operations strategies in hospital settings. This is the need that this paper, and the larger Research Collaborative project, aims to move forward the process of meeting.

Up to this point, the evidence base has developed independently for patient, worker, and environmental health and safety. Patient safety evidence has developed in the peer-reviewed literature from clinicians, stimulated by the Institute Of Medicine's Quality Initiative of the last decade. Worker health and safety evidence has developed external to the industry from occupational health professionals, and within the industry through the efforts of human resources departments and unions. Although the external studies appear in the peer-reviewed literature, much of the available internal knowledge is held within human resources departments of individual institutions and networks.

Environmental studies conducted by national and international governmental agencies and non-profit organizations are producing increasing evidence that environmental pollution, even at low exposure levels, is having adverse health impacts, from the increasing rates of asthma and respiratory illnesses to increases in the occurrence of cancer.

The newly developing evidence with respect to the impact of the built environment in health care has been observed and, at times, evaluated by facilities planners, architects, engineers, and contractors. Nearly all of this information is held within, and more recently shared between, planning offices of institutions and networks.

There is now a growing understanding among the leadership of health care providers that patient, provider, and community health and safety are profoundly interrelated. An initiative affecting one area inevitably impacts all three. For example, Brigham and Women's Hospital in Boston installed rubber flooring to reduce their toxic environmental impact through safer substitution of the chlorinated vinyl tiles previously used. Anecdotal evidence is beginning to emerge that, as a result, this change has increased back comfort among nursing staff, reduced lost time by hospital staff, decreased patient accidents, and decreased noise levels.

The Brigham and Women's Hospital experience demonstrates the valuable, and possibly unexpected, information that can emerge from assessment of a change in the hospital environment in terms of more sustainable building, operations or materials. The more detailed and quantified such a study can be, the more information it can yield that may be useful to other hospital and health care facilities — with greater potential increases in sustainability in regard to the three safeties.

II. GHSI/HCWH RESEARCH COLLABORATIVE

To respond to this understanding and to stimulate the development, integration and dissemination of such data, the Robert Wood Johnson Foundation provided three years of seed funding to HCWH to help launch a Research Collaborative in partnership with GHSI. HCWH, an international coalition of health care institutions, associations, providers, and environmentalists focused on improving the safety and sustainability of health care institutions, initially concentrated on reducing the volume and incineration of medical waste. It further prioritized safer substitution for mercury and polyvinyl chloride in the health care sector. In recent years, the issues of worker and patient safety related to safer needle technologies and environmental sustainability of the built environment have taken a place on center stage as well.

The Research Collaborative, based at the University of Illinois at Chicago School of Public Health, is funded by the Robert Wood Johnson Foundation through a grant to HCWH. The Research Collaborative's primary goal is to stimulate research about the patient, worker and environmental safety and health impacts of changes in approaches to building and operating health care-providing institutions. The Collaborative is working to stimulate the development, coordination and dissemination of research focused on patient and worker health and safety as well as the design, construction, and operation of the sustainable built environment in health care. This agenda is an attempt to conceptualize a research strategy for the intersection of these priorities that is responsive to health care institution, professional organization, and government agency priorities and that can identify areas of potential synergy.

In addition, during this past year, Ascension Health, Catholic Healthcare West, Hospital Sisters Health System, Kaiser Permanente, MedStar Health, Partners HealthCare, St. Joseph Health System of Orange, the University of California San Francisco and Advocate Health have joined HCWH in collaboration with the Center for Health Design and Practice Greenhealth in forming the Global Health and Safety Initiative. GHSI is dedicated to transforming the way that healthcare institutions design, build, and operate. The Research Collaborative is working with GHSI to support the development of an evidence base for improvements that advance patient and worker safety and environmental sustainability.

During the first year of funding for the Research Collaborative, Collaborative staff conducted meetings with executives of GHSI partner health systems, academic institutions and governmental entities to discuss the current state of health care research on safety and sustainability and to identify their research priorities — areas in which further information would be helpful to these organizations in their efforts to implement sustainability. In these meetings, several principles were highlighted by most of the health systems as priority criteria in developing a research agenda:

1. Incorporation of patient, worker, and environmental safety.
2. Production of evidence to provide a decision making base for operations and construction of facilities.
3. Evaluation of the costs and benefits of proposed changes in new policies and practices, including initial capital investment, institutional lifecycle costs, and community impacts.

Similar concerns were voiced by health care executives from the disciplines of clinical practice, human resources, and facilities planning and management. Industry leaders expressed concern about the stressors within the health care system that diverted attention and resources from their key goal of caring for individuals, often independently and without knowledge of parallel concerns in other disciplinary areas within health care.

The meetings with health care systems also led to identification of specific priorities as a broad consensus construct for research at the intersection of patient, worker, and environmental safety. In addition, certain projects were identified as currently underway, and several issues were identified as requiring greater definitional specificity. These are the focal point of this report.

Also in its first year, the Research Collaborative contracted for a series of background literature and data reviews addressing several of the pressing questions before GHSI and HCWH. Three of the papers include research recommendations: those focusing on green cleaners, resilient flooring, and pharmaceutical waste. Research recommendations from the reviews are included in the research priorities highlighted in this paper.

III. RESEARCH BACKGROUND AND A RESEARCH AGENDA INCORPORATING PATIENT, WORKER AND ENVIRONMENTAL HEALTH AND SAFETY

As the healthcare industry grows to accommodate the increasing and changing patient population in the United States, the modern hospital must evolve. The health system model constructed 50 years ago to deliver health care in a sterile, time-efficient, cost- effective, utilitarian environment no longer meets the needs of today's patients. Over the last decade, significant research has been published pointing out pressing safety issues that need to be addressed with respect to patient care.

In 1998, the Institute of Medicine (IOM) formed the Committee on the Quality of Health Care in America to develop a strategy that would result in a substantial improvement in the quality of health care over the next 10 years. IOM released a series of reports that together examined the quality of health care in America and how to achieve a threshold change in quality.

In 1999, the IOM released "To Err is Human,"[3] a report enumerating the medical errors that cause the deaths of tens of thousands of Americans each year. The committee systematically examined the scale and gravity of patient care quality issues in health care and developed strategies for improvement. The committee found that patient health and life are jeopardized at an unacceptably frequent rate due to outdated systems of health care delivery and that a higher quality of care will not be achieved by further stressing current systems, but rather through redesigning systems of care.

In 2001's "Crossing the Quality Chasm: A New Health System for the 21st Century,"[4] the committee proposed six areas of focus for building systems of care to achieve improvements in the key dimensions of patient care. The committee's recommendations stated that health care should be safe, effective, patient-centered, timely, efficient and equitable.

In 2004, the Institute for Health Improvement (IHI) embarked on the "100,000 Lives" campaign, calling for hospitals to institute six evidence-based-principle reforms to reduce harm caused by medical errors and save 100,000 lives. In 2006, IHI declared the 18-month campaign a success, with 3,100 institutions participating and more than 100,000 lives saved. In 2006, IHI initiated the "5 Million Lives" campaign, expanding on the work of the previous campaign and engaging a greater number of health systems in reducing preventable medically induced injuries in hospitals.

All of the health care systems that the Research Collaborative staff has met with have implemented internal system-wide quality care initiatives that include provisions aimed at improving patient outcomes through thoroughly analyzing hospital systems, increasing efficiency, eliminating patient injury due to medical error or nosocomial infection, improving patient hospital experience, and improving systems communication around patient care.

All systems reported seeing improvements in patient outcomes as well as cost savings associated with the reforms made. One system reports that it will pay back its initial investment in its initiative in 2.6 years and projects saving $16 million in five years while significantly improving patient outcomes.

These efforts demonstrate how a comprehensive research agenda combined with outreach and education in partnership with hospitals and health care systems can lead to large-scale change that saves lives while also saving money. This interest by health care systems in patient safety has now broadened to encompass all of the three safeties. All of the systems interviewed by the Collaborative have embedded into their

missions not only patient care, but also worker safety and environmental sustainability as priority areas for improvement. All of the systems are currently implementing quality improvement initiatives and conducting evaluative studies or research in one or more of these priority areas.

In addition to evaluating and reforming patient care practices, health systems have realized that the built environment can improve patient safety and contribute to overall patient and family well-being, thereby positively impacting patient outcome and satisfaction. In each of these systems, significant architectural work has produced improvements in patient care through the way hospital facilities are built and the materials that they use.

Based on the interviews conducted by the Research Collaborative and the white papers contracted for, this section identifies key priority areas for further research within patient, worker and environmental safety and health. It looks at the research background, including previous and ongoing research; identifies research priorities in each area; and explores the significance of these issues and of making changes in these areas. The issues are organized within four broad categories: the business case for sustainability in hospitals and health care systems; building design, construction, renovation and materials; pharmaceuticals and other chemicals used in hospitals and health care facilities; and hospital and health care institutional organization and operations. Within each of these categories, impacts on patients, workers and the environment must be considered.

This prioritization is based on the responses of hospital/health care system executives and federal agency staff in the interviews, as well as the potential significance for one or more of the three safeties of a change by the health care system in the context of an issue studied.

The Business Case for Sustainability and Improved Patient/Worker Safety And Health in Hospitals and Health Care Facilities

The Current State of Knowledge

Over the last decade, health systems in the United States have been working to incorporate a range of sustainability measures into their facilities and operations for a myriad of human and environmental health reasons. With the continued expansion of the built healthcare environment, the interviews conducted by the Research Collaborative indicate that hospital systems leadership wishes to take this opportunity to transform the way that hospitals build, buy and operate their facilities to make them healthier, safer and sustainable.

Current knowledge indicates that financial benefits to a facility and its community, over the life of the building, often well exceed the initial investment to design and construct a green facility. The current economic downtown presents significant challenges for the health care sector to meet the growing demand to invest capital in new facilities. Finding potential savings through efficiency measures will help the industry to continue to build while building sustainable ecologically friendly facilities. There is evidence that building green also improves patient and staff satisfaction. All of the health care systems the Research Collaborative staff met with have begun to incorporate green policies and practices into their operations.

Herbs grow on one of Metro Health Hospital's thriving rooftop gardens.

However, much more data is needed. There is an enormous range of possible sustainable measures that can be undertaken in the context of building design, construction and renovation, organization and operations, and use and disposal of materials, including chemicals and pharmaceuticals. A key question, in both the current challenging economic climate as well as during this period when hospital and health care systems are making long-term plans for building and growth, is what the costs and benefits are for these various sustainability measures. Hospitals and health care systems need to know what the costs are — both upfront and over the long term. In terms of savings, they need to know what the projected cost savings are both in terms of capital, maintenance and operations, such as lower energy bills, as well as the time frames for payback in sustainable investments. Additionally, they need information about the impacts of sustainability measures on patients, workers and the environment — for example, better patient outcomes; healthier, more productive workers; and environmental and health benefits to the surrounding community. As one health system executive stated in an interview with Research Collaborative staff, "Cost analysis is key. Any decision made will be based on both the initial and the overall cost of implementation." The economics of sustainability was a common thread that ran through the interviews conducted and was often mentioned as a priority research item.

Research Priority

Business Case for Sustainability in Hospitals/Health Care

Given the informational needs and desires of hospitals and health care systems as described above, a critical and key research priority is to conduct and publish business cases identifying the fiscal impact of sustainability measures in health care settings on costs associated with patient care, workers compensation, waste disposal, and premature aging of the built environment. These should examine a wide range of potential sustainability measures as well as the fullest possible range of both upfront and life-cycle costs and benefits leading to cost savings.

One group of health care system executives expressed particular interest in the amount of cost savings that can be realized through undertaking waste minimization activities. For example, building materials reuse and recycling are now being shown to have the potential to lead to significant cost savings, although there is perhaps a greater need to demonstrate this specifically in the health care sector.

Additionally, health care system executives expressed interest in data on the cost savings that a hospital/health care system can achieve by hiring a sustainability coordinator to develop and oversee a hospital/health care sustainability plan. Anecdotal data indicates that such cost savings can be substantial, but data could be helpful in making the case that hiring a sustainability coordinator is a worthwhile investment.

The Impact of Hospital and Health Care Building Design, Construction, Renovation and Materials on Patients, Workers and the Environment

The Current State of Knowledge

Hospital and health care building design, construction, renovation and materials affect patient safety and health, worker safety and health, and the environment in a myriad of ways, including by impacting global climate change. Awareness of these impacts by the hospital/health care sector has increased. In the mid-1990s, there were over 4,000 medical waste incinerators in the country, producing dioxin and mercury air and water emissions. Due to EPA regulations and concerns about the neurotoxic effects of these releases, almost all of these incinerators have been closed.[5] Many hospitals have reduced their waste generation significantly and moved towards safer treatment technologies for their waste — and they have saved money in the process. In the last 12 years or so, more than 5,000 hospitals in the country have virtually eliminated mercury from the health care sector. All of the major pharmacy chains in the country have stopped selling mercury thermometers.

In the United States, the health care industry consumes $6.5 billion of energy annually[6], making it the second most energy-intensive building sector, and it is often one of the largest users of water in the community. Additionally, hospitals generate millions of tons of waste each year. Each of these activities is contributing to the production of climate-changing greenhouse gasses and in turn to the global burden of disease caused by climate change. By implementing various energy consumption, water and waste reduction measures in the context of building design, construction, renovation, and materials, health care systems can have a significant impact on decreasing the impact of climate change and the public health impacts caused by climate change.

HCWH, GHSI and other partner organizations have already undertaken numerous research and technical assistance activities to reduce the environmental impacts of hospitals and health care systems in the context of their built environment. GHSI, in conjunction with Practice Greenhealth and other members, has undertaken research to measure the impact of health care on climate change and the public health effects of climate change. Practice Greenhealth has developed a web-based tool[7] to analyze the effects of mitigation by health care institutions for communities and the environment.

The Center for Health Design (CHD), a research and advocacy organization, has aided the institutions and systems in identifying initiatives and evaluating and understanding the results. CHD's Pebble Project health systems allow the sharing of these experiences with new technologies and materials. In addition, CHD recently launched the EDAC (Evidence-Based Design Accreditation and Certification) program, which is focused on teaching individuals about the use of evidence-based design. The program helps people, firms, and systems learn how to link research to design and encourages them to study the impact and measure the outcomes once a building project is completed. The Pebble Project provides examples of how health systems have used and applied an evidence-based design process and are sharing these experiences with others while also conducting their own research. Once completed, much of this information will be available on the RIPPLE database which houses design strategies linked to the three safeties and associated research.

The Green Guide for Health Care[8] is the health care sector's first quantifiable sustainable design toolkit integrating enhanced environmental and health principles and practices into the planning, design, construction, operations and maintenance of their facilities. This Green Guide provides the health care sector with a voluntary, self-certifying metric toolkit of best practices that designers, owners, and operators can use to guide and evaluate their progress towards high performance healing environments. Since its adoption in 2004, many health systems have adopted the Green Guide for new construction and engineering improvements. The Green Guide for Health Care will serve as the foundation for a new LEED (Leadership in Energy and Environmental Design, a program of the U.S. Green Building Council) certification for the health care sector. On

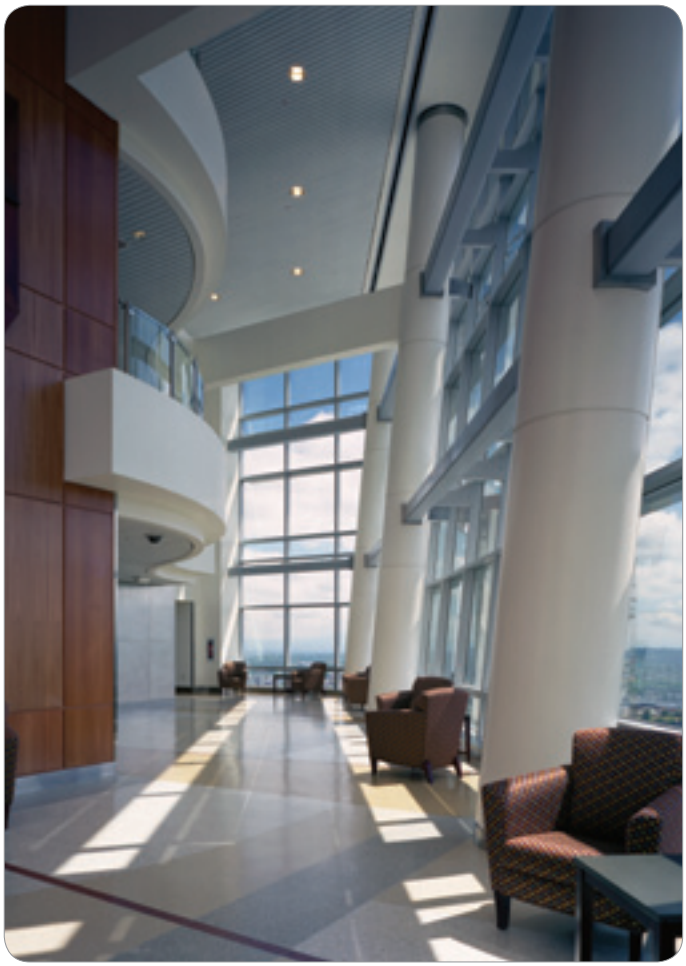
the operational end, Practice Greenhealth, a membership and networking organization for institutions in the healthcare community, provides health systems with the assistance and tools to green their operations and implement the Green Guide for Health Care.

One of the white papers contracted for by the Research Collaborative, and released in May 2009 by the Research Collaborative in conjunction with the Healthy Building Network, is entitled "Resilient Flooring and Chemical Hazards: A Comparative Analysis of Vinyl and Other Alternatives for Health Care."[9] The study addresses resilient flooring, evaluating potential health impacts of vinyl flooring and the leading alternatives — synthetic rubber, polyolefin and linoleum — currently in the health care marketplace. Vinyl flooring made from polyvinyl chloride (PVC) has the most pervasive presence of unavoidable PBTs in its life cycle of the four materials examined. There are also distinct differences between the materials reviewed with regard to the potential for manufacturers to further reduce the hazards.

While no ideal "green" material currently exists for health care flooring options, the white paper illustrates the range of alternative materials that are preferable to sheet and tile products made with PVC — posing fewer chemical hazards in their current formulations and having greater potential for further improvement. Yet hundreds of health care organizations continue to source PVC-based products for their facilities. Lack of information about performance, lack of experience in cleaning and maintenance, and the slow pace of change in the health care industry all contribute to slowing the transformation of the industry to safer alternatives.

Other research currently taking place includes the following:

Hospital Design: CDC/NIOSH and Kaiser Permanente are currently pursuing a collaborative research project focusing on hospital design. Working with CHD, the project team is compiling a data dictionary and is reviewing design elements that can be studied, linked to outcomes, and could have impacts on patient, worker and environmental safety. The CDC has committed $100,000 to Kaiser Permanente to assist in the identification and development of potential research topics and has expressed a willingness to partner on priority projects that come out of this work and to help seek funding to complete the work.



Peter Kohler Pavilion at Oregon Health Sciences University (GGHC). Photo by Eckert+Eckert.

Pebble Project Research: Within CHD's Pebble Project Research Initiative, several Pebble Partners are pursuing research projects focused on environmental health. In particular, Pebble partner Affinity Health System will assess whether green building design, when combined with an extensive program intervention to create a culture of sustainability, will result in competitive advantage. Affinity is currently defining its 10- year campus Master Plan, which will include improving the quality of service and patient safety, improving customer services, improving employee and physician satisfaction, achieving sustainable growth, improving operating margins, and integrating the new mission and values across the entire system. The patient experience is a key driver in the development of the Master Plan. Individual and unique patient destinations will differentiate care centers. Other drivers include an emphasis on daylighting and meaningful green space. These attributes support the patient experience, improve way finding, and increase staff satisfaction. An integrated overhaul of the mechanical systems will bring sustainable dividends, allow individual control and improve

thermal comfort. Affinity will use survey instruments, immersion courses, audits and kaizen type activities to collect the data.

Several Pebble Partners have begun investigating the acoustic environment relative to environmental, patient, and worker safety. Among these, Meridian Health-Jersey Shore University Medical Center is engaged in a study looking at the impact of carpeting and acoustical tiles in renovated units on noise levels and staff perceptions. Other Pebbles doing research in the area of acoustics includes the collaboration of Industry Pebble Partner John Mansville and Pebble Partner the Children's Hospital Aurora, CO, whose study is examining acoustic comfort and privacy at the Children's Hospital. Pebble Partner Palomar Pomerado Health in San Diego, CA, along with Industry Pebble Tandus, are undertaking an evaluation of the impact of flooring and ceiling tiles on objective and subjective measures of noise on an inpatient nursing unit. Pebble Partner University Hospitals - Cleveland, OH is undertaking an acoustical study in two representative nurseries in which sound will be actively monitored to determine the impact on parental and staff satisfaction and stress levels.

Pharos Project: The Healthy Building Network's (HBN) — with a mission is to harness the market to transform the manufacture of building materials to the use of safer chemicals and more environmentally and socially responsible practices — works with leading thinkers in the fields of architecture, materials analysis, and environmental and health policy to develop rational social and environmental measures in building specifications. These measures are codified in the Pharos Project, invoking a clear and powerful signal to the market for change, founded in the great Pharos lighthouse of Alexandria, one of the seven wonders of the ancient world. The project is a leading-edge materials evaluation tool used by green building and procurement professionals, conceived as a navigational aid for those seeking building materials that are good for people and the planet. Pharos evaluates claims and perceptions about products against verifiable data through development of a desktop software tool that helps designers, specifiers and purchasers quickly digest and compare a wide range of product and manufacturer data against the user's own values.

Research Priorities

Priority Research Areas

Pre- and Post-Occupancy Evaluations

Many health systems are considering incorporating sustainability measures into their facilities from energy and water retrofits to waste programs and chemical and sustainable food policies. A series of case studies could be produced to follow a facility through the implementation process from deciding on what types of measures to integrate into their system and evaluate the success of those measures.

Post-Occupancy Evaluation

Many health systems have recently built new or renovated hospital facilities that are built to a LEED standard, utilized the Green Guide for Health Care or have incorporated many sustainability innovations. A series of post-occupancy evaluation studies on facilities from different systems and regions could be published to highlight new innovations and evaluate them for efficacy, cost-benefit and impact on patient, worker and environmental health and safety.

Creation of a Materials Evaluation Template

Many new materials and technologies have been introduced over the last several years. While those materials have documented benefits for one of the safeties, there is little to no data on impacts on others (e.g., rubber floors are ecologically friendly; single patient rooms improve patient outcomes). As more new technologies and materials are brought to the health care market, an efficient and thorough evaluation tool would benefit health systems in making the most informed decisions. A study or several studies on existing materials and technologies should be pursued to develop a template for product evaluation. Product evaluations should look at the life cycle impacts from manufacture to waste on the environment and human health and include evaluations of the capital versus maintenance costs. The following is a list of identified priority products:

- Adhesives and sealants for flooring
- Flooring maintenance and treatment products
- Interior finish materials that are non-VOC but may be communicated through other pathways
- Bisphenol-A in building materials
- Acoustic materials used for noise suppression

One interviewee noted that cost-benefit analysis should take all relevant factors into account. For example, some green alternatives cost twice as much as conventional products, however, the life-cycle cost is less because maintenance is less expensive as a result of using the product. Improved worker safety and satisfaction may also decrease total cost. Another interviewee noted that life-cycle analysis should take into account all three aspects of sustainability — for example, while a product may have benefits for use in hospitals over other types of products, if manufacture is carried out in sweat shop conditions in developing nations that do not adequately protect worker safety and health, then that needs to be considered.

Another interviewee noted that children's hospitals also need information about the safety of the product specific to the concerns of children's health. What standards do children's hospitals use in their review of products?

Assessment of Installation and Performance Challenges and Benefits of Alternative Flooring Materials

The white paper, "Resilient Flooring & Chemical Hazards: A Comparative Analysis of Vinyl and Other Alternatives for Health Care," identifies exploration of various attributes of alternative flooring materials as a research priority. Through interviews with hospital staff, a study could explore a number of attributes of the alternative materials, including:

- Durability
- Safety – traction and effect on slips, trips and falls
- Glare
- Comfort, fatigue and strain
- Acoustics
- Installation, including analysis of both installation processes and toxic properties of adhesives and sealants recommended for use with the materials
- Time constraints
- Cleaning and maintenance.

The analysis should be extended to other flooring product types, including more newly developed synthetic polyethylene-based materials and other traditional materials such as terrazzo and cork.

Additional Specific Research Priorities

Construction Methodologies for Renovation

The challenges of renovating are significantly different than those of building a new facility from the ground up. Often the facility is still partially in use or near another facility presenting concerns about infection control, environmental exposures, construction noise and hazards. As many health systems are currently pursuing facilities renovations, a series of case studies could be produced from different health systems and different regions that evaluates methodologies for renovation and the impact on patient, worker and environmental health and safety.

Building and Renovating Hospitals in an Urban Setting

What are the unique challenges of building or renovating an urban hospital, and what are the best practices in terms of methods or technologies for addressing these challenges? Some of these specific challenges might include infection control barriers and noise containment, both of which are crucial to urban hospital projects. Another might relate to building on a brownfield or reconstructing on an existing site. This research could be done in the form of a case study about the health challenges associated with construction in an urban setting.

Hospitals' Impact on Climate Change, Including Community Health

Numerous hospitals have made community health a priority and are dedicating resources to measuring baselines in community health issues. Questions include: How can health systems provide community benefits? What are hospital systems' carbon footprints? What are potential best practices for reducing energy use and carbon production to provide benefits not only to the hospital, but also to the community and globally? One interviewee noted that California requires hospitals to conduct health assessments every few years to determine the needs of their communities. That assessment does not currently include impact to the environment; therefore, it would be valuable to conduct research that demonstrates the value to the community of incorporating environmental impacts and sustainability into those assessments.

More generally, while an increasing number of tools are available to assist hospitals with planning for and measuring emissions of greenhouse gasses, it would be valuable to carry out a study that correlates various aspects of hospital/health care design, construction, renovation, materials use and operations, with greenhouse gas emissions and reductions. This could be especially beneficial for hospitals and health care systems that are embarking on plans for construction or renovation — especially given the current concern in Washington about carbon emissions and discussion about the possibility of enacting carbon limits or taxes.

Green Metrics

This project would involve development of a tool to allow the evaluation of a variety of environmental interventions from the viewpoint of impact on the three safeties. This would provide a series of dependent data points to be collected in a variety of settings to allow a comparative estimate of relative value.

Daylighting, Incorporating Art, Lowering Noise Levels and Other Physical Factors that May Improve Patient, Worker and Environmental Well-Being

There is an increasing body of evidence indicating that physical aspects of the hospital/health care setting such as greater amounts of natural light in patient rooms[10,11], art[12], and lower noise levels[13] can lead to better patient recovery, including lower amounts of pain medications needed and fewer days of hospital care needed. However, more comprehensive studies are needed in order to confirm and expand the evidence base in regard to these factors and to make the case for including these physical aspects of the hospital/health care setting due to savings in improved patient, worker and environmental health and safety.

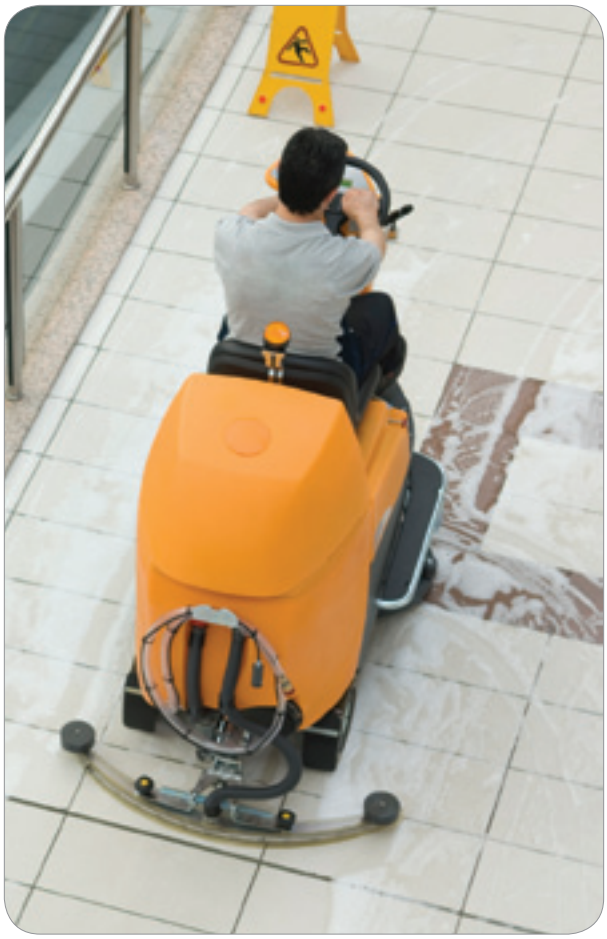
The Collateral Health Impacts of Pharmaceuticals and Other Chemicals Used in Hospitals and Health Care Facilities

Due to the nature of the hospital/health care setting, numerous chemicals are used on a regular basis that may impact patient safety and health, worker safety and health, and environmental sustainability. These range from cleaners and disinfectants, to pharmaceuticals (in different forms, including aerosols), to latex in gloves. As awareness of the possible hazards of these chemicals increases, at the same time that potentially less hazardous alternatives are becoming available, questions within the chemicals area have been identified by both health care systems executives and agency staff as priorities for a hospital and health care sustainability research agenda.

The Current State of Knowledge

Green Cleaners

While cleaning is important in all economic sectors, it serves the health care industry the dual functions of surface cleanliness and infection prevention and control. Many hospitals have increased the use of cleaning and disinfecting products to address healthcare-associated infections as well as other infection prevention and control concerns. However, conventional cleaning products and disinfectants bring a host of other health hazards that are of concern in regard to both hospital workers and patients. Conventional cleaning products are complex mixtures of chemical ingredients. Many of these ingredients are known or suspected to be associated with asthma and other respiratory disorders. Some others are associated with dermatitis, endocrine and neurologic effects, and cancer. However, many ingredients have not been tested and so their effects are still unknown. There is evidence that some cleaning product ingredients harm the environment; they may bioaccumulate in plants and animals, damage aquatic ecosystems, and pollute indoor air, outdoor air, and drinking water supplies.



Concerns about adverse human and environmental health effects of conventional cleaning products have led to the development of "green" cleaners. Some green cleaners may reduce human health and environmental effects as well as reduce costs. However, little is known about whether green cleaning programs meet or compromise infection control and prevention goals. And while respiratory and dermal exposures result from a combination of factors in the cleaning process (i.e., products used, ambient conditions, physical space, and the way tasks are performed — the "systems approach"), there is limited information about how cleaning tasks generate respiratory and dermal exposures. One of the white papers contracted for by the Research Collaborative, "Cleaning in Healthcare Facilities,"[14] evaluates existing literature about greener cleaners for efficacy, worker and patient health impacts, and environmental impacts, and identifies knowledge gaps and research and educational activities that could help to address them. Additionally, many healthcare systems interviewed identified cleaning, greener cleaners, and infection control as priority areas for research.

Since LEED for Healthcare is expected to be launched during the latter part of 2009, the period of 2009-2010 is timely for collecting baseline occupational exposure and health data. The baseline data, the paper notes, can be compared to the LEED post-implementation data to measure the standard's success.

Pharmaceutical Waste

Pharmaceutical waste disposal continues to be an area of great interest for hospitals and other health care facilities, as well as for federal and state policy makers. A third Research Collaborative white paper contracted for by the Research Collaborative and nearing completion will outline current pharmaceutical disposal systems, sources, options and problems; describe the current research on environmental and health implications of pharmaceutical waste; and define areas where further research is needed.

The problem is multi-faceted. The draft paper cites an Associated Press report that pharmaceutical residues were detected in the drinking water of 24 major metropolitan areas across the U.S. serving 41 million people. Pharmaceuticals include human and veterinary drugs, both prescription and over-the-counter, medical agents such as chemotherapeutic drugs, and x-ray contrast media. These materials may end up in the environment through manufacturing, waste from human or animal excretion, improper disposal such as flushing down a toilet, runoff from animal feeding operations, or leaching from municipal landfills.

There is little data available to calculate the relative contribution of improper disposal of pharmaceuticals (intentional releases) to the total release into the environment, and there has been surprisingly little work done to evaluate the detrimental effects of exposure to low levels of pharmaceuticals on human health — even though low-level exposures could pose risk, particularly to sensitive subpopulations such as the fetus, people with chemical sensitivities, or people with existing disease burdens that could be exacerbated by inadvertent exposures. Antimicrobials and hormone-disrupting chemicals have been singled out as a priority, the draft paper notes, due to both their ability to cause health harm at low concentrations and their high levels of production.

Research Priorities

Priority Research Areas

Evaluation of Both Existing and New Greener Cleaning and Disinfection Products, Materials, Practices and Systems

According to one health care system interviewee, disinfectants continue to be used on the floors of many of their hospital and clinics although, she believes, this may not be necessary. "If we could better guide where and when disinfectants are used to clean the healthcare environment," she suggested, "I think we could contribute to both infection prevention and greener healthcare." This interviewee also expressed interest in the effectiveness and cost-effectiveness of newer environmental cleaning technologies, such as peroxide vapor, electrolized water, and steam vapor. Another health care system interviewee mentioned a microfiber mop infused with anti-microbials that does not require large amounts of water or cleaning products, and noted that it would be helpful to evaluate this and other products in terms of efficacy for cleaning and disinfecting, as well as impacts to worker health and safety.

A tool that can offer a thorough and multi-faceted evaluation of these technologies, products and practices would benefit health systems in making the most informed decisions about cleaning in the context of all three safeties. A study or several studies on both existing and new products, materials and technologies should be pursued to develop a template for product evaluation. Product evaluations should look at impacts on patient safety and health, including infection control; worker safety and health; life-cycle impacts from manufacture to waste on the environment and human health; and should include evaluations of capital and maintenance costs. Interviewees emphasized the importance of showing a cost-benefit analysis.

Impact of Cleaning and Disinfectant Products, Practices and Protocols on Patient Infection Control

One of the very top research priorities articulated by health systems during interviews was a better understanding of best practices to control and prevent Hospital Associated Infections. New cleaning and disinfectant products are being introduced, including greener cleaners and anti-microbials. In healthcare it is crucial to understand how cleaning practices support infection prevention and control goals. The literature search conducted as part of development of the green cleaning white paper found that there are no systematic scientific evaluations publicly available on how effectively green cleaners meet infection prevention and control standards. Research is needed to evaluate existing disinfectant practices, products and protocols to test the existing assumptions about those practices and products. Additionally, an evaluation of new products, including antimicrobials, should be done documenting efficacy, human health and environmental lifecycle impacts and cost or cost savings associated with the practice or product. Studies should look at different patient populations (children, adults and the aged) and should provide a set of best practices for future evaluations and implementation of preferred practices.

Human Health Studies of Green Cleaners

While green cleaners offer great promise for human health and the environment, no evidence was found of comprehensive scientific health studies that examine health risks from green cleaners. The white paper recommends that human health studies be conducted on green cleaning products, focusing on asthma and other health effects.

Worker and Patient Exposure to Hazardous Drugs and Chemicals

Beyond cleaning agents, there are questions as to which chemicals in the healthcare setting are associated with adverse health effects among healthcare workers and patients — and which may also have community environmental effects. Health effects of concern include skin disorders, respiratory disease (such as asthma), adverse reproductive outcomes, and malignant diseases. It would be helpful to measure current exposure levels by various types of healthcare workers, as well as develop a mechanism for pre-evaluation of health and environmental impacts of new chemical-containing products and equipment.

Additional Specific Research Priorities

Qualitative Study of Green Cleaning Programs

The green cleaning paper recommends carrying out a qualitative study on the nature, effectiveness, and impacts of green cleaning programs in selected hospitals by conducting (i) in-depth interviews with key staff members who coordinate or participate in green cleaning teams, and (ii) focus groups with janitorial employees in these same hospitals. Previous research on sharps injuries in home healthcare demonstrated that qualitative data provide crucial in-depth information on the nature of the study topic as well as how it is influenced by different circumstances, perspectives, and social forces. These qualitative data are needed to fully define the main influences in the system of cleaning in healthcare and to identify gaps and lessons learned for information-rich case studies.

Exposure Assessment of Green Cleaners

Earlier work by the University of Massachusetts — Lowell[15] on exposure assessment of cleaners attests to the need and offers a baseline for conducting exposure assessment studies to develop improved work practices and cleaning. The white paper on cleaning recommends that a study be designed and conducted to assess worker exposures with green cleaners and typical work scenarios. Such a study could also assess patient exposures.

Case Studies on the System of Cleaning

It is important to have a comprehensive analysis of the broad system of cleaning, including its decision-makers, their roles, and responsibilities at various levels of work organization. Such an analysis currently does not exist. The white paper recommends the use of case studies to serve as practical overviews of implementing new products or practices. They should be detailed, comprehensive, and useful to a broad audience within the healthcare setting, systematically examining environmental, safety and health aspects of greener cleaners.

Defining "Green" for Health Care

What does it truly mean to be "green" in health care? There is not an accepted definition or standard for sustainability and "green" for health care. As the health care sector works to become more sustainable and green, a definition should be developed that sets a standard for the entire industry. There are many publications and ongoing work being done within the sector around sustainability. A literature review could be conducted and published that begins to identify the factors to be considered in defining "green" and setting a standard. Further, an evaluation could be conducted to look at "green" endorsements and products sold as "sustainable" to evaluate whether they truly meet the GHSI/HCWH standard for green and sustainable.

Material Evaluation Template

Many systems have incorporated new materials and technologies into their facilities over the last several years. While those materials have documented benefits for one of the safeties, there is little to no data on other impacts on others (i.e., rubber floors are ecologically friendly, single patient rooms improve patient outcomes). As more new technologies and materials are brought to the health care market, an efficient and thorough evaluation tool would benefit health systems in making the most informed decisions. A study or several studies on existing materials and technologies should be pursued to develop a template for product evaluation. Product evaluations should look at the life cycle impacts from manufacture to waste on the environment and human health and include evaluations of the capital verses maintenance costs. One priority product identified by interviewees is flooring maintenance and treatment products.

Environmental and Human Health Impact of Pharmaceutical Water Contamination

The draft report on pharmaceutical waste identifies five general targets of opportunity to tackle these problems: design, approval, production, use, and disposal. The primary knowledge gaps that should be addressed in any efforts to characterize the environmental and human health impact of pharmaceutical water contamination, as identified in the draft report and based on the experience of Research Collaborative staff, are the following:

- What is the volume (or magnitude measured by active units) of pharmaceuticals (and certain classes of pharmaceuticals) in our tap water and in our waterways?
- What proportion of pharmaceutical waste comes from humans (as opposed to pharmaceuticals from animal uses)?
- In terms of pharmaceutical waste from humans, how much is coming from where? How much comes from people's homes and how much from institutions? What is the pharmaceutical footprint of various types of institutions?
- Can these amounts cause or contribute to adverse human health effects, considering sensitive populations and their presence as a complex mixture in drinking water?
- Is there a pharmaceutical class or category of pharmaceutical of biggest concern?
- What proportion of pharmaceutical contaminants (and certain classes of pharmaceuticals) come from excretion from humans versus disposal down the toilet?
- Is the disposal in landfills a significant source of contamination? What is the best disposal method to protect the environment?
- How persistent are pharmaceuticals (and certain classes of pharmaceuticals) in the environment, and how effective is conventional wastewater treatment and drinking water treatment in destroying them?
- What is the magnitude of waste per unit of desired product coming from manufacturing pharmaceuticals (and certain classes of pharmaceuticals), and how much of this waste is active ingredient, hazardous chemicals, or biological hazardous waste?

Orthophthaladehyde (OPA) Hazard Assessment

This continuing project, Orthophthaladehyde (OPA) Hazard Assessment[16], was identified by NIOSH as a priority research item. It would assess occupational exposures to OPA and determine if workers are experiencing adverse effects associated with exposure in the health care sector. To assess exposure, this study would also develop analytical methods for environmental monitoring of OPA and determine the feasibility of an OPA biomarker. Because of the absence of published toxicological data on OPA, testing will be conducted in experimental animals. The toxicological testing will focus on dermal and respiratory irritation and sensitization. Dose-response data will be obtained for hazard identification risk assessment, which, along with health assessments, will serve as the basis for establishing exposure limits.

Development of Exposure Assessment Methods and Survey Questionnaire for the ISAIH

The healthcare industry is the largest and fastest-growing industry in the US[17]. Data from Sentinel Event Notification System for Occupational Risk (SENSOR) and Europe show healthcare workers have elevated risk for WRA, associated with exposure to groups of agents such as cleaning products, latex, indoor air pollution, VOCs and bioaerosols. Recent epidemiologic studies of healthcare workers have utilized job exposure matrices (JEMs) based on probability of exposure, however, specific exposures/etiologic agents are not well characterized and quantitative exposure measurements are lacking. This project will augment the existing JEM with quantitative exposure data, which will significantly enhance the existing JEMs and develop a survey questionnaire for asthma in healthcare. The results of this study will be used to develop a National Occupational Research Agenda (NORA) proposal for an international epidemiologic study of asthma in healthcare workers.

Recommended Exposure Limit (REL) for Waste Anesthetic Gases

The project on waste halogenated anesthetic gases — isoflurane, desflurane, and sevoflurane — will evaluate the data and determine if they provide a sufficient basis for a REL.

Revised Recommended Exposure Limit for Glutaraldehyde

The purpose of this project is to develop a policy document to update the existing REL for glutaraldehyde.[18] Contact dermatitis and asthma have been noted in workers with exposure below the existing NIOSH REL (0.2 ppm, ceiling). In accordance with NIOSH's mission to assure a safe and healthful workplace, a policy document will be developed to provide a summary of the relevant health effects data, a revised REL and guidelines to reduce the risk of adverse health effects in workers across two NORA sectors (manufacturing and health care). This revised REL will commit the latest research to the practice of protecting working men and women from the health effects of occupational glutaraldehyde exposure.

The Impact of Hospital and Health Care System Institutional Organization and Operations on Patients, Workers, and the Environment

This section addresses two areas of impact on patient safety and health, worker safety and health, and environmental sustainability. First, hospital/health care organization may include such factors as doctor or nurse work schedules and length of shifts, organizational cultures, and other factors that may, for example, impact worker stress, which could in turn affect patient safety and health. Second, operations refers to practices such as those that affect energy and water use, waste disposal, and the use of worker protective equipment.

The Current State of Knowledge

Workplace safety in the hospital setting faces several unique challenges. According to the U.S. Centers for Disease Control and Prevention (CDC), rates of occupational injury to health care workers have risen over the past decade. Health care workers face a wide range of hazards on the job, including needle stick injuries[19], back injuries, latex allergy, chemical exposure, violence, and stress. Although there are ways to prevent or reduce health care worker exposure to these hazards, health care workers are experiencing increasing numbers of occupational injuries and illnesses. The CDC estimate that each year 385,000 needle sticks and other sharps-related injuries are sustained by hospital-based health care personnel; the average per day is 1,000 sharps injuries. Injuries from needles and other sharp devices used in health care and laboratory settings are associated with the occupational transmission of more than 20 pathogens, including Hepatitis B, Hepatitis C and HIV.

In 2004, the Institute of Medicine released "Keeping Patients Safe: Transforming the Work Environment of Nurses,"[20] which identified solutions to problems in hospital, nursing home, and other health care organization work environments that threaten patient safety through their effect on nursing care. The report's findings and recommendations addressed the related issues of management practices, workforce capability, work design, and organizational safety culture. The report presents evidence from health services, behavioral, and organizational research, and human factors and engineering contexts to address pressing public policy questions including nurse staffing levels, nurse work hours, and mandatory overtime.

Nurses from 36 hospital medical-surgical units within 17 health care systems, including Ascension Health, Kaiser Permanente and numerous other health systems, participated in the Robert Wood Johnson Time and Motion Study released in 2008. The three-part study aimed to establish a baseline of data to define and describe the impact of variables on nursing time and motion.[21] This study found that more than three-quarters of nurses' time was devoted to nursing practice; patient care activities accounted for only 19.3 percent of nursing practice; there is no relationship between architectural design of work units and the time nurses spent with patients and that nurses traveled between 1 and 5 miles per 10-hour daytime shift and between 1.3 and 3.3 miles at night.

Because of the unique workplace environment in hospitals, the National Institute for Occupational Safety and Health (NIOSH) has made health care research a priority, creating the Health Care and Social Assistance Research program, with a mission to enable the sector to eliminate occupational diseases, injuries, and fatalities through a focused program of research and prevention. The August 2009 draft National Occupational Research Agenda (NORA)[22] includes a National Healthcare and Social Assistance Agenda that identifies five priority areas for research: safety and health programs, musculoskeletal disorders, hazardous drugs and other chemicals, sharps injuries, and infectious diseases.

The 2009 draft NORA notes that overexertion incidents are the leading source of workers' compensation claims and costs in healthcare settings. It cites the Bureau of Labor Statistics (2003) in stating that frequent lifting and repositioning of patients is the leading source of injury for healthcare workers. In 2005, more than 20,000 recordable cases of back and other pain, carpal tunnel syndrome, and tendonitis were reported in the health care and social assistance sector by the BLS, according to the NORA, and of these, more than 40 percent were among healthcare support occupations such as aides and assistants. The NORA notes that as the U.S. population becomes older and heavier, the problem of musculoskeletal disorders in health care workers is likely to grow. This high injury rate, coupled with a critical nursing shortage, "raises serious concerns about the nursing workforce's capacity to care for our nation's expanding population," according to the NORA.

Nurses are also susceptible to illnesses as a result of their high levels of exposures to chemicals in hospital and health care settings. In 2009, the University of North Carolina at Charlotte published a study identifying occupational exposure risk factors associated with development of new-onset asthma for nurses after entering the nursing profession.[23] A statewide cross-sectional survey was administered to a representative sample of Texas nurses with active licenses, and compared to three other healthcare professional groups (physicians, respiratory therapists, and occupational therapists). Outcome variables were physician-diagnosed new-onset asthma after entry into the health care profession and symptoms associated with bronchial hyper-responsiveness (BHR). Occupational exposures were ascertained through an externally developed job-exposure matrix, grouped into four categories: cleaning-related tasks, use of powdered latex gloves, administration of aerosolized medications, and tasks involving adhesive compounds, glues and/or solvents.

After adjustment for age, sex, ethnicity, atopy, smoking, body mass index, and seniority, reported asthma was significantly greater among nursing professionals involved in medical instrument cleaning and exposure to general cleaning products and disinfectants. Use of powdered latex gloves between the years 1992 and 2000 was associated with 1.6 times the odds of reported asthma, but not thereafter. Similarly, the odds of BHR-related symptoms were significantly greater among nursing professionals exposed to general cleaning products and disinfectants and adhesives, glues and/or solvents. The study concluded that among nursing professionals, workplace exposures to cleaning products and disinfectants increase the risk of new-onset asthma.

Additionally, female nurses may be at increased risk of adverse reproductive outcomes through exposure to a variety of reproductive hazards in their workplace.

Distributed Ventilation: Several health systems are currently working together to pilot a new distributed ventilation system in hospitals that would use 30 percent less energy than traditional systems. As hospitals are one of the largest energy-using industries in the nation, such an innovation has great potential to significantly decrease energy use for the entire sector. In evaluating this new system, there may be the added benefit of decreasing hospital-acquired infections. By changing the air current in a hospital room, the ventilation system may improve the indoor air quality, producing a significant health impact while decreasing the environmental effect on the public and reducing cost to the hospital. The experience of this pilot activity will be reported and available for distribution.

Research Collaborative interviewees identified multiple initiatives specifically aimed at addressing identified problems, including no-lift bed systems, educational campaigns to reduce back injuries, reduction in the use of latex materials to decrease allergies, use of self-sheathing and other safety systems to reduce needle stick injuries, switching where possible to needles syringes, and modifications to the use of certain chemicals to decrease exposures. Interviewees also identified numerous areas in which research would be helpful in their efforts to increase worker health and safety — with those efforts also likely to greatly benefit patients.

Research Priorities

Priority Research Area

Musculoskeletal Injuries in Patients and Health Care Workers

Given that health care workers are particularly susceptible to musculoskeletal injuries, central research questions include: What is the relationship between work organization factors, job demands, workload, and physical factors, and the risk of musculoskeletal injuries in patients and health care workers? What is the effectiveness of best practices for safe patient handling and movement in hospitals and other health care settings? Additionally, a business model could be developed to demonstrate the cost-effectiveness of safe patient handling, and work organization models should be developed and tested with respect to the recruitment, retention and injury rates of nursing staff.

Additional Specific Research Priorities

Emotional Stress and Health Care Workers

How do stressful conditions in healthcare contribute to medical errors? A research project could identify specific stressors and propose a hierarchy of controls to reduce the effects of stress on hospital and health system workers' ability to be present and productive at work. Additionally, such a study could identify ways of developing skills among staff and managers that could be helpful in managing workplace stress.

Safety Culture

A priority identified in the August 2009 draft NORA agenda is research around how to optimize a culture of safety in healthcare organizations. Research projects identified include identifying best practice guidelines for scheduling, staffing and worker/patient/client ratios; assessing the impact of excessive workloads and demanding work schedules on recruitment of new staff, retention and job exit; identifying key safety culture elements; and developing "return on investment" metrics associated with safety culture initiatives.

Sharps Injuries

According to the August 2009 draft NORA agenda, the risk to healthcare personnel of exposure to blood borne pathogens through needle sticks, cuts, or other sharps injuries is well-documented. Current potential research projects include identifying the number and types of healthcare personnel employed in settings other than hospitals who sustain percutaneous injuries, and the circumstances, mechanisms, procedures and devices involved in these injuries; identifying the types of healthcare establishments most likely to not write, update or implement a written exposure control plan, and the reasons for not doing so; and to assess the extent of compliance with the OSHA mandate that frontline workers be involved in the selection and evaluation of devices.

Infectious Diseases

Also a priority in the new NORA, research priorities include understanding mechanisms and routes by which infectious diseases are transmitted in the healthcare and social assistance setting; conducting research to better understand characteristics associated with airborne transmission, and assessing barriers and developing interventions to increase rates of healthcare and social assistance workers receiving vaccinations against influenza, hepatitis B, whooping cough, and other vaccine-preventable infectious diseases.

Reuse of Clinical and Infection Control Devices

Some devices used in hospitals and health care settings are reusable, and reusing them would reduce waste and therefore have environmental benefits. However, infection control is the primary reason not to reuse a device. When is it safe to reuse a disposable item?

Hazards in Healthcare: Organizational

NIOSH staff identified this project as a priority and a potential partnership opportunity between the agency and the Research Collaborative. NIOSH is currently developing a series of educational and technical documents critically assessing available data on occupational safety and health hazards to health care workers in hospitals, homes, and other settings. The series will address subjects such as violence, ergonomic stressors, emotional stress, needle sticks, and tuberculosis. It will also outline preventive strategies. This information is intended for use by safety and health professionals, workers and employers. Additionally, this project focuses on several priorities under the National Occupational Research Agenda - disease/injury (musculoskeletal disorders and work organization). This research-to-practice project will produce communication products supporting the NIOSH mission to assure a safe and healthful workplace.

Chemical and Organizational Hazards and Implications for Nurses' Reproductive Health

How might hospitals and health care institutions be able to judge risks to allow them to make an informed decision about the potential reproductive harm in hospitals, laboratories, x-ray rooms, and other areas? Are Universal Precautions being followed? Are there new procedures that are using chemicals that have not been tested as possible mutagens? What about acquired allergies to products used daily, e.g., radiology film allergies or mixing drugs such as compounds for chemotherapy or antibiotics for children? NIOSH identified as a research priority a project to characterize the impact of chemical and physical exposures, as well as the impact of work schedules, on reproductive health. That study would contribute to the NORA target areas of cancer, reproductive, and cardiovascular disease cross-sector, healthcare and social assistance sector, and the exposure assessment cross-sector.

Surgical Units

Staff of Health Care Without Harm, Practice Greenhealth, the Health Care Research Collaborative, and the Johns Hopkins Center for Surgical Outcomes Research met during the past year to discuss potential research projects that could be carried out to evaluate improvements around patient, worker and environmental safety in surgical settings. Surgical settings present unique challenges and opportunities for green practices. A paper could be developed that reviews the literature and conceptualizes the areas of concern related to the operating room. It would identify data needs and a set of best practices for safety improvements, including an analysis of the cost associated with implementing those measures.

R2P (Research to Practice) Assistance on Engineering Controls for Hazardous Drugs

The Research to Practice initiative at NIOSH is focused on the transfer and translation of knowledge, interventions, and technologies into highly effective prevention practices and products which are adopted into the workplace.This project seeks to re-establish the r2p momentum necessary to support the health care worker-protective objectives within the NIOSH Alert, Preventing Occupational Exposure to Antineoplastic and Other Hazardous Drugs in Health Care Settings and to facilitate the adoption of its protective engineering guidance into public health practice. The r2p efforts will nurture the adoption of NIOSH worker-protection guidance via three critical arenas: (1) Consensus standard development, (2) Foster development of protective engineering equipment performance consensus standards, and (3) Ongoing information dissemination responding to client-driven inquiries and uncertainties.

Respirator and Surgical Mask Efficacy from Cough Aerosols

The purpose of this project is to measure how well surgical masks and disposable respirators protect healthcare workers from infectious aerosols produced by patients during coughing, and to provide health care recommendations based upon the results. A cough simulator will "cough" a simulated aerosol-laden cough through a standard head form. A second head form will be connected to a breathing machine to simulate the inhalation and exhalation of a healthcare worker; this second head form can be outfitted with a mask or respirator. The head forms will be placed in a test chamber, which will simulate the cough of a patient and the respiration of a healthcare worker, and measure the amount of the aerosol that is inhaled by the breathing head form with or without a mask or respirator, impacting Respiratory Disease and Personal Protective Technology in the Health Care Sector.

Permeation of Protective Gloves by Chemotherapy Drugs

The newly established American Society for Testing and Materials Standard D6978-05 [24] the first established specifically to evaluate permeation of protective gloves by chemotherapy drugs, will require testing a large number of gloves in order to demonstrate adequate performance. The proposed project will test a wide range of gloves against seven drugs required under the standard and others selected according to stakeholder interest. Whenever possible, necessary drug quantification will be done using liquid chromatography-tandem mass spectrometry, which provides the necessary analytical sensitivity and specificity. Reliable and objective permeation data compiled through rigorous testing according to the standard criteria will assist stakeholders including health care providers who may be exposed to chemotherapy drugs in the course of work and glove manufacturers seeking to document product performance.

Reuseability of Filtering Facepiece Respirators

This project focuses on the reusability of NIOSH certified filtering facepiece respirators (FFR) that are used for respiratory protection against influenza and other infectious aerosols. Laboratory studies will be conducted to understand the efficacy and impact of decontamination methods on respirator performance and to understand the risks associated with handling a respirator contaminated with virus. These studies will be used by NIOSH and CDC to develop scientific recommendations on respiratory protection for healthcare workers, emergency responders, and the general public. These studies will also be used by national and international standards development organizations to support new test methods.

The Impact of Respirator Use on CO2 Levels and O2 Saturation

Healthcare workers will be required to wear filtering facepiece respirators (FFR) to protect themselves during an influenza pandemic. Long term use may result in increased CO2 retention and a decrease in O2 saturation which reduces the performance of the wearer. To prolong the useful life of the FFR, a surgical facemask may be additionally worn as an overlay to the FFR thus exaggerating the CO2 and O2 issues. This study will evaluate the magnitude of these effects in subjects exercising on a treadmill at a predetermined work load. This data can be used by both manufacturers of FFR respirators to improve their products and by consensus standards organizations to develop appropriate performance levels and write guidance documents.

Respirator and Surgical Mask Efficacy from Cough Aerosols (NORA)

The purpose of this project is to measure how well surgical masks and disposable filtering facepiece respirators protect healthcare workers from potentially infectious aerosols produced by patients during coughing, and to provide health care recommendations based upon the research results. To do this, we will design and construct a cough aerosol exposure simulation system. A cough simulator will be built that "coughs" a simulated aerosol-laden cough through a standard head form (called the coughing head form). A second head form (called the breathing head form) will be connected to a breathing machine to simulate the inhalation and exhalation of a healthcare worker; this second head form can be outfitted with a mask or respirator. The coughing and breathing head forms will be placed in a test chamber, which will then allow us to simulate the cough of a patient and the respiration of a healthcare worker, and measure the amount of the cough aerosol that is inhaled by the breathing head form with or without a mask or respirator. Five masks and five respirators corresponding to those in the Strategic National Stockpile will be tested in this project.

Project BREATHE

More than 14 million workers in the United States are employed in the healthcare field.[25] The threat of emerging infectious diseases has highlighted the need for effective respiratory protective equipment for healthcare workers (HCW) who may be required to wear respirators for extended periods of time. Project BREATHE (Better Respirator Equipment utilizing Advanced Technologies for Healthcare Employees) is a collaborative effort between the Veterans Health Administration (VHA) and NIOSH to identify and integrate advanced technologies into respirators utilized by HCW. The project consists of a Working Group to explore design features that would result in the development of a HCW-specific respirator that would enhance the wearers' safety and comfort, resulting in increased compliance and protection. Subsequent tasks focus on prototype development and testing, with eventual commercialization

Control Banding Literature Review

Control Banding is a complementary approach to protecting worker health by focusing resources on exposure controls. A chemical is assigned to a "band" for control measures, based on its hazard classification, the amount of chemical in use, and its volatility/dustiness. The principle of control banding was first applied to dangerous chemicals, chemical mixtures, and fumes. The control banding process emphasizes the controls needed to prevent hazardous substances from causing harm to people at work.

Several European nations as well as NIOSH have begun to craft policies developing control banding for industrial and business settings. In the hospital setting, control banding could offer worker and patient health protection benefits. Kaiser Permanente and NIOSH have begun work on control banding advisories for glutaraldehyde. In addition, the World Health Organization and the Panamerican Health Organization are exploring the development of Control Banding initiatives for the health care sector. NIOSH has identified as a priority research item development of a literature review and paper that outlines the control banding work done by NIOSH and internationally for industrial chemical use, looks at the work that Kaiser and NIOSH have conducted specific to glutaraldehyde use in hospitals, and makes recommendations for potential next steps for developing control banding policies and potential pilots for hospitals.

Expedient Airborne Isolation for Emergency Response Exercises

The project will utilize current partnerships as well as establish new partnerships as potential sites and community exercises are identified. The research will attempt to translate knowledge learned from prior research on expedient isolation within healthcare environments to a non-traditional "infectious" mass casualty environment such as that which might be established in a cafeteria, gymnasium, or other shelter. In addition to increasing responder familiarity with these specific control concepts, the objective will be to demonstrate and subsequently report upon the aerosol containment and reductions in healthcare worker exposures in a mass-casualty environment.

Demonstration and Sentinel Surveillance System for Personal Protective Technology

It is proposed that the current Vanderbilt Medical Center policies, procedures, and surveillance systems be used to describe biological hazard interventions for health care workers in the medical center setting that utilize Personal Protective Equipment (PPE) to prevent nosocomial transmission of infections in both routine and pandemic conditions. [26] This would include (1) documentation of surveillance systems (including data) and related policies and procedures utilized; (2) investigation and monitoring of employees who report a potential nosocomial disease, are exposed without appropriate PPE, and clusters of nosocomial disease identified through surveillance for the purpose of determining PPE failure, specifically respirators, (3) determine compliance and satisfaction with PPE, (4) identify PPE related data that is not monitored using current surveillance systems, policies and procedures (5) determine useful information to provide NIOSH and CDC via the Early Aberration Reporting System (EARS)for the of national surveillance related to PPE; and (6) determine and report on interventional best practices.

IV. CONCLUSION AND RECOMMENDATIONS

The time is right to move forward as quickly as possible to translate the research priorities detailed in this white paper into research projects that can get off the ground expeditiously and begin to provide the kind of data and information that hospital, health care and federal agency staff and executives have indicated are critical as they move forward in their efforts to green the hospital and health care sector.

There are several compelling reasons to develop and get these research projects off the ground in as timely a manner as possible. First, many hospitals and health care facilities were built in the 1950s and 60s, and now need to be replaced or renovated. Thus, the hospital/health care sector is currently embarking on and already engaged in a building boom. Decisions being made now will have impacts for decades to come.

Second, there is an increased interest on the part of hospital and health care executives and agency researchers and regulators in making the most sustainable choices in hospital and health care design, construction, renovation, materials and chemical use. Yet the evidence base in these areas, while growing, has many gaping holes, and these decisionmakers are seeking answers in these areas that can be provided by the kind of research discussed in this paper. Some health care executives have expressed a desire for further information in specific areas as soon as possible as they look to enter into long-term procurement contracts.

Third, health care reform is currently a top priority item in Washington, and regardless of the direction in which those discussions move, the fact that health care has become increasingly expensive in this country will continue to be a source of concern and discussion. Health care reform and health care spending dovetail closely with the interest of hospital, health care, and federal agency executives in greening the hospital and health care sector. These executives understand that greening this sector of the economy has the potential to lead to substantial cost savings through:

- reducing patient injuries and infection rates and hastening patient well-being and recovery, thereby shortening hospital stays and lowering overall hospital and societal health care costs;
- increasing worker satisfaction and reducing worker injuries, illnesses, and stress levels, leading to more satisfied, healthy and productive hospital and health care workers, lower rates of worker turnover, and lower rates of workers compensation claims for these workers; and
- reducing the environmental health and safety impact of this sector, including leading to lower CO2 emissions and preparing this sector of the economy for regulatory constraints on CO2 emissions likely to take place in the near future; improving relationships with hospitals' surrounding communities and neighborhoods as hospitals reduce their emissions of pollution and toxics; and, based on the evidence collected to date, lead to substantial cost savings for hospitals, health care systems, and society overall as this sector reduces the amount of waste it creates and therefore the cost of handling and disposing of that waste, reduces its energy use and therefore its energy costs, and reduces its use of harmful materials and chemicals and the costs involved with managing and disposing of those materials.

The evidence collected to date shows that greening the hospital and health care sector can lead to substantial benefits and cost savings. For example, the report "The Business Case for Greening the Health Care Sector," from Practice Greenhealth, offers a taste of these potential cost savings. [27] Among the evidence compiled by the report, it notes that one hospital found that by applying green design practices in its redevelopment project, it was able to reduce nosocomial infections by 11% and decrease nursing turnover rates to below 7%. In many cases cited in the report, sustainability measures led to benefits in all "three safeties" — patient safety and health, worker safety and health, and environmental sustainability — leading to substantial cost savings relative to the investment made.

Yet while the evidence base to date is compelling and is proving helpful to hospital and health care executives as they make decisions about buildings, materials and operations, the white papers commissioned and published and the interviews conducted by Research Collaborative staff over the past year point to the need for much more research to be undertaken. This research agenda attempts to prioritize and point the way in undertaking this research. All of the research items included in this paper have been identified as priority items. Through additional discussions and interviews with key hospital, health care and federal agency staff, the authors of this paper have further identified seven areas that are the top priorities for research. It is the recommendation of the authors of this research agenda that research projects in these seven top priority areas be developed and pursued as soon as possible in order to be of the greatest possible assistance to decisionmakers in this sector.

1. **Business case for Sustainability in Hospitals/ Health Care.** A key research priority is to conduct and publish business cases identifying the fiscal impact of sustainability measures in health care settings on costs associated with patient care, workers compensation, waste disposal, and premature aging of the built environment. These cases should examine a wide range of potential sustainability measures, as well as the fullest possible range of upfront and life-cycle costs and benefits leading to cost savings. Additionally, business case data/information should be included as a critical component of every research project identified in this report.

2. **Post- / Pre- and Post-Occupancy Evaluations:** Many health systems have incorporated, or are considering incorporating, sustainability measures into their facilities ranging from energy and water retrofits to waste programs and chemical and sustainable food policies. A series of case studies could be produced to follow a facility through the implementation process from deciding on what types of measures to integrate into their system and evaluate the success and lessons learned of those measures. Additionally, since many health systems have recently built new or renovated hospital facilities that are built to a LEED standard, utilized the Green Guide for Health Care or incorporated various sustainability innovations, a series of post-occupancy evaluation studies could be published to highlight new innovations and evaluate them for efficacy, cost-benefit and impact on patient, worker and environmental health and safety.

3. **Creation of a Materials Evaluation Template.** Many new materials have been introduced over the last several years. While these materials have documented benefits for one of the safeties, there is little to no data on impacts on the others (e.g., rubber floors are ecologically friendly; single patient rooms improve patient outcomes). As more new technologies and materials are brought to the health care market, an efficient and thorough evaluation tool would benefit health systems in making the most informed decisions. A study or several studies on existing materials and technologies should be pursued to develop a template for product evaluation. Product evaluations should look at the life cycle impacts from manufacture to waste on the environment and human health and include evaluations of the capital verses maintenance costs.

4. **Assessment of installation and performance challenges and benefits of alternative flooring materials:** The Research Collaborative white paper, "Resilient Flooring & Chemical Hazards: A Comparative Analysis of Vinyl and Other Alternatives for Health Care," evaluates the potential health and environmental impacts of vinyl flooring and several leading alternatives. It identifies exploration of various attributes of alternative flooring materials as a research priority, including durability; safety — traction and effect on slips, trips and falls; glare; comfort, fatigue and strain; acoustics; installation, including analysis of both installation processes and toxic properties of adhesives and sealants recommended for use with the materials; time constraints; and cleaning and maintenance. The analysis should be extended to additional flooring product types, including newer synthetic polyethylene-based materials and traditional materials such as terrazzo and cork.

5. **Evaluation of both existing and new greener cleaning and disinfection products, materials, practices and systems; impact of cleaning and disinfectant products, practices and protocols on patient infection control; human health studies of green cleaning products:** Cleaning and green cleaning questions were one of the top research priorities cited by hospital, health care and agency interviewees. Many would like to move to greener cleaning products, but need more information. Key questions that research could help to answer include: How well do greener cleaners clean? What is their efficacy in regard to patient infection control in comparison with conventional cleaning products? What is their effect on worker health? When do disinfectants need to be used? Perhaps most fundamentally, what cleaning products should hospitals and health care facilities use, where, and for what purpose?

6. **Worker and patient exposure to hazardous drugs and chemicals**: Beyond cleaning agents, there are questions as to which chemicals in the healthcare setting are associated with adverse health effects among healthcare workers and patients — and which may also have community environmental effects. Health effects of concern include skin disorders, respiratory disease (such as asthma), adverse reproductive outcomes, and malignant diseases. It would be helpful to measure current exposure levels by various types of healthcare workers, as well as develop a mechanism for pre-evaluation of health and environmental impacts of new chemical-containing products and equipment.

7. **Musculoskeletal injuries in patients and health care workers:** Health care workers are particularly susceptible to musculoskeletal injuries. Central research questions include: What is the relationship between work organization factors, job demands, workload, and physical factors, and the risk of musculoskeletal injuries in patients and health care workers? What is the effectiveness of best practices for safe patient handling and movement in hospitals and other health care settings? Additionally, a business model could be developed to demonstrate the cost-effectiveness of safe patient handling, and work organization models should be developed and tested with respect to the recruitment, retention and injury rates of nursing staff.

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