

Linking Environmental Sustainability, Health, and Safety Data in Health Care: A Research Roadmap

NEW SOLUTIONS: A Journal of
Environmental and Occupational
Health Policy
2017, Vol. 27(2) 189–209
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sagepub.com/journalsPermissions.nav
DOI: 10.1177/1048291117710784
journals.sagepub.com/home/new



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Abstract

Limited but growing evidence demonstrates that environmental sustainability in the health-care sector can improve worker and patient health and safety. Yet these connections are not appreciated or understood by decision makers in health-care organizations or oversight agencies. Several studies demonstrate improvements in quality of care, staff satisfaction, and work productivity related to environmental improvements in the health-care sector. A pilot study conducted by the authors found that already-collected data could be used to evaluate impacts of environmental sustainability initiatives on worker and patient health and safety, yet few hospitals do so. Future research should include a policy analysis of laws that could drive efforts to integrate these areas, elucidation of organizational models that promote sharing of environmental and health and safety data, and development of tools and methods to enable systematic linkage and evaluation of these data to expand the evidence base and improve the hospital environment.

Keywords

environmental and occupational health and safety, health care, patient safety, sustainability

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Introduction

The health-care sector has a large environmental footprint, using large amounts of energy and toxic chemicals and producing large amounts of waste. These practices in the health-care sector result in pollution linked with a range of adverse health outcomes. At the same time, there is a growing appreciation of patient risks in health care related to medication and surgical mistakes, health care-acquired infections (HAIs), and fall hazards. Illness and injury among health-care workers are also of concern, given the growing number of workers in the sector and the risky nature of their work, with an injury and illness rate in hospitals nearly double that of private industry as a whole and higher than the rates in construction and manufacturing.

As health-care leaders have become aware of the sector's environmental and related health impacts, they are increasingly launching environmentally sustainable initiatives. Increasing anecdotal evidence suggests that environmental sustainability in the health-care sector can impact worker and patient health and safety. Such potential linkages are a particularly timely area for study due to health care, environmental, and worker and patient safety policies—including the Affordable Care Act—that emphasize prevention of illness, establishment of a culture of safety, and incentives to improve health-care efficiency and outcomes.

This article summarizes the published and gray literature on health outcomes linked with environmental sustainability in the health-care sector. It uses results of a pilot study of 12 hospitals to demonstrate the ways in which these areas align, as well as challenges to data sharing. Finally, it presents a road map for research on how data related to environmental sustainability, to patient health and safety, and to worker health and safety can be linked and used to evaluate their interactions vis-a-vis longer term outcomes.

Background

Health-Care Sector Environmental Footprint

The health-care sector, which accounts for more than 17 percent of Gross Domestic Product,¹ has a large environmental footprint. Hospitals—which are open around the clock and use complex, sophisticated equipment—have more than 2.5 times the energy intensity and carbon dioxide emissions of commercial office buildings.² One study found that in 2013, the health-care sector was responsible for significant fractions of national air pollution emissions and impacts, including acid rain (12%), greenhouse gas emissions (10%), smog formation (10%), criteria air pollutants (9%), stratospheric ozone depletion (1%), and carcinogenic and non-carcinogenic air toxics (1%–2%).³

The study estimated health damages from these pollutants at 470,000 Disability-Adjusted Life Years lost from pollution-related disease, or 405,000 Disability-Adjusted Life Years when adjusted for recent shifts in power generation sector emissions.

The health-care sector produces twenty-nine pounds of waste per staffed bed daily,⁴ including items, such as those included in pre-packaged operating room kits, that are thrown away without being used. Waste disposed of in landfills can create air emissions of gas containing carbon dioxide, methane, volatile organic compounds, and hazardous air pollutants that can adversely affect public health and the environment.⁵ Some medical waste, such as sharps and pathological wastes, may be incinerated, emitting highly toxic mercury and dioxin airborne pollution.⁶ Hospitals use large amounts of toxic chemicals, including cleaners, disinfectants, pesticides, and fragrance chemicals.⁷ Products such as intravenous therapy bags and tubing may contain harmful chemicals like polyvinyl chloride and the plasticizer di-(2-ethylhexyl)phthalate.⁸ Pharmaceuticals used in the sector can contaminate drinking water.⁹ Overall, these environmentally unfriendly practices in the health-care sector create pollution that greatly affects public health.

Patient Safety

At the same time, there is a growing appreciation of patient risks in health care related to medication and surgical mistakes, HAIs, and fall hazards. The Institute of Medicine initiated a patient safety campaign in 1999 with its report, “To Err is Human,” which stated that as many as 98,000 people die in hospitals each year as a result of medical errors that could have been prevented.¹⁰ The Institute for Healthcare Improvement implemented several patient safety campaigns that encouraged hospitals to take steps to reduce morbidity and mortality among hospitalized patients; recommended steps included preventing adverse drug events by implementing medication reconciliation, preventing central line infections by implementing a series of interdependent steps, and preventing surgical site infections by reliably delivering the correct perioperative antibiotics at the proper time.¹¹

Recently, Dr. Donald Berwick—one of the first to sound the alarm on patient harm—and co-authors examined improvements since the patient safety efforts were implemented.¹² They identified varying levels of improvement, citing several successful projects, such as tool kits to prevent central line-associated bloodstream infections. Yet, they stated, “it remains unclear if other efforts, such as more widespread use of surgical checklists, have been effective.” As health leaders shift their focus to the broad arena of quality and value-based care, they wrote, patient safety is at a crossroads and increasingly part of a total-systems approach.

In that context, they described steps for achieving total-systems safety in health care, as described in a new report, *Free From Harm: Accelerating Patient Safety Improvement 15 Years After “To Err Is Human,”* by a group of experts convened by the National Patient Safety Foundation. The panel largely agreed that health care is safer now than it was fifteen years ago, and evidence indicates that certain harms, such as HAIs, have been reduced. Still, they report, 13 percent of harms occurring in hospitals are serious, and there is likely additional harm taking place in the ambulatory setting, where substantially more care is provided. The new report calls for a total-safety system, in which a safety culture is established that ensures that errors and near-misses are reported, reviewed, and acted upon to prevent recurrence. Recommendations include “Create centralized and coordinated oversight of patient safety,” “Create a common set of safety metrics that reflect meaningful outcomes,” and “Support the healthcare workforce.”

Worker Illness and Injury

Illness and injury among health-care workers are also of concern, given the growing number of workers in the sector and the risky nature of their work. Health-care occupations and industries are expected to have the fastest employment growth and to add the most jobs between 2014 and 2024.¹³ In 2011, U.S. hospitals recorded 6.8 work-related injuries and illnesses for every hundred full-time employees.¹⁴ The injury and illness rate in hospitals is nearly double the rate for private industry as a whole and is higher than the rates in construction and manufacturing.¹⁴

Among the occupational health hazards described by the National Institute for Occupational Safety and Health National Occupational Research Agenda for the Health Care and Social Assistance sector are injuries from previously used sharp medical devices (i.e., sharps injuries); slips, trips and falls; acute musculoskeletal injuries; and exposures to hazardous drugs and other chemicals.¹⁵ A number of National Occupational Research Agenda goals may potentially relate to environmental practices and/or environmental sustainability initiatives, including developing data systems that track, trend, and communicate hazards, illness, and injuries; root cause analysis of work-related incidents and injuries; reducing musculoskeletal disorders and slips, trips, and falls; reducing or eliminating exposures to chemical agents; including cleaning and disinfecting agents, chemical sterilants, anesthetic gases, surgical smoke, natural rubber latex, mercury, and tissue preservatives, occupational exposure to which has been linked to adverse health effects including allergic contact dermatitis, kidney and liver disorders, asthma, and cancer; identifying asthma-inducing agents to be targeted for preventive interventions or substitution; and reducing sharps injuries.

Exploration of Worker and Patient Safety Synergy With Environmental Sustainability

Worker health and safety and patient health and safety are currently treated as separate areas within the health-care sector. Typically, environmental safety and health departments and human resources departments of hospitals address worker health and safety issues, while patient safety/quality departments manage patient safety issues. Environmental sustainability efforts are based in varying departments. Similarly, different government agencies provide oversight of these realms. On the federal level, oversight of environmental protection is primarily carried out by the U.S. Environmental Protection Agency, as well as the Department of Energy, which focuses on energy use; the Occupational Safety and Health Administration addresses worker safety and health; and the Center for Medicare and Medicaid Services provides oversight of numerous health insurance programs and works to ensure quality of patient care, while the Agency for Healthcare Research and Quality conducts research and tests new approaches in this area.

Recently, however, worker and patient health and safety are being explored for alignment and synergy. The National Occupational Research Agenda Health Care and Social Assistance states, “The potential hazards which exist in health-care settings – such as exposures to airborne infectious agents . . . [and] slippery floors – affect both patients and workers.”¹⁵ The Joint Commission report, *Improving Patient and Worker Safety: Opportunities for Synergy, Collaboration and Innovation*, bridges

topics that are often siloed within the specific disciplines of patient safety/quality improvement and occupational health and safety . . . [O]pportunities to coordinate patient and worker safety improvement should be identified and explored for data that support combined patient/worker health and safety issues.¹⁶

An article about the physical environment as an often unconsidered patient safety tool, published by Agency for Healthcare Research and Quality, notes a growing body of evidence suggesting that

medication safety is markedly influenced by the physical environmental conditions in areas where medication-related activities occur. These conditions include light levels, sound and noise, work space design to mitigate interruptions and distractions, and work space organization. Performance on visual tasks such as dispensing medications improved in an outpatient pharmacy at higher illumination levels.¹⁷

Another study found that office workers who worked in windowless environments reported poorer well-being and sleep quality than those exposed to natural light.¹⁸

Still, the Center for Health Design, which researches connections between facility design and health, notes the

lack of commonly used metrics and tools for data collection, absence of a reporting process that tracks extrinsic factors (such as flooring conditions) alongside the outcomes of interest (such as falls), and the challenge of changing flooring conditions due to maintenance issues regarding cleaning and surface coating.¹⁹

Environmental Sustainability in Health Care

As health-care leaders have become aware of the sector's impact on the environment and health, they are increasingly launching environmentally sustainable initiatives. Healthier Hospitals, a national program that has enrolled 1300 hospitals around the country to implement sustainability activities in the areas of leaner energy, less waste, safer chemicals, smarter purchasing, healthier food, and engaged leadership, includes some of the largest and most influential health systems in the country, such as Kaiser Permanente and Partners HealthCare. Goals in its safer chemicals area, for example, include commitments to purchase Green Seal- or UL ECOLOGO-certified cleaning products and furnishings and furniture manufactured without formaldehyde, antimicrobials, and other chemicals linked with health problems.²⁰

Anecdotal Evidence of Linkages

Increasing anecdotal evidence suggests that environmental sustainability in the health-care sector can impact worker and patient health and safety. A research collaborative based at the University of Illinois at Chicago explored these intersections and produced several reports; one on green cleaning noted,

For Magee-Womens [Hospital], some of the potential benefits from the adoption of green cleaning practices include the reduction of healthcare associated infections and reduced complaints from staff and patients . . . The measurements of the effects of green cleaning could use certain data routinely collected by the hospital for other purposes, such as budgets for chemicals and infection rates. However, the data have not been used to critically evaluate green cleaning efforts.²¹

A report on the experience of hospitals that have installed resilient, sustainable flooring noted that some interviewees indicated that these flooring choices were more comfortable to stand and walk on, and that they reduced noise levels and the need for harsh cleaning chemicals that may cause workers to feel ill.²²

Connection With Policies

Such potential linkages are a particularly timely area for study due to the Affordable Care Act's emphasis on prevention of illness and incentives to improve health-care efficiency and outcomes, as well as the recently enacted policy of Center for Medicare and Medicaid Services not to pay hospitals the additional cost of treating certain conditions that occur while the patient is in the hospital, including falls and some HAIs.²³

Limited but growing evidence demonstrates that environmental sustainability initiatives in the health-care sector can improve worker and patient health and safety. Yet, the connections between environmental sustainability, worker safety and health, and patient safety and health are not appreciated or understood by decision makers in health-care organizations or by oversight agencies. Data that could increase understanding of these linkages are rarely shared among hospital departments. Thus, health-care organizations are missing an opportunity to synergize and economize by not examining purchases, databases, physical plant issues, health-care worker training, and policy documents in a comprehensive and holistic way. There are potential win-wins for all the parties working on each component and for the health-care system as a whole in terms of improving environmental sustainability, protecting workers, and protecting patients.

Methods and Findings

Literature Review

A literature search was conducted in order to find evidence for direct relationships between environmental sustainability, worker health and safety, and patient safety in the health-care sector. Search terms were selected based on previous work in this area carried out by the University of Illinois at Chicago research collaborative and on the National Institute for Occupational Safety and Health National Occupational Research Agenda for the Health Care and Social Assistance sector. Combinations of the search terms "health care," "health," "hospital," "environmental," "sustainability," "metrics," "safety," "healthcare acquired infections," "asthma," "waste management," "green," "post occupancy evaluation," and "LEED" were used. Search engines used were PubMed Central, Lexis-Nexis Academic, Google Scholar, and Google. Articles were reviewed to look for overlaps between any two areas (environmental safety, worker health and safety, and patient health and safety). Also searched for were articles by several specific researchers whose work the authors are familiar with from past experience in this area. The salient articles are presented.

Several studies evaluated impacts of green hospital buildings. Bilec et al.²⁴ developed a method for comparing performance and environment-related

metrics of the relocation of a children's hospital to a new, green facility, including quality of care and staff satisfaction. The comparison tool found statistically significant improvements in productivity, staff satisfaction, and quality of care; these improvements were credited to green building design, mechanical equipment upgrades, and organizational or cultural shifts related to Magnet nursing designation, a nursing recognition program developed by the American Nurses Credentialing Center.^{25,26} Campion et al.²⁷ compared a women's oncology unit that spanned traditional hospital space and a new green addition that featured high-efficiency heating, ventilation and air conditioning and lighting systems, low-volatile organic compound products, and high-efficiency particulate air filters. They found that quality of care and productivity stayed relatively unchanged between the two areas on the unit, while staff and patient satisfaction saw a general upward trend from traditional to green.²⁷

A post-occupancy evaluation of Oregon Health and Science University's new green medical facility aimed to understand the impact of its energy- and water-efficient features on occupant satisfaction, illness symptoms, and absenteeism.²⁸ The green features include displacement ventilation, in which air circulates through natural convection as opposed to being blown by fans, reducing air contaminant levels; daylighting and natural ventilation of the stairwells; demand-controlled ventilation using sensors, so spaces are not over-ventilated or overlit when not in use; and night flush cooling, using outside air, until one hour before daily occupancy. The evaluation showed variable satisfaction with the interior environmental quality, ranging from a high of 65% rating daylight positively to a low of 35% positive for voice privacy. In terms of productivity, 40% of respondents said the new building made work easier than their previous building, while 52% said their performance had not changed and 7% said the new building made their work more difficult. Though not statistically significant, occupants of the new building took more sick leave than in the old building and in a comparison new, non-green building. The authors suggest that future research should focus on understanding the variability in human comfort and identifying strategies to achieve higher levels.

One study integrated pollution prevention and occupational safety and health interventions.²⁹ The eleven interventions implemented in six hospitals were an aliphatic fixative that replaced xylene in three histology laboratories; a mercury reduction plan in three clinical laboratories; digital imaging to replace wet chemical film processing in three radiology departments; a less toxic aldehyde to replace formaldehyde in one hospital histopathology laboratory; and conventional mopping, replaced by microfiber mopping in one hospital. The researchers concluded that

in general, the alternatives were beneficial, although each had limitations that resulted in process and task changes with potentially negative P2 and/or OSH impacts... For example, in radiology, the change to digital imaging had mostly

positive impacts on the environment. It also had significant positive impacts on OSH, but one potentially serious negative impact was job loss.

The authors conclude that while it is difficult to identify totally harmless alternatives to hazardous products, a method of examining environmental health and occupational health impacts together “should be used as a continuous process to identify, implement, and evaluate substitutes as they become available.”

A number of publications from the gray literature identify potential worker and patient health and safety benefits resulting from green initiatives in the operating room, though there is not rigorous evaluation of these interventions. One hospital’s greening efforts describe implementation of a closed, fluid collection system for the collection and disposal of surgical waste in the operating room, which greatly reduces the volume of waste that was previously sent to the incinerator and “minimizes risk of harmful exposure to fluids for health care workers by preventing contact with infectious fluids and possible splash exposure.”³⁰

Another document from the health-care greening organization Practice Greenhealth posits worker/patient health and safety benefits resulting from environmental sustainability initiatives in the operating room that include the following: safer, more precise fluid management systems, which can reduce regulated medical waste and protect workers through reduced exposure (infection risk), slips from spills, and electrical hazards; reusable sterilization containers to decrease waste, reduce rewrapping and flash sterilization, and reduce ergonomic wrapping injuries for sterile processing staff; transitioning to polyvinyl chloride and di-(2-ethylhexyl)phthalate-free medical supplies to reduce the risk of exposure to these chemicals, particularly in hemodialysis, neonatal intensive care unit or transfusion situations; and new systems that can absorb waste anesthetic gases rather than inefficiently ventilating them outdoors, which exposes the surgical team to agents linked to miscarriages and cancer and releases potent greenhouse gasses to the ambient environment.³¹

To summarize, the review found descriptions of unevaluated practices related to the intersection of environmental sustainability, occupational safety and health, and patient safety; however, we found no comprehensive research that provides evidence to guide best practices.

Pilot Study

The authors completed a National Institute for Occupational Safety and Health-funded pilot study to address the question of potential overlaps and synergy between environmental sustainability, worker health and safety, and patient health and safety in twelve hospitals highly ranked for their commitment and practices related to sustainability. Health systems that had participated in previous research studies conducted by the University of Illinois at Chicago-based

health-care sustainability research collaborative, as well as ten of the leading health-care systems within Healthier Hospitals, a national program that has enrolled hospitals to implement sustainability activities, were recruited. Healthier Hospitals was started by the non-profit organization Health Care Without Harm. It offers health-care organizations resources and tools for achieving greater environmental sustainability; hospitals that enroll agree to collect and report data in order to help track sector progress. All of the health-care systems that participated in this study were early adopters of environmental sustainability practices and have been recognized for their efforts in this area. Five are based in the Midwest, three in the West, two in the Northeast, and two in the Mid-Atlantic. All are health-care organizations that include hospitals and an array of outpatient facilities.

An interview tool was developed, comprising twelve mostly open-ended questions that aimed to understand whether the interviewees use data collected by their institution to evaluate impacts of environmental sustainability initiatives on worker and patient health and safety. (The interview instrument is included in Appendix A.) The research protocol was reviewed by University of Illinois at Chicago's Institutional Review Board, which granted an exemption (#2015-0711). Participants were given a recruitment letter describing the project. For each health system, the sustainability director was contacted and his/her participation requested. By participating in the interviews, they indicated their consent to participate. The interview questions were asked in telephone conversations lasting about forty-five minutes each. A safety manager also participated in one of the interviews. The interviews took place between September and December 2015. Data analysis was done by both counting responses by hand and using Atlas.ti software.

Prior conversations indicate that the sustainability directors' positions are typically full time; some of the health-care systems have sustainability offices with several full-time staff. Their backgrounds vary, with degrees or backgrounds in nursing, civil engineering, journalism, business/management consulting (three interviewees), public administration (two interviewees), environmental science and management, and non-profit management; information on the backgrounds of two interviewees was not available. Five of the interviewees noted reporting to the Chief Executive Officer, Chief Financial Officer, Executive Director of Business Services, Senior Vice President of Support Services and Operations, and Chief Executive Officer of one of the health system's hospitals.

Multiple worker and patient databases were identified that could be used to evaluate impacts of environmental sustainability initiatives on worker and patient health and safety. However, only a few hospitals apply the data in this way. When asked whether their health system tracks, evaluates, and reports impacts of the green initiatives on worker or patient outcomes, two of the twelve interviewees said yes, but only as problems are identified, rather than in a systematic approach. Four additional interviewees said no to this question,

but responses to other questions indicated they do carry out this type of evaluation, although, again, only as issues are identified and not on a formal, intentional basis. Table 1 includes examples of issues for which they evaluated these impacts.

The sustainability directors were asked whether they receive six types of data that could potentially reflect impacts of environmentally sustainability initiatives on worker or patient health and safety: worker illnesses and injuries, sick leave, and disability; and patient HAIs, slips and falls, and relevant responses to patient satisfaction surveys. They mostly do not. Most of the interviewees confirmed that the data are available to them, and could be useful for this purpose, although they do not use it. One said,

We do this more anecdotally. But I wonder what sorts of data sources we have that we could use. We're testing different paints; we're going to zero-emission paint. We tested them in areas, like the neonatal intensive care unit, where employees have

Table 1. Examples Given by Sustainability Directors as to How They Evaluate Impacts of Green Initiatives on Worker or Patient Outcomes.

<p>After a Leadership in Energy and Environmental Design-certified (green) building is occupied, they conducted surveys on occupant comfort and indoor environmental quality around lighting, temperature, and other aspects of the building.</p> <p>There is a plan to study the body burden of specific chemical agents among cleaning crews, including those involved in green cleaning.</p> <p>They use worker injury data to look at products that, for example, worsen worker asthma. They installed mix stations to properly dilute cleaning chemicals. "People usually think the more cleaner you add, the better," said the sustainability director. A mix station "takes human error out of the picture. This . . . is safer, and reduces the costs of chemicals."</p> <p>After switching to a bleach cleaner, nurses started to complain about respiratory distress. "We mostly got rid of the bleach cleaner as a result," noted the interviewee. "The nurses complained to the Chief Nursing Officer, who relayed them to the Sustainability Director:"</p> <p>"We looked at the risk of eye splash injuries for certain cleaners and chemicals. We looked at the data on worker injuries and illnesses. We did find a risk," said the sustainability director. She noted: "This helps to justify some safer chemicals choices. We could, if we saw injuries arising from a new environmentally preferable product, look at environmental health and safety data to see if there is a link. Concerns about greener products may arise in an ergonomics context. In terms of slips and falls, we are doing more work in root cause analysis of workplace injuries. We could see more identification of products that contribute."</p> <p>"We tried triclosan [an endocrine disruptor]-free soap in one hospital. Infection Control ran a study and found this did not negatively impact HAI rates. We are going to take this system-wide," the interviewee said. "We were looking into bleach-free disinfectant wipes; the HAI data was shared."</p>	<hr/>
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expressed concerns. We found no negative reactions to the zero-emission paints. But again, that is anecdotal.

Another sustainability director noted that his office included worker health and safety in its analytics for selecting a canister for management of fluid waste in the operating room. (The environmental goal was reduced generation of medical waste.) “But we never went back to look at actual outcomes,” he said. “This is another example of an opportunity to look at outcomes.” All possible linkages between environmental sustainability activities and worker or patient health and safety outcomes that were mentioned in the interviews are listed in Table 2.

When asked whether they think the ability to correlate environmental sustainability initiatives with worker or patient health and safety outcomes influences the feasibility of green innovations for their hospital over the long term, eleven of the twelve hospitals noted important overlaps: “Absolutely,” one sustainability director responded. “Whether worker or patient, it would help to make a good business case – to either reduce injuries and illnesses or rebut the perception that these greener products are less safe.” Another said,

Yes, definitely. If you can make this connection, it is another reason for these programs. It makes them more appealing for leadership too. For example, I have had more luck getting rid of Styrofoam in our children’s hospital than some other products because it is easier to make a connection with health outcomes.

A probing question was asked of one interviewee: What would be required organizationally for the data that is already collected by the hospital to be used to evaluate impacts of green initiatives on worker or patient health and safety outcomes? The response was that a formal way of linking data from different departments—like human resources, safety, and employee health departments—would be needed. The interviewee said that obstacles to sharing these data include incompatible software systems among the salient departments, and the need for a directive from management to pursue such types of data linkage and evaluation, particularly given existing time constraints.

One interviewee commented that the home department of the sustainability director greatly affects which issues they try to address—for example, a sustainability director placed in the real estate department will affect decisions in that arena, while a sustainability director based in the food department may have a particularly strong influence on food-related decisions.

Road Map for Research

This literature review and the survey of sustainability directors in twelve health-care systems highly ranked—for example, as Practice Greenhealth award

Table 2. Possible Linkages Between Environmental Sustainability Activities and Worker or Patient Health and Safety Outcomes Mentioned in Interviews of Sustainability Directors in Twelve Health-Care Organizations.

Green product or practice	Possible health or safety link mentioned
Cleaners	
Conventional and green cleaners or cleaning	Employee illness, asthma, safety, health care-acquired infections, costs of chemicals
Disinfectant wipes, other cleaners	Eye splash injuries
Triclosan-free soap	Health care-acquired infections
Other chemicals	
Ice melt	Winter slips, trips and falls
Pest control chemicals	Worker health (these chemicals have been linked in studies with health issues including asthma, cancer, infertility, and learning disabilities)
Conventional and low-emission paints	Health impacts (paint can contain volatile organic compounds linked with headaches and other impacts)
Chemicals indoors, e.g., polyvinyl chloride, formaldehyde, flame retardants	Health impacts, headaches, respiratory issues, cancer risk, measurements of chemicals in workers
Green hospital buildings	
Differences in air flow, furnishings, operations, and chemicals used	Worker ailments. Exposures to toxic chemicals from building products are linked with some cancers, birth defects, infertility, asthma, and chemical sensitivities.
Leadership in Energy and Environmental Design certification	Occupant comfort, indoor environmental quality re: lighting, temperature; chemical body burden of cleaning crews
Facilities, energy, standards for new, or renovated construction	Employee health awareness, such as the ability of employees to control light and temperature; indoor air quality
Flooring	
Rubber or resilient flooring	Slips, trips and falls, exposure to flooring cleaning chemicals and their respiratory impacts
Waste management	
Selection of fluid canister in operatingroom	Worker safety and health, reducing employee exposure to infectious waste
Safe waste disposal, including sharps and pharmaceutical waste management	Worker safety and health; reducing employee exposure to infectious waste, needlesticks, etc.

(continued)

Table 2. Continued.

Green product or practice	Possible health or safety link mentioned
Lighting	
Light-emitting diodes (LED) and full-spectrum lighting vs. commercial or fluorescent lighting	Employee preference for LED; brightness of parking garage and feeling of safety; impact of lighting color on patient outcomes; improvements for people who have trouble with fluorescent lighting
Healthier food	
Buy local efforts	Connect employees with local environment
Food changes, like elimination of sugar-sweetened beverages	Employee or patient feedback
Changes such as eliminating fryers	Long-term employee health
Worker engagement and wellness	
Energy initiatives, like taking the stairs, education, engagement on sustainability's links with health, perceptions of whether hospital is sustainable	Employee wellness, including reduction in insurance premiums; employee health, motivation, happiness
Transportation	
Number of cars around hospital	Respiratory health
Patient satisfaction	
Patient questions or comments about environmental issues	Patient responses to satisfaction surveys re: environmental issues
Transportation	Developing patient satisfaction regarding transportation, parking concerns, efforts to develop greener transportation programs

winners—for their commitment and practices related to environmental sustainability illuminate ways in which environmental sustainability, patient health and safety, and worker health and safety align. This work also identifies obstacles to connecting these three realms and the efforts needed to focus and promote integrated initiatives.

Future research should include, first, elucidation of organizational models that promote sharing of these three areas of data, including identifying and characterizing the programs, players, policies, and data sources in health-care institutions that could contribute to the linkage and integration of these areas. Organizationally, many of the hospitals that participated in the pilot study have structures in which the sustainability director is either located in or regularly interacts with representatives of other departments that develop or implement

practices related to worker and patient health and safety. These departments include environmental/worker health and safety, infection control, food service, housekeeping, supply chain (purchasing), transportation, facilities management, and human resources. Clinical staffers are involved in many activities that directly involve or synergize with sustainability efforts. Typically, sustainability directors report to a high-ranking executive who is positioned to approve decisions that involve moving forward with an environmental sustainability initiative that has higher upfront costs. Many hospitals have written sustainability goals and plans that can be elaborated to maximize the potential of existing personnel, protocols, and data systems to protect the health of workers, patients, surrounding communities, and the ambient environment.

These organizational factors appear to be critical in linking worker and patient data with sustainability efforts. There are five lines of research needed to move this area forward.

First, a policy analysis of federal, state, and local laws that could drive this effort is in order. Relevant environmental legislation, labor and occupational safety and health laws, and health-care rules that protect patients should be systematically investigated to identify laws and regulations that could drive integration. Exploration of the interaction of these laws with the protocols adopted by a sample of health-care organizations would elucidate potential avenues for intervention. Such a policy analysis could be conducted by a university research center or other independent organization. Following publication of the analysis, either a university research center or an independent organization such as the Joint Commission, which accredits health-care organizations and programs, could initiate a workshop to bring together government and health-care decision makers to share experiences and thoughts about such overlaps and integration, and develop a road map for moving forward. This effort should involve representatives of the federal agencies most involved in these three areas, including U.S. Environmental Protection Agency, National Institute for Occupational Safety and Health, Occupational Safety and Health Administration, Agency for Healthcare Research and Quality, and Center for Medicare and Medicaid Services. A previous example of a joint effort is the federal Partnership for Sustainable Communities, in which U.S. Environmental Protection Agency, the Department of Housing and Urban Development, and the U.S. Department of Transportation, in recognition that the areas they address are closely intertwined, joined forces to help communities “improve access to affordable housing, increase transportation options, and lower transportation costs while protecting the environment.”³² It can be challenging to bring federal agencies together across mission areas. Yet even in a time of lean budgets and debate over the proper extent of government intervention, such efforts at integration have the potential to increase health-care quality and efficiency and reduce costs—goals shared across the political spectrum.

Second, it would be instructive to conduct in-depth case studies of highly sustainable hospitals in order to obtain detailed information about their relevant policies and protocols, including sustainability and communication structures; the functions and protocols of departments that deal with worker safety and health, patient safety and health, and environmental sustainability; the data systems used to monitor and evaluate performance of protocols (the software, variables, and outputs) in these three areas; the mechanisms for sharing data; and examples of protocols that evaluate impacts of sustainability on worker or patient outcomes, including how and why they decide to do these evaluations and challenges to doing so more systematically. This would help to more clearly determine the potential drivers that can lead to further integration of these three areas.

Third, based on this information, it would be useful to develop tools and methods to enable systematic linkage and evaluation of relevant data, including a software application to allow for collection and linkage of data from the areas of environmental sustainability, worker health and safety, and patient health and safety. A process tool or flow chart should be developed to assist health-care organizations to develop organizational structures that can strengthen data sharing among these areas, including examples of personnel and program structures, policies, protocols, plans, and priorities found in the case studies to be linked with greater data sharing and use.

Fourth, researchers should identify priority issues for research in this area, collect data, and carry out studies in order to begin to expand the evidence base. The literature review and pilot study identify some of the challenges for such an effort, including the need to better understand variations in what different patients and workers consider to be a comfortable environment, and the need to consider potential interactions of environmental sustainability and safety and health impacts, such as when a process change that is beneficial for the environment has a combination of positive and negative impacts on workers.

Finally, researchers and policymakers should identify ways of developing and supporting an online library of scientific evidence in this area as the evidence base develops.

Conclusion

Hospitals have a large environmental footprint, they are among the most hazardous places to work, and there is a growing appreciation of patient risks related to medication and surgical mistakes, HAIs, and fall hazards. Each of these areas—environmental sustainability, patient safety and health, and occupational safety and health—operate in different realms and rarely interact. As a growing number of hospitals commit to decreasing their environmental footprint to protect the health of the public and the environment, there is potential to promote synergistic activities that protect patient and worker health, protect

the environment, and reduce health-care costs. The literature review and survey of hospital sustainability directors found rare studies and limited awareness of the impact of environmental sustainability on the health and safety of health-care workers and patients. However, the gray literature and the survey did uncover a number of apparently effective interventions that impact all three realms, and a will, on the part of sustainability directors, to explore the potential value of integrating these efforts.

There is a need for further research that can develop an evidence base to inform integrated and cost-saving interventions to protect workers, patients, and the environment. Research priorities include a policy analysis, hospital case studies, development of a framework and software application, identification of promising areas for research, and a research agenda that provides an evidence base to drive best practices.

Such efforts have the potential to improve health-care outcomes and save money at a time when these goals are central to national policy efforts.

Appendix A

Linking environmental sustainability, health, and safety data in health care

Pilot project: Interview questions for environmental sustainability director

Name of hospital or health system:

City and state in which it is located:

Name and title of interviewee:

Phone number:

Email address:

Date of interview:

Hospital type:

Number of beds:

Number of employees:

A. The hospital’s environmental sustainability initiatives and structure

1. Has your hospital committed to any of the six Healthier Hospitals Initiative planks? If so, please indicate which ones.

- Engaged leadership
- Healthier food
- Leaner energy
- Less waste
- Safer chemicals
- Smarter purchasing

2. Has your organization implemented other major environmental sustainability initiatives—for example, construction or renovation of a green or Leadership in Energy and Environmental Design-certified building or

- implementation of a chemical purchasing policy that limits purchase of products containing chemicals of concern (from interview, website, reports, or a combination of these)?
3. What is the structure of the hospital's environmental sustainability initiatives?
 - a. What department(s) or who plans, implements, and evaluates the initiatives?
 - b. How are these efforts structured? e.g., one green team meeting per month; environmental sustainability a topic at CEO meetings
 4. Can you provide a hospital organizational chart? Y/N

B. Experiences and perceptions

1. Under Environment of Care and other planning and decision-making efforts, how does your hospital take into account worker or patient health and safety outcomes of environmental sustainability programs?
2. a. Does your hospital track, evaluate and/or report impacts of the green initiatives on worker or patient outcomes?
 - Yes
 - No
- b. If so, what data do you collect for this purpose?
3. If your hospital has made an effort to correlate environmental sustainability initiatives with such outcomes:
 - a. What challenges have you encountered?
 - b. What successes have you experienced?
4. Are there aspects of your hospital's environmental sustainability program that you think would be particularly useful to evaluate in terms of impacts on worker or patient safety and health? If so, which ones and why? For example, some hospitals that replaced vinyl tile flooring with rubber flooring are interested in possible impacts on falls and of differing cleaning regimens.
5. Which of the following data are shared with you, as the sustainability director?
 - Worker injuries and illnesses
 - Worker sick time
 - Worker disability status
 - Patient health care-acquired infections
 - Patient slips and falls
 - Patient responses to patient satisfaction surveys
6. How do you make use of this data?
7. What data would assist you and others at your institution to identify impacts of environmental sustainability initiatives on worker and patient health and safety?

8. Do you think the ability to correlate environmental sustainability initiatives with worker and/or patient health and safety outcomes influences the feasibility of green innovations for your hospital over the long term? If so, how?

Acknowledgments

The authors thank Peter Orris for his input on development of the pilot study, Nadine Peacock for advice on data analysis, Muzit Gebretensae for research assistance, and the study participants for their time and thoughtful comments.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: The contents are solely the responsibility of the authors and do not necessarily represent the official views of NIOSH.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This article was supported by the National Institute for Occupational Safety and Health Grant #T42/OH008672.

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