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Major article

Cleaning and disinfecting environmental surfaces in health care: Toward an integrated framework for infection and occupational illness prevention

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Background: The Cleaning and Disinfecting in Healthcare Working Group of the National Institute for Occupational Safety and Health, National Occupational Research Agenda, is a collaboration of infection prevention and occupational health researchers and practitioners with the objective of providing a more integrated approach to effective environmental surface cleaning and disinfection (C&D) while protecting the respiratory health of health care personnel.

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Methods: The Working Group, comprised of >40 members from 4 countries, reviewed current knowledge and identified knowledge gaps and future needs for research and practice.

Results: An integrated framework was developed to guide more comprehensive efforts to minimize harmful C&D exposures without reducing the effectiveness of infection prevention. Gaps in basic knowledge and practice that are barriers to an integrated approach were grouped in 2 broad areas related to the need for improved understanding of the (1) effectiveness of environmental surface C&D to reduce the incidence of infectious diseases and colonization in health care workers and patients and (2) adverse health impacts of C&D on health care workers and patients. Specific needs identified within each area relate to basic knowledge, improved selection and use of products and practices, effective hazard communication and training, and safer alternatives.

Conclusion: A more integrated approach can support multidisciplinary teams with the capacity to maximize effective and safe C&D in health care.

Hospitals and other health care institutions are engaged in essential and intensive efforts to prevent health care–associated infections (HAIs). HAIs are of particular concern to infection prevention professionals because many of these are caused by rapidly developing strains of multidrug-resistant organisms (MDROs). These MDROs can cause serious illness in both patients and health care workers. Cleaning and disinfecting are important parts of a comprehensive infection prevention strategy. While demand for more effective cleaning and disinfecting is growing, there is also increasing evidence that exposure to cleaning and disinfecting can result in acute and chronic health effects, particularly respiratory illness. In response, some hospitals are seeking less toxic (often called green) cleaning and disinfecting products. However, not all of these products have standardized criteria for health protection, and many have not been fully evaluated for their infection prevention effectiveness. The following cases reported to state health departments in Massachusetts and New Jersey exemplify the concerns related to both effective infection prevention and occupational respiratory illness prevention:

1. Eighteen employees in a hospital operating room developed respiratory symptoms, 2 of whom experienced onset of work-related asthma. After a detailed investigation, the hospital determined that cleaning and disinfecting with quaternary ammonium compounds was the likely cause. The hospital switched to a product with parachlorometaxylenol that did not cause employees to have symptoms. However, testing of the parachlorometaxylenol product by the hospital indicated it was not effective at killing *Staphylococcus aureus.* The hospital decided the new product put patients at an unacceptable infection risk and returned to using the original product with quaternary ammonium compounds. The 2 asthmatic employees had to stop working in the operating room. The hospital was able to provide an alternate work assignment for 1 employee, but had to lay off the other (E. Pechter, Research Scientist, Occupational Health Surveillance Program, Massachusetts Department of Public Health, personal communication, 2014).
2. A nurse in her 40s with pre-existing asthma experienced an asthma attack from exposure to a floor care product at a hospital. The nurse had a brief exposure while walking in and out of a small area where the product had been applied. She presented to the emergency room and was treated with medication. She returned to work a few days later and had a repeat exposure to the floor care products resulting in another asthma attack. The hospital switched to a third-party certified green floor care product and scheduled the application around the nurse's work schedule to prevent triggering her asthma. A health department scientist reviewed the ingredients listed on the product's safety data sheet and found that it contained monoethanolamine, which has been designated as an asthmagen by the Association of Occupational and Environmental Clinics,[1] and diethylene glycol monoethyl ether, a potential respiratory irritant. It was recommended that the hospital switch to another green product (A.C. Stephens, Research Scientist, Consumer, Environmental and Occupational Health Service, New Jersey Department of Health and Senior Services, personal communication, 2014).

These cases, and the 2 cases reported in California and Michigan concerning the development of work-related asthma in a hospital environmental services worker and a receptionist in a medical clinic (Appendix 1), illustrate the complexity of infection prevention and occupational health issues related to cleaning and disinfecting in health care and the need for an integrated approach. Thus far, there has been limited collaboration between the disciplines of infection prevention and occupational health to coordinate and optimize efforts to provide effective cleaning and disinfecting practices for HAI prevention while protecting the respiratory health of health care workers, patients, volunteers, visitors, and other building occupants. This lack of coordination has led to gaps in knowledge and practice guidance. The Cleaning and Disinfecting in Healthcare (CDHC) Working Group of the National Institute for Occupational Safety and Health (NIOSH) National Occupational Research Agenda (NORA) was established to develop this multidisciplinary review of the issues and identify future research and practice needs The CDHC Working Group comprised a wide range of stakeholders in the public and private sectors.

OBJECTIVES

This article provides a multidisciplinary summary of current knowledge and knowledge gaps that can impact professionals, workers, researchers, and policymakers involved in infection prevention, control, and occupational safety and health in all types of health care settings, including hospitals, long-term care, ambulatory care, and home health care. The broad objective is to provide an integrated framework for researchers and professional groups to use in developing future scientific evidence and guidance for practice. Specific objectives were as follows:

1. To provide a multidisciplinary summary of the benefits and hazards related to cleaning and disinfection of noncritical environmental surfaces and patient care items in health care.
2. To identify key scientific literature.
3. To identify major gaps in knowledge, policies, or practice.

4. To identify needs for research, practice guidance, and preventive actions.

This document focuses on cleaning and disinfecting practices used on noncritical patient care items and noncritical environmental surfaces, which involve using cleaning products and low-level and intermediate-level disinfectants, and the occupational hazards associated with these processes. The term cleaning and disinfecting is used because these processes are often performed together, either sequentially or concurrently. This term refers to the physical activities and tasks and the products used for cleaning and disinfecting. Although sterilization and high-level disinfection are extremely important processes to prepare critical and semicritical instruments and devices for patient use, a thorough discussion of the occupational health issues associated with them is beyond the scope of this article. Definitions of key terms are provided in the subsequent sections.

METHODS

The CDHC Working Group was convened in accordance with the goals of the NORA, a partnership program to stimulate innovative research and improve workplace practices. Established in 1996, the NORA is a research framework for the NIOSH and the nation. Diverse public and private sector parties collaborate to identify critical issues in workplace safety and health. Partners work together to develop goals and objectives for addressing these needs.[2]

The NORA's activities are divided among 10 industry sectors. The NORA Healthcare and Social Assistance Sector Council initiated the CDHC Working Group. Consistent with the NORA's goal of involving diverse parties, the CDHC Working Group included >40 participants from 4 countries. Two cochairs (from a U.S. university and the NIOSH) directed the activities of the CDHC Working Group. Regular telephone conference calls were conducted with all Working Group members during October 2012-March 2014. In addition, numerous calls were conducted between the cochairs and between the cochairs and different Working Group members to provide cross-disciplinary learning and to develop specific topics. The document went through multiple revisions recommended by CDHC Working Group members and implemented by the cochairs through October 2014. This article comprises contributions from members of the CDHC Working Group, representing different perspectives; it is not a consensus document.

BACKGROUND FROM INFECTION PREVENTION AND OCCUPATIONAL HEALTH

Definitions and functions of cleaning and disinfection in health care

Although cleaning is important in most economic sectors, it is essential in the health care industry for environmental surface management and infection prevention and control.[3,4] The Centers for Disease Control and Prevention (CDC) and Healthcare Infection Control Practices Advisory Committee recommend that all health care settings, regardless of the level of care provided, make infection prevention a priority and that standard precautions, including environmental cleaning, be used as a means to reduce infection transmission.[4,5]

Antimicrobial products are substances or mixtures of substances used to destroy or suppress the growth of harmful microorganisms, whether bacteria, viruses, or fungi, on inanimate objects and surfaces. These products contain about 275 different active ingredients and are marketed in several formulations: sprays, liquids, concentrated powders, and gases.[6]

It is important to understand the specific definitions of sterilization, disinfection, and cleaning and the classification of devices and surfaces that require these actions. Sterilization is the process to eliminate all forms of microbial life.[7] An example of a sterilant is ethylene oxide gas.[3] Compared with sterilization, disinfection generally provides a lower level of antimicrobial activity that inactivates virtually all vegetative microorganisms (defined as those that are metabolically active) but not necessarily all microbial forms (eg, bacterial spores).[5] High-level disinfection will inactivate all microorganisms with the exception of large numbers of bacterial spores. An example of a high-level disinfectant is 7.5% hydrogen peroxide.[3,7] Intermediate-level disinfection will inactivate vegetative microorganisms and possibly low numbers of bacterial spores. An example of an intermediate disinfectant is 70%-90% isopropyl alcohol.[3] Low-level disinfection inactivates most vegetative bacteria and some fungi and viruses, but it does not inactivate bacterial spores.[7] An example of a low-level disinfectant is a quaternary ammonium germicidal detergent solution.[3] Cleaning refers to the removal of soil and organic contamination from a device or environmental surface using the physical action of scrubbing, the chemical action of a surfactant or detergent, and water to wet, emulsify, or reduce surface tension. Cleaning removes large numbers of microorganisms from surfaces, thereby reducing the levels of organic bioburden on these surfaces. Cleaning precedes disinfecting on surfaces, especially those with visible contamination, and helps to ensure the effectiveness of the subsequent disinfection step.

The surfaces that require cleaning, disinfection, or sterilization are classified according to their potential to transmit an infection at the time of use.[3,8] Critical items confer a high risk for infection if they are contaminated with any microorganism. Therefore, surgical instruments and devices that enter sterile tissue or the vascular system must be sterile because any microbial contamination could result in infection. Semicritical items are those that come in contact with mucous membranes or nonintact skin. This category includes respiratory therapy devices and anesthesia equipment. These medical devices should be free from all vegetative microorganisms prior to use. Thorough cleaning prior to high-level disinfection will reduce the numbers of bacterial spores, and high-level disinfection is sufficiently potent to inactivate any residual spores. Semicritical items minimally require high-level disinfection using liquid chemical sterilants or high-level chemical disinfectants. Noncritical items are those that come in contact with intact skin but not mucous membranes. Intact skin acts as an effective barrier to most microorganisms; therefore, the sterility of items coming in contact with intact skin is not critical.

In the CDC's and Healthcare Infection Control Practices Advisory Committee's Guideline for Environmental Infection Control in Healthcare Facilities,[4] noncritical items are divided into noncritical patient care items and noncritical environmental surfaces. Noncritical environmental surfaces can be porous or nonporous and include bed rails, bedside tables, patient furniture, and floors. Noncritical environmental surfaces can serve as reservoirs of microbial contamination. Surfaces frequently touched by hands (eg, bedside tables, bed rails) pose a notable challenge in this regard. Transfer of microbial contamination from hand contact with environmental surfaces or equipment surfaces to patients, other workers, or other surfaces represents an indirect mode of transmission.[3]

Health care workforce with a focus on occupations that perform environmental surface cleaning and disinfecting

Health care is the fastest-growing sector of the U.S. economy, employing >18 million workers.[9] The term health care worker

refers to all those employed in direct patient care, including but not limited to, physicians, nurses, nursing assistants, therapists, technicians, and emergency medical service personnel, and those not directly involved in patient care but potentially exposed to infectious agents during the performance of their daily activities, including those employed in facility operations, laundries, and food service.[10]

Environmental services workers are the main occupational group performing cleaning and disinfecting activities in health care facilities; their work is overseen by environmental services directors and managers.[11] In addition, cleaning is conducted by a variety of other health care occupations. In a recent study, investigators followed health care workers in 5 hospitals for entire shifts and recorded workers' activities every 5 minutes.[12] This research confirmed previous observations: environmental services workers cleaned environmental surfaces other than medical equipment on 96% of the person days observed. At the same time, many other occupations in health care also conducted cleaning as a routine activity. For example, equipment cleaning was observed on approximately one-fourth of the person days for registered nurses (23%), one third of the person days for licensed practical nurses (33%), and nearly all the person days for dental assistants (91%). Registered nurses and licensed practical nurses were more likely to conduct this activity when working in dialysis units or operating rooms. The spraying of cleaning solutions can facilitate inhalation of chemicals, and this method was used by environmental services workers to clean surfaces such as windows and mirrors on 54% of person days (mean duration, 52 minutes per shift) and by dental assistants to clean equipment and counters on 55% of person days (mean duration, 13 minutes per shift).[12] In addition, nurses and other health care workers who do not perform cleaning directly can experience airborne exposures if they are in the same room with someone else who is cleaning. According to a surveillance report by the NIOSH,[13] >400 health care workers reported acute illnesses or injuries associated with exposure to disinfectants in 2002-2007 in 4 states; environmental services workers were the most common occupation (24%), followed by nursing or medical assistants (16%), technicians (15%), and nurses (11%).

Transmission of infectious agents from environmental surfaces

HAIs are a serious risk to patients.[14] The infectious agents that cause HAIs in patients also pose a risk of infection to health care workers.[15,16] A number of factors contribute to HAIs among patients, including venous or urinary catheter use, ventilator use,[17] antibiotic therapy,[18-20] inadequate hand hygiene by health care workers,[21] and length of hospital stay.[17] Sharps injuries and other blood and body fluid exposures from patients contribute to occupationally acquired infections among health care workers.[22,23] Environmental surface contamination in the health care setting is one factor in the transfer of infectious agents that contributes to HAIs in patients, and these same agents may cause infections in health care workers.[24-27]

Pathogens may be transmitted via the hands of patients or health care workers to environmental surfaces, where they can persist or proliferate if cleaning and disinfection are not performed.[28] Depending on the organism, microbes can persist in the environment for hours (eg, some enveloped viruses), days or weeks (eg, most vegetative bacteria and fungi), or months (eg, bacterial spores and fungal spores).[27,29,30] Common surfaces in the rooms of patients colonized or infected with the bacteria methicillin-resistant *S aureus* or vancomycin-resistant enterococci (VRE) may become contaminated and touched by health care workers.[29] Prior room occupants colonized or infected with VRE, methicillin-resistant *S aureus*, or *Clostridium difficile* also increase the risk of colonization or infection for the next occupant.[31,32]

Infectious agents can also be transferred to patients and health care workers after contact with a contaminated surface, as demonstrated by health care worker hand imprint cultures after contact with environmental surfaces in patient rooms.[33] One study found that environmental surface contamination is a determinant of transmission of MDROs to the protective clothing of health care workers.[26]

Role of environmental surface cleaning and disinfecting in preventing infections

A recent review of intervention studies suggests that improvements in environmental disinfection may prevent the transmission of infectious agents and reduce HAIs; however, the author concluded that there remains a need for carefully conducted studies to determine the impact of disinfection interventions.[25] Another study found that cleaning—not disinfection—can reduce the number of microbes on a surface and reduce the risk of infection.[24] Improved environmental cleaning resulted in decreased contamination and infection, as shown in a study of the spread of VRE in a 21-bed medical intensive care unit with high-level endemicity.[34] In a study of *C difficile* in a Veterans Administration hospital, increased cleaning and disinfection of high-touch surfaces led to decreased contamination on surfaces but uncertain results on disease transmission.[35] Recent publications also emphasize the importance of thorough terminal room cleaning, defined as cleaning and disinfection of the room of an infected patient after discharge. Terminal room cleaning with bleach significantly reduces the rate of nosocomial infections[36,37]; however, extensive observational studies show overall that the thoroughness of manual terminal cleaning is currently lacking.[38,39]

Chemical respiratory hazards in cleaning and disinfecting

Although the demand for more effective cleaning and disinfecting is growing, there is also increasing evidence that exposures to cleaning can cause acute[13,40] and chronic health effects,[41] particularly respiratory illness. Conventional cleaning and disinfecting products are complex mixtures of chemical ingredients, some of which are associated with adverse human health effects, including dermal and respiratory sensitization, dermal and respiratory irritation, work-related asthma, chronic bronchitis, and sensitization. Potentially harmful occupational exposures from cleaning and disinfecting are a function of multiple factors, including (1) the chemical characteristics of the cleaning or disinfecting product, (2) the physical characteristics (aerosols vs liquids), (3) the methods of product application (spraying vs wiping), and (4) the characteristics of the built environment (ventilation, room size).[42]

Health care workers account for approximately 15% of work-related asthma in the United States.[43] The workers may be exposed to a complex mixture of volatile organic compounds, and the use of cleaning and disinfecting products contributes to this exposure.[44] There are a number of chemicals present in cleaning and disinfecting products that can cause or exacerbate asthma because of their irritant or allergenic properties.[45] In cleaning products and disinfecting products (both low-level and intermediate-level products), these include, but are not limited to, chlorine, ammonia, ethanolamine, 2-butoxyethanol, and quaternary ammonium compounds.[42,46-57] Bello et al[47] provide a review of potentially hazardous chemicals in cleaning and disinfecting products used in health care.

Environmental surface cleaning and disinfecting chemicals are also routinely applied in other settings outside the health care industry, particularly by professional cleaners in commercial buildings, schools, food service, and hotels. The tasks and products used in these settings are often similar to those used for environmental surface cleaning in health care. Reviews in the last decade documented an increased risk of asthma, chronic bronchitis, wheeze and other respiratory symptoms, and dermatitis among janitors and other workers with regular exposure to cleaning agents and cleaning activities.[58,59]

Respiratory health effects of cleaning and disinfecting

There are numerous case reports on work-related asthma associated with exposure to cleaning agents and disinfectants.[56,60-63] Surveillance systems in different countries have observed an increased incidence of work-related asthma among both cleaners and health care workers,[64-69] and these notifications were associated with exposure to cleaning chemicals. Several studies have reported that cleaning chemicals associated with respiratory disorders[70] were also associated with skin disorders, in particular hand dermatitis.[49,71-75]

Epidemiologic studies based on general population samples have observed an increased incidence or prevalence of asthma or respiratory symptoms in cleaners[76-83] and also in nurses or other health care professionals.[76,80,84] Regarding the type of cleaning work, studies in Spain found higher asthma risks for home cleaners and hospital cleaners compared with other indoor cleaners,[85] whereas a large Finnish study found consistently increased risks across a wide variety of cleaning workers.[86] In population-based studies using job exposure matrices, exposure to cleaning agents across different occupations was associated with asthma and severe or uncontrolled asthma in several studies with different designs.[78,80,84,87-91] In workforce-based studies, specifically designed questionnaires for the respective sectors have been used and have consistently shown associations between the use of cleaning products and asthma among cleaners[92,93] and health care professionals.[41,94,95] Two workforce-based studies confirmed an increased asthma risk in cleaners compared with other employees of the same companies.[92,93]

The identification of specific cleaning exposures that are driving an increased asthma risk is limited but crucial for the development of preventive strategies. Among workers who perform cleaning, asthma symptoms or exacerbations have been associated with the use of sprays[84,96-99] and bleach,[97,100,101] floor waxing,[92] and a history of acute inhalation events.[93,101] Among health care professionals, asthma was associated with exposure to bleach, ammonia, and sprays.[84,102] There is increasing evidence of a deleterious role of the use of cleaning products in spray form in asthma incidence and prevalence or in severe and uncontrolled asthma both at work and home.[103,104] Important causal mechanisms for these effects probably include development of irritant asthma or allergic-sensitization asthma that can involve non-IgE– or IgE-dependent pathways and exposure routes of entry into the body, including both the respiratory tract and the skin. Appendix 2 gives examples of practices to minimize respiratory hazards during cleaning and disinfection of environmental surfaces.

Search for less toxic cleaning and disinfecting, including green cleaners

The occupational hygiene model for hazard prevention and control recognizes elimination or substitution of hazards with safer alternatives as most effective compared with engineering and administrative controls, and it considers personal protective equipment (PPE) as the last resort. With the introduction of green chemistry initiatives,[105] green cleaners and cleaning and disinfecting products with less hazardous formulations have been produced. Currently, there is no standard definition of green cleaning or disinfecting. Independent organizations have developed their own criteria for green cleaners and certify cleaning products according to them. For example, Green Seal-37 criteria prohibit cleaning and disinfecting products for industrial and institutional use from containing chemicals causing skin corrosion or serious eye damage and ingredients known to be carcinogens, mutagens, reproductive toxins, asthmagens, or skin sensitizers.[106]

Chemical disinfectants, which are classified as antimicrobial pesticides, are registered with the U.S. Environmental Protection Agency (EPA) in accordance with the Federal Insecticide, Fungicide and Rodenticide Act.[107] More than 5,000 antimicrobial products are registered with the EPA and sold in the marketplace. Nearly 60% of antimicrobial products are registered to control infectious microorganisms in hospitals and other health care environments.[6] Health care institutions often require EPA-registered disinfectants as part of their environmental surface cleaning protocols. The EPA registration process for disinfectants may require that a human health risk assessment be conducted for the active ingredients in each product; however, asthma is not a health effect required under EPA test guidelines. The EPA provides employers with guidance on purchasing green cleaners[108] and moving toward the green end of the pesticide spectrum by developing guidance for less hazardous antimicrobial products.[109] The Occupational Safety and Health Administration also provides employers and workers with tools for identifying safer chemicals, often called safer alternatives, using a systematic approach that relies on informed substitution and alternatives assessment.[110] The effort to green clean has mostly focused on replacing conventional liquid cleaning products with presumably safer chemical formulations. However, new, nonchemical-based technologies are emerging which could meet definitions of green, including those using steam, ultraviolet light, microwave, solid surfaces such as bench tops made of materials with antimicrobial properties (eg, copper),[111] microfiber cloths,[112] and electrolyzed or ozonated water.[113] For certain uses, copper is an EPA-registered antimicrobial product.[114] However, wide use of many new, nonchemical technologies has been constrained because the EPA does not register and approve them; therefore, protocols calling for an EPA-registered disinfectant cannot use them. In addition, there are insufficient data regarding the efficacy of some devices.[115] Currently, there are few systematic evaluations of green cleaning and disinfecting products, new technologies, and application methods for effective infection prevention or for occupational health and safety. The City of San Francisco has initiated a resource to review and collect this information when it becomes available.[116]

RESULTS

Gaps in knowledge, research, and practice

Health care infection prevention and occupational health are often practiced separately. The Working Group determined that there is a need to develop a more integrated approach to minimize harmful cleaning and disinfecting exposures for health care workers and patients without reducing the effectiveness of infection prevention efforts. However, current gaps in basic knowledge and practice guidance are barriers to developing an integrated framework. Based on the literature summary previously presented, the professional experience of Working Group members, and Working Group discussions, these gaps were identified and grouped in the 2 following broad areas:

1. There is a need to better understand the effectiveness of cleaning and disinfecting products and procedures to reduce the incidence of infectious diseases and colonization in health care workers and patients.
2. There is a need to better understand the adverse impact of cleaning and disinfecting products and procedures on the health of health care workers and patients, especially the impact on respiratory health.

Within each of these areas, the Working Group identified specific gaps in understanding related to basic knowledge, selection and use of products and practices, hazard communication, and safer alternatives. A summary of these gaps and needs is subsequently reported. It is intended to focus future research efforts and to serve as a guide to infection prevention and occupational health professional groups with the ability to improve practice; it is not intended to provide a detailed assessment of each issue.

Effectiveness of cleaning and disinfecting products and procedures

Basic knowledge

Currently, there is a narrow focus on assessing the efficacy of products used for cleaning and disinfecting, with limited assessment of infection prevention effectiveness in actual health care settings. There is a need for further research to assess the contribution of surface contamination to the risk of infectious diseases among health care workers and patients. In particular, there is a need to:

- Evaluate the extent to which contact with surfaces that are contaminated with infectious agents contribute to HAIs in patients and to occupationally acquired infections in health care workers.
- Evaluate the potential of environmental surfaces to transmit infections to health care workers and patients in health care settings other than hospitals (eg, nursing homes, ambulatory care settings, home health care).

Selection and use

- Product selection
  - There is a need for guidance that specifies which types of chemicals and products to use on different types of equipment and surface materials. Manufacturers' recommendations regarding which product to use on specific equipment often focus on brand names of proprietary products rather than classes of chemicals that can be effective and safe. Both the CDC and EPA encourage the use of EPA-registered products.
  - There is a need for guidance on the effectiveness and safety of newer chemical disinfectants (nano silver, thymol, citric acid, accelerated hydrogen peroxide) and alternative disinfecting technologies.
- Potential for antimicrobial neutralization
  - There is a need for research on the impact of biofilms (a group of microorganisms which adhere to each other on a surface) or surface soil to interfere with the efficacy of disinfectants applied to environmental surfaces. New research on this topic also needs to be translated for improved practice guidance.
- Cleaning vs disinfecting and the effectiveness of 1-step products
  - Currently, disinfecting without precleaning is considered an off-label use for EPA-registered products. Research is needed to determine the conditions under which a 1-step process using a combined detergent-disinfectant product can be as effective for reducing contamination on surfaces as a 2-step process in which cleaning is followed by disinfection. This research should evaluate the impact of the presence of organic matter on the extent to which disinfecting can be effective. A 1-step process could simplify the number of products that environmental services workers are required to use and may prevent confusion and inappropriate use that is more likely when multiple products are required.
- Contact time
  - Contact time is usually considered critical to disinfection, but it can be difficult to fulfill in the time-pressured health care environment. Further evaluation and hazard communication is needed regarding the extent to which thorough disinfecting practices that do not follow contact time recommendations can be effective for infection prevention.

Adverse impact of cleaning and disinfecting products and practices

There is an increasing trend in use of products to prevent HAIs. As infection prevention needs for these products increase, there is a concurrent need to integrate worker and patient health and safety into their development and application. Health and safety concerns should address both the protection of respiratory health and reduction of infection.

Basic knowledge

Research is needed to better assess the hazards of environmental surface cleaning and disinfecting and the effectiveness of potential safer alternatives. Specifically, research is needed on the following:

- Toxicologic risk assessment
  - Cleaning and disinfecting product risk assessment methods are needed to evaluate the potential for respiratory and dermatologic illness.
- Hazard assessment of products, application methods, and work practices
  - As part of the effort to assess infection prevention effectiveness in actual health care settings, there is also the need for occupational health assessments of cleaning and disinfecting work practices in those worksites. Any evaluation of cleaning and disinfecting should include assessment of application methods and work practices and scrutiny of the products being used.
- Exposure assessment
  - Chemical cleaning and disinfecting products are typically complex mixtures of ingredients having a variety of physical and chemical properties that require multiple monitoring measurement methods. Multiple measurement methods are resource and time intensive, therefore making it infeasible for occupational and environmental health practitioners to routinely quantify potential exposures. There is a need to research and develop practical exposure measurement methods that can be used in health care settings to monitor cleaning and disinfecting exposures related to respiratory and dermal health effects.
- Hazard assessment of residual cleaning and disinfecting products on environmental surfaces
  - Methods are needed to assess the extent to which cleaning and disinfecting product ingredients can deposit and remain on environmental surfaces and whether they pose a health risk to those who contact the surfaces.

- Illness surveillance systems
  - The cases of work-related asthma identified in sentinel and population-based surveillance conducted by health departments are frequently not recognized in health care worksite illness and injury recording systems. Research is needed to document the extent of under-reporting, determine the barriers to reporting, and to develop strategies to improve identification and reporting of work-related illness at the worksite.

Selection and use

Improved guidance is needed to assist health care institutions in selecting from a range of effective and safe products and practices, including the following:

- Selectively clean and disinfect as needed
  - Hospital areas are often classified by the level of infection risk with the cleaning and disinfecting methods differentiated accordingly (eg, thorough cleaning only, 1-step cleaning and disinfecting, 2-step cleaning and disinfecting, level of disinfectants needed). There is a need to identify best cleaning and disinfecting practices for each area in a health care facility, in particular, whether nonclinical public spaces are suitable for cleaning only (ie, do not need disinfecting). If disinfection is not necessary in all areas, guidelines specifying cleaning only could reduce the exposure of workers and patients to disinfectants.
- Floor cleaning and disinfection
  - There is a need for research on floor surface materials that clean well, do not provide a reservoir for microbes, and do not promote slips, trips, and falls. Additionally, there is a need for improved guidance related to the cleaning and disinfection of floors in hospitals and other health care settings. In particular, evidence is needed regarding whether floors should be disinfected at all and, if so, in which areas of the health care setting (eg, patients' rooms, waiting areas). Reducing chemical and particle exposures from floor cleaning could significantly improve indoor environmental exposures for workers, patients, and other building occupants because floors are cleaned frequently and have a high surface area, therefore requiring application of substantial amounts of cleaning and disinfecting products throughout health care facilities.
- Floor polishing
  - There is a need for improved guidance related to the effectiveness of and need for high-gloss floor polishing as a final step in cleaning. Reducing chemical and particle exposures from floor polishing also could have an important impact on reducing airborne chemical and particle exposure because of the high surface area of floors.
- Frequency of cleaning
  - Further evaluation is needed to determine the frequency with which cleaning and disinfecting should be performed with the objective to reduce chemical exposure while not reducing effectiveness of infection prevention.
- Continuous improvement and evaluation
  - Practice guidance is needed regarding how to implement a model of health care improvement using the plan-do-study-act approach to assess the level of cleaning and disinfecting needed for different health care facility areas, environmental surfaces, and noncritical devices; practice guidance is also needed to review different cleaning methods and products, evaluate their efficacy, and evaluate the health and safety outcomes.[117]
- Selection of PPE
  - PPE (eg, gloves, goggles, face shields, aprons) should be selected based on the type of cleaning products, technologies, and methods used. Selecting PPE for cleaning and disinfecting is challenging because the products are complex mixtures. There is a need for comprehensive guidance for PPE for environmental services workers and other workers who are exposed to cleaning and disinfecting.[118]

Hazard communication

- Training
  - Practice guidance is needed to effectively engage all levels of staff in a health care organization (eg, workers, supervisors, administration) in the selection and safe use of cleaning and disinfecting products, including regular training and evaluation of the training. Additionally, a variety of stakeholders from all types of health care organizations should be engaged to design, implement, and evaluate training for the selection and use of cleaning and disinfecting products. These stakeholders should include infection prevention, employee health, and occupational safety personnel, purchasing managers, group purchasing organizations, and environmental services workers and managers.
- Labeling and safety data sheets
  - To support the safe use of cleaning and disinfecting products, safety data sheets and labeling of these products must be accurate. Future risk assessments of chemical ingredients and mixtures should incorporate asthma, other respiratory effects, and dermatologic conditions as health endpoints so that safety data sheets are relevant to these health concerns.
- Information for clinical practice
  - A listserv or other communication forum is needed for clinicians to share information and resources to support an integrated approach to infection and occupational illness prevention.
- Communication to stakeholders
  - Many clinicians, administrators, allied health professionals, environmental service workers, purchasing managers, group purchasing organizations, and other stakeholders do not routinely read epidemiologic literature regarding the potential health effects of cleaning and disinfecting environmental surfaces. New communication strategies are needed to reach these audiences with this information, including worker education curricula and training materials, pamphlets, posters, slide presentations, articles in trade journals, use of social media, and regularly updated Web sites.

Safer alternatives

Green cleaning and newer technologies for cleaning and disinfecting have the potential to reduce toxic exposures and may be effective for infection prevention; however, there is the need for the following:

- Standardized criteria to define green cleaning
  - Some third-party certifiers of green products now include human health criteria and environmental criteria. These criteria need to be standardized across all certifiers and other groups defining green products. Future definitions of green cleaning products should encompass minimizing any impact on the health and safety of workers and others who may be exposed and protecting the environment. The development of health-based criteria should be done using a

collaborative approach that engages a variety of stakeholders.

- Green cleaning health effects evaluation
  - Although some green cleaning products may present fewer health hazards and be more environmentally preferable (eg, less biopersistent), there are very few quantitative assessments of green cleaning products and technologies. Specifically, there are limited data evaluating respiratory, dermal, or other hazards associated with specific green cleaning products, and potentially harmful cleaning exposures are not only a function of the product characteristics, but also a function of the way that the products are applied (eg, spraying vs wiping) and the work practices and conditions with which they are used. This latter point is seldom addressed in current discussions of green cleaning.
- Green cleaning infection prevention evaluation
  - Research is needed on the effectiveness of green cleaning on infection prevention in all types of health care settings.
- Nonchemical technologies evaluation for cleaning and disinfection
  - There is a need for guidance regarding the feasibility and effectiveness for infection prevention and safety of nonchemical alternatives for cleaning and disinfecting (eg, steam cleaning, ultraviolet light, antimicrobial surfaces for bench tops and other surfaces).
- Prevention through design implementation
  - When planning renovations or new construction, prevention through design should be implemented, a proactive approach to design out, or minimize hazards, in the design phase. Therefore, infection prevention and other health and safety protections could be incorporated into the new design of architecture, building construction, and new materials.[119]

CONCLUSIONS

There is a need for a more integrated approach to infection and occupational illness prevention. Professional organizations in infection prevention and occupational health are well-positioned to take leadership in this effort by establishing joint committees and engaging with funders to set priorities and a time table to move the research and improved practice guidance forward.

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APPENDIX

Appendix 1. Supplemental case reports of work-related asthma from environmental surface cleaning and disinfecting in health care

The following case reports provide additional examples of the health care settings and types of health care employees that have developed work-related asthma from environmental surface cleaning and disinfecting exposures.

1. A hospital environmental services worker in Michigan: A man in his 20s, lifetime nonsmoker, worked in a hospital environmental services department for 2 years with no health problems. He developed asthma after the introduction of a new cleaning product that immediately caused him to wheeze and become short of breath. The cleaning product contained the quaternary ammonium compounds didecyl dimethyl ammonium chloride and alkyl dimethyl benzyl ammonium chloride. He was treated at his hospital's emergency department after his initial exposure, and he subsequently had 1 hospitalization and 3 additional emergency department visits until use of the cleaning product was discontinued after manufacture of the product ceased. He requires medication on an ongoing basis to manage his asthma symptoms. His case was identified in the Michigan Work-Related Asthma Surveillance Program.[120]
2. A medical records clerk in a medical clinic in California: A 57-year-old woman, nonasthmatic, lifetime nonsmoker, worked as a receptionist and records clerk in a medical clinic. Her desktop, phones, and computer keyboard were wiped by a coworker with disinfectant wipes containing the quaternary ammonium compounds, alkyl dimethyl benzyl ammonium chloride and dimethyl ethyl benzyl ammonium chloride. Immediately on contact with the phone, the receptionist developed burning and vision loss in her left eye and then experienced difficulty breathing. Initially uncertain what caused the reaction, the clinic medical staff administered oxygen, advised her to wash her hands, and sent her to the Workers' Compensation physician. She was diagnosed with work-related asthma. Over a 6-month period, when the wipes were used on office surfaces, the receptionist's respiratory symptoms worsened. Use of wipes was discontinued in the offices and when the wipes were used elsewhere in the clinic, the receptionist was instructed to leave the building. Two years later, after changing buildings, she was sent to the emergency department when instruments were cleaned in a room next to her office and again after cleaning and disinfecting surfaces in the clinic waiting room with the same quaternary ammonium compounds. Based on medical advice, the receptionist stopped work 3 years after her initial incident. She continues to have difficulty breathing and requires multiple medications to manage her illness. Her respiratory sensitization has become more generalized and she now needs to restrict her contact with other chemicals, including some personal care products (J. Weinberg, Industrial Hygiene Research Scientist, California Department of Public Health, personal communication, 2014).

Appendix 2. Examples of practices to minimize respiratory hazards during cleaning and disinfection of environmental surfaces.

Occupational exposure limits exist only for a limited number of cleaning and disinfecting product ingredients, such as chlorine, ammonia, and 2-butoxyethanol. Nonetheless, cleaning and disinfecting with chemical products should follow basic occupational hygiene procedures for safe chemical handling, including the following:

- Follow the manufacturers' instructions for the selection and use of cleaning and disinfection products. Avoid using products that provide a higher level of disinfection than needed for a particular application.
- Use cleaning and disinfection products that are less harmful to human health and the environment, when possible.
- Use automated diluting systems that reduce direct personal contact (respiratory and dermal) with concentrated products and meter correct dispensing proportions, when possible.
- Use the manufacturers' recommended amount of product and contact times to accomplish the level of cleaning and disinfection needed. Exceeding the recommended amount of product does not lead to increased effectiveness for removing microorganisms and may pose health risks to health care workers, patients, and other building occupants.
- Choose chemical application methods that minimize aerosol production. Spraying usually generates higher airborne exposures than wiping and can lead to skin and respiratory health risks. The toxicologic category of the substance should be considered; therefore, spraying of more toxic substances is especially discouraged.
- Use ventilation when cleaning and disinfecting products are applied in small rooms, such as a single-patient bathroom, examination room, or utility closet where products may be mixed.
- Conduct an occupational hazard assessment of cleaning and disinfecting tasks. When chemicals are used in the workplace, employers should conduct a hazard assessment to evaluate the cleaning needs of the facility, the safest cleaning chemical options, and alternative, safer cleaning methods.[110,118] As in all work environments, appropriate PPE must be provided to workers.[121] PPE may include gloves, eye protections, face shields, protective clothing, or respirators. Guidelines for PPE usage and the proper time table to replace them depend on the physical and chemical properties of the cleaning and disinfecting products, routes of exposure, intensity of exposure, duration of exposure, and frequency of PPE use.[121]
- Educate and train users effectively. Cleaning and disinfecting chemicals can have a spectrum of health impacts, and education and training needs to be done so that employers and workers can be actively engaged to develop and apply a critical-thinking process to select the appropriate cleaning and disinfecting chemicals, practices, and technologies that both prevent infection and chemical exposures. The OSHA requires worker training under the OSHA Hazard Communication Standard.[122] Workers without this training should not use these products.
- Ensure that the OSHA hazard communication training has been completed in the language of the employees using the products, automated dilution systems are demonstrated, and different products for different uses are well-labeled.