

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

This paper is part of a series in which the Collaborative will provide research and analysis of the health and environmental impacts of select groups of this new generation of materials and facilitate sharing of experiences on installation, maintenance and performance.

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The Sustainable Hospitals Program

The Sustainable Hospitals Program (SHP) was initiated at the University of Massachusetts Lowell in 1998 to provide science-based technical guidance to the healthcare industry for selecting products and practices that promote occupational and environmental health and safety. Based within the Lowell Center for Sustainable Production (LCSP), the SHP aims to fully integrate occupational and environmental health and safety into comprehensive solutions for more sustainable healthcare.

The SHP and LCSP have a research program to promote safer and more environmentally sound cleaning materials and practices. This work has the following components:

- 1. Conducting exposure assessments.** Identifying what workers, patients and other building occupants are exposed to is the first step in improving cleaning. The SHP has an occupational/environmental hygiene laboratory and field equipment and has developed the technical expertise to measure exposures from cleaning.
- 2. Characterizing the health effects of cleaning products.** Epidemiologists on our team have experience conducting field studies as well as in-

ducting systematic reviews of the health literature. The LCSP collaborated with Health Care Without Harm to write “Risks to Asthma Posed by Indoor Health Care Environments: A Guide to Identifying and Reducing Problematic Exposures”.¹

- 3. Assessing the effectiveness of new cleaning products.** The Surface Solutions Laboratory (SSL) of the LCSP-UMass Lowell sister organization, The Toxic Use Reduction Institute (TURI), conducts efficacy testing on cleaning products and promotes the use of green cleaners.²⁻⁴ TURI offers an interactive, free-of-charge online database on surface cleaning⁵—called CleanerSolutions—to help manufacturers find safer cleaning alternatives that perform as well as the products based on hazardous chemicals. It also provides online information including “Ten Ways to Find Safer and Greener Cleaners”.⁶ The TURI SSL is certified by Green Seal—the US eco-labeling organization—to test the efficacy of green products.
- 4. Conducting field studies to assist healthcare facilities in implementing alternative cleaning products and practices.** Over the past decade, the SHP has used participatory processes for implementing healthier and more sustainable workplace programs through the Pollution Prevention-Occupational Safety and Health alternatives assessment strategy (P²OSH).⁷
- 5. Translating sound environmental practices into social policy and regulations.** We work with healthcare providers and insurers to improve the provision of environmental remediation for asthma triggers in the home.⁸⁻¹⁰ Another example of the translation of research to practice is a project with a Brazilian women’s organization to educate Brazilian domestic cleaners about the hazards of household cleaners and help them to replace these with less toxic cleaners made from safer ingredients.¹¹

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EXECUTIVE SUMMARY

Cleaning of healthcare facilities is performed for medical and cultural reasons. Maintaining an environment with a low pathogenic burden is essential for avoiding complications during the care and recuperation of patients. A healthy, safe, and aesthetically pleasing space with clean surfaces is comforting to patients and their families by giving an impression of good quality care without additional health hazards.

While cleaning is important in all economic sectors, it serves the healthcare industry the dual functions of: (i) surface cleanliness, and (ii) infection prevention and control. As such, healthcare settings require intensive and frequent cleaning with a wide range of products. This document summarizes the main health and environmental impacts related to conventional surface cleaning, describes a systems approach for designing and implementing healthier and environmentally friendlier cleaning strategies for the healthcare sector, and indicates areas where future research and policy initiatives are needed.

Cleaning for infection prevention and control

Improvements in the health and environmental impacts of cleaning must be considered along with concerns for infection prevention and control. Healthcare settings are engaged in a battle against healthcare-associated infections (HAIs).¹² The importance of infection prevention and control is increasing due to rapidly developing strains of multi-drug resistant organisms (MDROs) that can result in serious illness and even death in workers and patients. In 2002, US hospitals reported about 1.7 million HAIs, associated with almost 99,000 deaths.¹³ The proportion of *S. aureus* bloodstream infections due to MRSA increased significantly from 27% in the period of 1990-1994 to 54% during 2000-2004 ($P > .001$).¹³ Studies have estimated that antimicrobial drug-resistant infections



have increased direct costs to society by 30%-100%.¹⁴ The excess cost of a single MRSA infection compared with a methicillin-sensitive *S. aureus* infection was estimated to range from \$3,000 to \$25,000.¹⁴ This suggests that MRSA costs the healthcare system (patients and healthcare facilities) an estimated additional \$830 million to \$9.7 billion in 2005—excluding the indirect costs related to psychological suffering of patients and their family members as well as lost work time spent in the hospital.¹⁴

Potential health and environmental impacts of cleaning chemicals

Many hospitals have increased the use of cleaning and disinfecting products to address HAIs as well as other infection prevention and control concerns. However, conventional cleaning products and disinfectants bring a host of other health hazards despite their capacity to fight against MDROs. This document provides a literature review of cleaning products and their adverse effects on human health and the environment. Conventional cleaning products are complex mixtures of chemical ingredients. Many of these ingredients are known or suspected to be associated with asthma and

other respiratory disorders. Some others are associated with dermatitis, endocrine and neurologic effects, and cancer. However, many ingredients have not been tested and so their effects are still unknown. Potentially harmful exposures from cleaning are a function of multiple factors, including: (i) the chemical characteristics of the cleaning product, (ii) the physical characteristics (aerosols vs. liquids for example), (iii) the characteristics of cleaning tasks (spraying vs. mopping), and (iv) the characteristics of the built environment (ventilation, room size).¹⁵ There is evidence that some cleaning product ingredients harm the environment. They may bioaccumulate in plants and animals, damage aquatic ecosystems, and pollute indoor air, outdoor air, and drinking water supplies.¹⁶

Greener cleaning

Concerns about adverse human and environmental health effects of conventional cleaning products have led to the development of “green” cleaners. Some green cleaners may reduce human health and environmental effects as well as reduce costs. However, little is known about whether green cleaning programs meet or compromise infection control and prevention goals. Interestingly, there is no widely accepted definition of “green” or “green cleaning”. US Executive Order 13101 defines “environmentally preferable” as “*products or services that have a lesser or reduced effect on human health and the environment when compared with competing products or services that serve the same purpose*”.¹⁷ However, the American Society for Healthcare Environmental Services (ASHES) recommends that the “green cleaning” definition be expanded to address the efficacy of infection control and prevention “*towards effective products with the fewest adverse effects on human health and the environment*.”¹⁸

There are several widely recognized standards for green cleaners, including: Green Seal, the Canadian Environmental Choice program, the US EPA’s design for the Environment Formulation Program, Cradle-to-Cradle, the Nordic Swan, European Union’s EcoLabel, and Blue Angel in Germany.¹⁹ The healthcare sector as a whole is working to develop and implement sustainable and green initiatives, including green cleaning programs. One of the most visible and influential initiatives is the impending 2009 launch of the new Leadership in Energy and Environmental Design (LEED) certification program tailored for the healthcare indus-

try.²⁰ One of the issues it addresses is increased sensitivity to chemicals and pollutants, which will increase interest in implementing green cleaning programs in healthcare facilities.

Systems approach for greening the cleaning

Frequently, green cleaners have been designed as “drop-in” substitutes for conventional cleaning products—a product with a new formulation of chemical ingredients that can simply replace the conventional product. This method typically fails to take into account the “three safeties” described by the Global Health and Safety Initiative—patient, worker, and environmental safety—and may adequately address only one aspect. Greening the cleaning process is not just about transitioning to more benign chemicals but also about broadly examining the purpose that cleaning serves and systematically considering alternative, and sometimes very different, strategies for minimizing unintended consequences while achieving the desired outcome. Therefore, the system approach to cleaning is crucial. It considers a range of options spanning the entire cleaning service as well as the procurement, use, and disposal of cleaning products, materials, and equipment. Furthermore, it takes into account different levels of the built environment (e.g., building materials), new technologies (e.g., UV light for disinfection), new cleaning chemicals (e.g., greener products), and the social-economic influences on cleaning in healthcare (e.g. Centers of Medicare/Medicaid reimbursement policies). The implementation of a change in the cleaning system should involve all parties affected and manages the change program comprehensively in a step-by-step fashion.

Moving toward non-chemical alternatives

Successful green cleaning programs move upstream in the cleaning process towards non-chemical or less toxic alternatives by identifying new technologies, building materials, work practices (e.g., how cleaning products are used and disposed, how cleaning tasks are performed, or the physical conditions in which cleaning is performed) as a means of strengthening infection prevention and control goals. For example, microfiber mops and cloths have been shown as effective and safe alternatives to traditional rag mops, decreasing the use

of harsh chemical cleaners, and potentially reducing back pain and injury from water buckets and mops.^{7, 21-24} An entire building and its operational design needs to be considered for environmentally friendlier cleaning strategies. This may range from choosing surface materials that are easy to maintain and clean with the greenest product available to minimizing patient and worker exposure to cleaning and disinfecting products.

Recommendations and closing the knowledge gap

The authors recommend the following future action areas:

- Develop a **systematic definition of green cleaning** to address the importance of:
 - (i) human health and environmental protection, as well as
 - (ii) infection control and prevention efficacy.
- Develop a **universal standard** to test cleaning and disinfection efficacy in different laboratories and workplaces.
- Examine **cleaning in healthcare from a systems perspective** to effectively address “three safeties”—patient, worker, and environmental safety.

While green cleaning products offer promise for human health and the environment, the literature review for this paper found few comprehensive scientific studies examining important aspects of green cleaning. Although infection prevention and control are fundamental reasons for cleaning in hospitals, there were few studies examining the efficacy of green cleaning products for this purpose. No scientific studies were found on the health impacts of green cleaners. While it has been shown that respiratory and dermal exposures result from a combination of factors (i.e., products used, ambient conditions, physical space, and the way tasks

are performed), there is limited information about how cleaning tasks generate respiratory and dermal exposures. The following research projects and educational initiatives could address these knowledge gaps:

- **Collaborative studies with infection preventionists, microbiologists, and health scientists** to evaluate how effectively green cleaners meet infection control and prevention goals.
- **Qualitative studies** to provide in-depth information on the nature, effectiveness, and impacts of environmentally friendly cleaning programs in selected hospitals.
- **Human health studies** on green cleaning products focusing on asthma and other health effects.
- A study to **assess worker exposures with green cleaners** in typical work scenarios.
- A freely accessible, **clearinghouse on green cleaning**—i.e., an online central repository of information about green cleaning for identifying and sharing best practices.
- Factsheets for frontline workers to provide reader-friendly **how-to-guidance** on various green cleaning products and practices.
- **Case studies** to serve as practical overviews of implementing new cleaning products and practices.

I. INTRODUCTION

Cleaning is a common activity performed to maintain a healthy, safe, and aesthetically pleasing environment. Various cleaning products have become ubiquitous parts of our everyday lives. There is increasing evidence that cleaning is related to asthma and other respiratory illnesses among those who perform cleaning tasks or spend time in recently cleaned indoor environments. While cleaning is common in nearly all industry sectors and in homes, it is particularly important in healthcare which requires intensive and frequent cleaning and uses a wide range of cleaning and disinfecting products.

Cleaning in healthcare serves the dual functions of providing surface cleanliness and infection prevention and control. Both the importance and complexity of infection prevention and control are increasing due to rapidly developing strains of multidrug-resistant organisms that can result in serious worker and patient illness and even death. The recent decision²⁵ of the Center for Medicare and Medicaid Services (CMS) that it will no longer provide additional reimbursement to hospitals for specific hospital-acquired infections may add a strong economic incentive for infection prevention and control measures, including the use of more cleaners and disinfectants. More importantly

the media attention to certain antibiotic-resistant organisms such as *Methicillin-resistant Staphylococcus aureus* (MRSA) or infectious agents that form spores (e.g., *Clostridium difficile*) has intensified interest in cleaning and disinfection in healthcare facilities.²⁶



Cleaning products are complex mixtures of chemical ingredients. Toxicologic analyses of cleaning products show that many contain chemicals that are known or suspected triggers of asthma and other respiratory problems. Some of these ingredients are also associated with dermatitis, endocrine and neurologic effects, and cancer. However, many ingredients have not been tested and so their effects are still unknown.

Several population-based studies confirm that health-care workers who are exposed to cleaning products have high rates of asthma and other respiratory symptoms, including illness severe enough to result in lost time from work. However, very few of these studies provide information about which specific ingredients are related to the health effects and which cleaning tasks are most hazardous.

In addition to human health effects, there is evidence that some cleaning product ingredients harm the environment, damaging aquatic ecosystems and causing air and water pollution. Concern for the environmental effects of cleaning products led to the development of new products, called “green cleaners”. However, these new products neither have consistent criteria for their environmental benefits, nor do they always consider the human health effects. As a result some green cleaners can still cause health problems.

Changes to reduce the harmful effects of cleaning must ensure effective infection prevention and control as well as being more healthy, safe, and environmentally sound. To develop new approaches that account for health, environment as well as infection prevention and control, it would be useful to have a broad overview of the functions of cleaning and the work environment systems in which it is performed. With this information, a full range of options for effective change can be identified and evaluated.

III. PURPOSE AND DEVELOPMENT OF THIS DOCUMENT

The purpose of this document is to summarize the main health and environmental impacts related to conventional surface cleaning and define a systems approach for designing and implementing healthier, more environmentally sound cleaning strategies in the healthcare sector. It is structured in three major sections: (i) Scientific and professional evidence on health and environmental hazards related to surface cleaning, including disinfection*²⁷; (ii) Green cleaning in healthcare and a systems approach to implement it; and (iii) Conclusions and recommendations to identify knowledge gaps and recommendations for future action.

This document is primarily written for hospital decision makers including operations and facilities managers, infection preventionists, and occupational and environmental hygienists who can use the information to improve current cleaning practices or take steps to advance healthier, more environmentally sound cleaning in their facilities. The document will also serve as a useful tool for other stakeholders, including public health practitioners, clinicians, healthcare environmental health and safety advocates, researchers, insurers, manufacturers, and cleaning service providers.

The SHP reviewed current studies, literature, policies, advocacy materials, and Internet-based tools. The literature cited in this document includes international and US-based health studies related to cleaning products, professional journals on infection prevention and control as well as reports and magazine articles on green cleaning, studies and reports developed at the University of Massachusetts Lowell (UMASS Lowell), and green cleaning advocacy materials. As examples of a systems approach in implementing green cleaning practices within a specific group or department of a healthcare facility, we present both the SHP's Pollution Prevention-Occupational Safety Health (P²OSH)

strategy as well as Practice Greenhealth's** "Ten Step Guide to Green Cleaning Implementation."²⁷ This document also draws examples from valuable tools and guidelines developed for sustainable healthcare including INFORM, INC's Cleaning for Health report,²⁸ Green Guide for Health Care,²⁹ Sustainable Healthcare Architecture,³⁰ Minnesota Technical Assistance Program's Intern Project (MnTap),³¹ US EPA sources,^{21, 32, 33} and Practice Greenhealth website on green cleaning.³⁴ The selected resources are used as examples and there is no implication that these are the only resources or the most appropriate for a particular application.

* This document does not address sterilization of medical instruments/ equipment.

** Practice Greenhealth is a membership and networking organization for the healthcare community institutions (e.g., hospitals, healthcare systems, businesses, and other) committed to sustainable and eco-friendly practices.

III. BACKGROUND

Definitions for cleaning and disinfection

Cleaning products are designed to remove surface contaminants like soil particles and grease. Disinfecting products are meant to destroy microorganisms. Both cleaning and disinfecting products are often a mixture of many chemical ingredients. The Centers for Disease Control and Prevention (CDC) uses these definitions for cleaning, disinfection, and sterilization in healthcare^{35,36}:

- **Cleaning** is the removal of visible soil (e.g., organic and inorganic material) from objects and surfaces and normally is accomplished manually or mechanically using water with detergents or enzymatic products.³⁵ *or*
- **Cleaning** is a form of decontamination that renders the environmental surface safe to handle or use by removing organic matter, salts, and visible soils, all of which interfere with microbial inactivation.³⁶
- **Disinfection** describes a process that eliminates many or all pathogenic microorganisms, except bacterial spores, on inanimate objects.³⁵

In addition, the CDC defines **sterilization** as a process that destroys or eliminates all forms of microbial life, including bacterial spores.³⁵

Antimicrobial products are registered as pesticides under the US Environmental Protection Agency (EPA) which uses this definition for antimicrobial pesticides³⁷:

- **Antimicrobial pesticides** 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. Antimicrobial pesticides have two major uses: (1) disinfect, sanitize, reduce, or mitigate growth or development of microbiological organisms; (2) protect inanimate objects (e.g., floors and walls), industrial processes or systems, surfaces, water, or other chemical substances from contamination, fouling, or deterioration caused by bacteria, viruses, fungi, protozoa, algae, or slime.³⁷



Cleaning and potential harms to health and the environment

While cleaning and disinfecting have essential benefits for combating infections, there is evidence of an association of conventional cleaning products with adverse health effects among cleaning staff and building occupants. Epidemiologic studies (see Section IV), carried out mostly in Europe, show that cleaning products are associated with respiratory irritation and asthma. In addition to potential harms to health, environmental risks are evident: many cleaning chemicals released into the environment biodegrade slowly or incompletely, posing a risk of water supply contamination and/or impact on wildlife. Nearly all used cleaning products and wastewater are disposed into municipal sewers. So far, efforts to replace toxic cleaning products with green cleaners have mostly focused on environmental impacts and not accounted

for worker and patient health impacts, nor have they adequately addressed infection prevention and control functions. This has led to green cleaners that are less bio-persistent in the environment, but may still contain asthmagens or other unhealthy ingredients to the respiratory system.

There are significant driving forces in the US for implementation of green cleaning. For example, Colorado, Connecticut, New Jersey, New York, and Wisconsin have issued Executive Orders for greener cleaning practices.³⁸ Even more important may be the widespread acceptance of Leadership in Energy and Environmental Design (LEED), the US Green Building Council's (USGBC) third-party certification program and benchmark for the design, construction and operation of high performance green buildings. LEED promotes a whole-building approach to sustainability by recognizing performance in five key areas of human and environmental health: sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality. Cleaning strategies are one element of LEED green performance.³⁹ In addition to voluntary adoption of the LEED certification program, the LEED criteria have been mandated by many federal, state and municipal governments (e.g., through legislation, executive orders, resolutions, ordinances, incentives, and the like) for buildings receiving their funding. As of January 1, 2009, this was evident in at least 44 US states, including 172 localities (112 cities, 32 counties, and 28 towns), 31 state governments, 12 federal agencies or departments, 15 public school jurisdictions and 39 institutions of higher education.⁴⁰

Significance of cleaning in the healthcare sector

Cleaning holds special importance for hospitals and other healthcare facilities. The healthcare industry represents a significant population for health studies on cleaners because of the intensive and frequent cleaning with a wide range of cleaning and disinfecting products.

While the aesthetic benefits of cleaning are necessary for attracting and retaining patients, cleaning and disinfection play an essential role in healthcare settings by

preventing healthcare-associated infections (HAIs)*. In 2002, United States hospitals reported about 1.7 million HAIs which caused almost 99,000 deaths.¹³ The fight against multidrug-resistant organisms (MDROs) is essential in HAI prevention efforts.¹³ Specifically, the proportion of *S. aureus* bloodstream infections due to MRSA increased significantly overall, from 27% in the period 1990–1994 to 54% in the period 2000–2004 ($P > .001$).¹³ Studies have estimated that antimicrobial drug-resistant infections increase death, illness, and direct costs by 30%–100%.¹⁴ Estimates of the excess cost of an infection with MRSA compared with an infection with methicillin-sensitive *S. aureus* range from ≈\$3,000 to \$35,000.¹⁴ This suggests that MRSA cost the healthcare system (patients and hospitals) an extra \$830 million–\$9.7 billion in 2005, even without taking into account indirect costs related to patient pain, illness, and time spent in the hospital.¹⁴

Cleaning has been highlighted as a serious responsibility and a critical factor in the battle against HAIs.¹² HAI prevention has led to an international debate on the extent to which surface disinfection is necessary for patient care.^{41–50} Besides educational interventions, researchers have recommended evaluating the thoroughness of cleaning and disinfection.^{26,51–54} Carling and colleagues developed a pioneering method for measuring removal of microbes: an environmentally stable, non-toxic targeting solution with a chemical marker that fluoresces brightly in ultraviolet or “black” light.^{51,54} In 2008, Carling et al published the results of a study which showed the effectiveness of cleaning and disinfection in randomly selected patient rooms and bathroom areas of 23 acute care hospitals.^{26,54} They found that cleaning thoroughness varied widely. For example, toilet handholds, bedpan cleaners, light switches, doorknobs, patient phones, nurse call devices, and bedside rails were poorly cleaned.^{26,54} Providing these findings to healthcare workers led to measurable cleaning improvements.

As the use of cleaning and disinfecting agents is increasing due to infection prevention and control efforts, there is movement towards green cleaners or products that have fewer potential harms to health. A LEED certification program tailored for the healthcare industry, LEED for Healthcare (Green Guide for

* Also referred in the literature as “hospital-acquired infections” or “nosocomial infections”.



Health Care), is expected to be launched in 2009.^{20,29,30} One of the issues it addresses is sensitivity to chemicals and pollutants, which will increase interest in implementing green cleaning programs in healthcare facilities.²⁹ Other studies and groups are also driving forces for change; Lehman and INFORM, Inc. called for redefining “clean” and noted that one of the fundamental environmental protection guidelines is to clean for health first and appearance second—sparkling “whiter than white” appearance is not necessarily the healthiest and the smell of truly healthy cleaning is no smell at all.^{28,55} Hence, it is not surprising that healthcare is one of the top five fastest-growing segments in the environmentally friendly cleaning industry.¹⁸

There are many challenges associated with improving cleaning practices in hospitals. Healthcare staff and administrators often react skeptically to change, fearing that new cleaning products and practices might detract from rigorous infection prevention and control practices and thus lead to increased cases of HAIs. Another challenge is that many “improved” products, including green cleaners, are usually designed as “drop-in” substitutes for conventional cleaning products—a product with a new formulation of chemical ingredients that can simply replace the conventional product. This method typically fails to take into account the “three safeties” described by the Global Health and Safety Initiative—patient, worker, and environmental safety—and may adequately address only one aspect.⁵⁶

Improving cleaning is not just about transitioning to more benign chemicals but also about broadly examining the purpose that cleaning serves and systematically considering alternative, and sometimes very different, strategies for minimizing unintended consequences while achieving the desired outcome.

The cleaning system

In addition to the chemical characteristics of the product, the work of Bello et al¹⁵ shows that potentially harmful exposures from cleaning are also a function of (i) the physical characteristics of the cleaning product (aerosols vs liquids for example), (ii) characteristics of cleaning tasks (spraying vs. mopping), and (iii) characteristics of the built environment (ventilation, room size). Other studies demonstrate that building design itself can enhance or hinder effective cleaning.³⁰ All of these together form the system of cleaning along with the network of people who perform cleaning, purchase cleaning products and materials, and dispose of them. The system approach considers a range of options spanning all aspects of cleaning operations as well as the procurement, use, and disposal of cleaning products, materials, and equipment. It also considers different levels of the built environment (e.g., building materials), new technologies (e.g., UV light for disinfection), new cleaning chemicals, and the social-economic influences for cleaning in healthcare (e.g., as noted earlier the Center for Medicare and Medicaid Services [CMS] reimbursement policies for HAIs may increase cleaning in healthcare). The implementation of a change in the cleaning system involves all parties affected and manages the change program comprehensively in a step-by-step fashion.

IV HEALTH AND ENVIRONMENTAL HAZARDS: SCIENTIFIC AND PROFESSIONAL EVIDENCE

Human health effects

Nearly all cleaning products are complex mixtures of chemicals. The material safety data sheets (MSDSs) for many products indicate that they contain hazardous ingredients with the potential to cause adverse health effects, including serious respiratory ailments, eye and skin irritation, central nervous system disorders, reproductive disorders, blood disorders, and even cancer. However, MSDSs are notorious for being incomplete and are only required to report ingredients that constitute at least 1% by volume of the product. This means that some hazardous ingredients are not reported on the MSDS and workplaces cannot rely on them for complete toxicologic information. In addition, it has been suggested that chemical mixtures may magnify hazardous characteristics of some individual ingredients.^{57,58} Appendix A lists the most common chemical compounds in cleaning products and their health effects.

- **Chemical types.** A toxicologically significant chemical group used in cleaning chemicals is **volatile organic compounds (VOCs)**, which evaporate readily at ambient conditions (i.e., they have a low boiling point and high vapor pressure).⁵⁹ VOCs belong to different families of organic chemicals defined by their chemical formula—each of which possesses common properties, although there may be major toxicological differences from family to family.⁶⁰ Many VOCs are associated with poor indoor air quality^{59,61} and are known to participate in photochemical reactions both indoors and outdoors, generating harmful ozone (smog) in the environment.⁶² **Glycol ethers** are another common chemical group in cleaning products. Although glycol ethers have higher boiling points than many other organic solvents, they are hazardous compounds.⁶³⁻⁶⁸ Starek and colleagues found that ethylene glycol alkyl ethers have both acute and chronic health effects and target the central nervous system, blood and blood-forming organs, and reproductive system.^{67,68} Among ethylene glycol alkyl ethers, 2-butoxyethanol has

gained interest in health studies⁶⁹ because of its toxic properties and frequent use in cleaners. **Quaternary ammonium compounds**—used as disinfectants—are strong skin and eye irritants¹⁵ and associated with occupational asthma.^{15,61,70,71} **Phenols**, such as ortho-benzyl-para-chlorophenol (OBPC) and ortho-phenyl phenol (OPP), are disinfectants less commonly used in hospitals, with more shift to quaternary ammonium compounds for general cleaning and are severe eye irritants as well as corrosive and sensitizing to the skin at high concentrations.⁷² **Ethanolamines**—applied as surfactants in cleaning products—have also been associated with occupational asthma and at certain threshold concentrations, the vapors can irritate the nose, throat, and lungs causing coughing, wheezing and shortness of breath.⁷³ Among inorganic chemicals, **chlorine compounds**⁷⁴ (in particular **sodium hypochlorite** [bleach]⁷⁴⁻⁷⁶) and **ammonia**⁷⁴ are common ingredients used in disinfectants.

- **Acute injuries** from chemical exposures also occur. The 1995 - 1997 workers' compensation data for the State of Washington revealed that about 290 janitors per year who were working in various industries submitted claims for lost time injuries from chemical exposures—these injuries comprised 43% eye irritations or burns, 36% skin irritations or burns, and 12% inhalation of chemical fumes.³³ In 1989, two janitors in Chicago died after inhaling toxic fumes while cleaning a floor.⁷⁷ It was found that the floor cleaning solution contained methylene chloride.⁷⁷ In their study of female domestic cleaners in Spain, Medina-Ramon and colleagues reported that more than half of the study population had at some time accidentally inhaled a large amount of cleaning product vapors, gas, or fumes when using cleaning products. About two thirds of these accidents were related to inappropriate mixing of two or more cleaning products, mostly containing bleach. Accidents related to a single product involved predominantly hydrochloric acid or ammonia.⁷⁴

Epidemiologic and professional reports provide strong evidence that exposure to cleaning products is associated with **asthma and other respiratory symptoms**.^{1,59,61,70,71,73-76,78-92} Delclos and colleagues (2007) found an approximately twofold increased likelihood of work-related asthma among US health care workers for tasks involving instrument cleaning and disinfection, use of general cleaning products used on indoor building surfaces, use of powdered latex gloves, or the administration of aerosolized medications.⁶¹ Pechter et al. investigated four US state-based surveillance systems for occupational asthma data during 1993-1997.⁸⁷ Despite demographic and employment pattern variations across four states, healthcare emerged as the first or second most frequently reported industry among all occupational asthma cases, based on physician reports. Cleaning products, both cleaners and disinfectants, were the predominant exposure source, followed by latex, glutaraldehyde and formaldehyde, and indoor-air pollutants.⁸⁷ Rosenman et al. studied the same four surveillance systems to characterize individuals with work-related asthma associated with exposure to cleaning products and found that asthma cases were reported across a wide range of job titles.⁸⁹ In the report by Health Care Without Harm, “cleaners, disinfectants, and sterilants” topped the list of factors with strong evidence of asthma potential in healthcare. The report recommended implementing safer alternatives or elimination when possible.¹

In a recent Brazilian study of 341 non-domestic cleaners in Sao Paulo, 11% of subjects had asthma and 35% had rhinitis, mostly related to chlorine and dust. Both asthma and rhinitis cases increased with years of employment in non-domestic cleaning.⁸⁰ Asthma and rhinitis often coexist—allergic rhinitis often precedes the onset of asthma.⁸⁰ Medina-Ramon and colleagues reported lower-respiratory tract symptoms on working days among Spanish female domestic cleaners. The symptoms were predominantly associated with exposures to diluted bleach, degreasing sprays/atomizers, and air fresheners.⁷⁶ Thirty percent of the study subjects scored positively for work-related asthma.⁷⁶ Medina-Ramon’s team also found an excess risk of both asthma and chronic bronchitis among female domestic cleaners and identified statistically significant associations for ammonia, bleach and hydrochloric acid as cleaning product exposure sources.⁷⁴ In Finland, studies have shown strong evidence that cleaning work is associated with an increased risk of adult-onset

persistent asthma.⁸² A large European study in 26 areas of 12 countries found that increased asthma was most consistently associated with two occupations: farmers and cleaners.⁸³ Case reports support the evidence that toilet bowl cleaners containing the quaternary amine—benzalkonium chloride—have induced occupational asthma.^{73,78}

Studies have also reported occupational **hand dermatitis** and other adverse skin effects among hospital cleaning workers.^{93,94} In addition to chemical hazards, cleaning is a physically demanding job with frequent awkward postures caused by poorly designed non-ergonomic cleaning equipment or challenging physical work spaces. For these reasons, cleaning is a high-risk occupation for developing **musculoskeletal disorders** (MSDs).⁹⁵⁻⁹⁹

Exposure assessment efforts

Very limited quantitative exposure assessment data exist for cleaning personnel. This is mostly because cleaning products are complex mixtures of chemicals and are a challenge to measure. In addition, most hospital health and safety studies focus on patients. The healthcare occupational health and safety studies that do exist tend to focus on clinicians rather than support staff. However having a better understanding of the exposures of cleaning staff could provide information to protect the health of patients and clinicians as well. Bello et al. propose that hospital cleaning workers may be at higher exposure risk compared to other groups of cleaning personnel because: 1) hospitals use a wide range of products including disinfectants, and 2) the frequency of cleaning activities has increased rapidly in hospitals to ensure compliance with existing regulations and guidelines for protecting patients and workers from infectious diseases.^{15,100} Common cleaning tasks—especially in hospitals—include: preparation of cleaning solutions, floor cleaning, window cleaning, mirror cleaning, toilet bowl cleaning, sink cleaning, and floor finishing tasks (buffing, waxing and stripping).^{15,86,100}

Rosemann and colleagues reported that asthma cases were associated with exposure to cleaning products across a wide range of job titles.⁸⁹ Bello’s study characterizing exposures to common cleaning tasks in hospi-

tals identified high-exposure jobs such as floor finishing tasks like stripping, waxing and buffing, as well as a combination of various cleaning tasks.¹⁵ Delclos and colleagues compared self-reported occupational exposures with a workplace-specific job exposure matrix (JEM) by asthma status among Texas healthcare professionals. Asthmatics' self-reports on exposures showed better agreement than non-asthmatics' reports with the JEM for patient-care-related cleaning tasks.⁹² The team recommended using externally developed methods of exposure classification.⁹²

Human exposure to cleaning chemicals depends on many inter-related factors including chemical composition of the product, ventilation of the room, air movement and transport between the rooms, potential for dermal exposures, interactions of surfaces with cleaning products, and the methods of product application and disposal.^{15,100} Because there are limited occupational hygiene analyses and workplace exposure data, there is a need for systematic evaluation of cleaning products' ingredients and their exposures in the workplace, particularly the healthcare environment. In addition, the absence of epidemiologic studies on cleaning has prevented comprehensive identification of agents responsible for asthma and other reported respiratory symptoms. What we know is that cleaning workers are at risk of acute and chronic inhalation exposures to chemical vapors and aerosols generated from product spraying, as well as dermal exposures mostly through hands.

Environmental impacts

Possible environmental impacts of cleaning products include indoor and outdoor air pollution, bioaccumulation in plants and animals subsequently affecting the food chain, endocrine disruption in wildlife, stratospheric ozone depletion, and water pollution, including drinking water quality.¹⁶ The US EPA has recommended attributes for selecting commercially available cleaning products. In addition to human health attributes (to avoid irritation and chronic health risks), environmental attributes included:¹⁹

- Biodegradation time—the faster a chemical degrades, the lower the exposure potential;



- Bioconcentration value—the higher the value, the more likely it is to accumulate in the food chain;
- Percentage of VOCs which generate smog;
- Amount of product packaging—reduced packaging decreases the amount of waste;
- Presence of ozone depleting substances;
- Adequate safety precautions that minimize exposure to the concentrated solution;
- Flammability—non-flammable products are preferable;
- Presence of cosmetic additives (e.g., fragrances and dyes)—considered to increase harmful life-cycle impacts (overall health, safety, and ecological concerns); and
- Energy needs—products that work effectively in cold water reduce energy consumption.

V HEALTHIER AND MORE ENVIRONMENTALLY FRIENDLY CLEANING FOR HEALTHCARE

What is green cleaning?

There is no widely accepted definition of “green” or “green cleaning.”¹⁸ US Executive Order 13101—issued in 1998 by the Clinton Administration—defines “environmentally preferable” as “products or services that have a lesser or reduced effect on human health and the environment when compared with competing products or services that serve the same purpose.”¹⁷ OneSource—a provider of outsourced facilities services in the US—defines “green cleaning” as “cleaning to protect health without harming the environment.”¹⁰¹ Patti Costello, executive director of the American Society for Healthcare Environmental Services (ASHES) expands the “green cleaning” definition further to address the infection prevention and control efficacy “toward effective products with the fewest adverse effects on human health and the environment.”¹⁸ Even criteria for the outcomes, e.g. “protect health,” “fewest adverse effects” and “without harming the environment,” are not well established.

Benefits of green cleaning and examples of efforts

Green cleaning programs are usually undertaken to reduce adverse human health and environmental impacts. Cost savings from implementing green cleaning efforts have also been reported, including reduced overall cleaning costs, waste volumes, and need for storage space.¹⁰² Among others, the Olmsted Medical Center (Rochester, MN) expected their annual cost savings to reach more than \$20,000 through reduction of unnecessary chemicals, process improvements developed by standardizing cleaning and disinfecting procedures, and eliminating redundant chemical use.³¹ Another example is the University of California Davis Medical Center (Sacramento, CA) which experienced the following benefits by replacing conventional mops with microfiber mops: 60% lifetime cost savings for mops, 95% reduction in chemical costs associated with

mopping tasks, and 20% labor savings a day.¹⁰³ Rutala and colleagues showed that microfiber mops with a regular detergent cleaner demonstrated superior microbial removal compared with cotton string mops (95% vs 68%, respectively).²⁴

In general, it is difficult to find comprehensive examples of green cleaning efforts in healthcare facilities (see Appendix B). Beyond the examples provided above, peer-reviewed, scientific studies on the effectiveness of green cleaners in healthcare facilities are minimal. Nonetheless, some hospitals have engaged in encouraging green cleaning efforts. For example, two New York City hospitals—Jacobi Medical Center and North Central Bronx—reported that they instituted green cleaning programs in 2004 and replaced most of their conventional cleaning products with more environmentally preferable ones.¹⁰⁴ One of the improvements was to replace ammonia- and chlorine-based cleaning products with products made from biodegradable, nontoxic ingredients such as soy, cornstarch and citric acid. Promising green cleaning efforts have been reported in other hospitals, for example in above-mentioned Olmsted Medical Center and University of California Davis Medical Center, Hackensack University Hospital (NJ), Suburban Hospital, Bethesda (MD), and others provided in Appendix B.^{27,31,103,105,106}

The transition from conventional cleaning products to safer alternatives in the healthcare sector is complex. While some green cleaning products may have fewer health effects and be more environmentally sound, the purchase of green cleaning products does not assure the overall reduction of risks. The main reasons include: a) there are little data about the hazards associated with specific green cleaning products; b) certification of green products was initially based on environmental performance and only recently have health effects been taken into account (e.g., revised Green Seal GS-37 standard); and c) 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 and disposed. This latter point is seldom addressed in current discussions of green cleaning.

From an infection prevention and control perspective, it is not clear whether green cleaners are effective in reducing or eliminating micro-organisms at the level needed for a particular application. Patti Costello, executive director of the American Society for Healthcare Environmental Services, stressed that changing approaches without sufficient research and data on the efficacy of alternative greener procedures and products is simply trading one set of problems for another:¹⁰⁷

“We are an environmental group, so for us not to encourage our members to be involved in caring for the environment would be against who we are, but our number one priority is patient safety and infection prevention ... The clean needs to come first, and then you work on being green. And there are many ways to do that. From where we sit, you need to remove visible soil and dirt, and for that, a neutral detergent is okay. But for high-touch areas and patient care areas, you need to clean and disinfect. Disinfectants, by their very nature, kill micro-organisms. I’ve never seen a green disinfectant, and I doubt if we ever will. That is not to say that cleaning procedures and products can’t be effective and greener... There’s a lot of [environmentally friendly] technology out there, and everyone is striving to find the most effective solutions. But there’s a lot of research and data and peer review that needs to take place before you can jump on the ‘bandwagon of the day’ as it relates to green.”¹⁰⁷

Cleaning, disinfecting, and antimicrobials products

This document provides the Centers for Disease Control and Prevention (CDC) definitions for cleaning, disinfection, sterilization, and antimicrobials in the Background section. In 2003, the CDC provided more specific guidelines for environmental infection prevention and control in healthcare facilities, including principles for cleaning and disinfecting environmental surfaces.³⁶ The guidelines reinforced cleaning as the necessary first step of any successful disinfection or sterilization process. For housekeeping surfaces in patient care areas, the guidelines (p.74) highlight the importance of carefully considered cleaning ³⁶:

*“Most, if not all, housekeeping surfaces need to be cleaned only with soap and water or a detergent/disinfectant, depending on the nature of the surface and the type and degree of contamination. Cleaning and disinfection schedules and methods vary according to the area of the healthcare facility, type of surface to be cleaned, and the amount and type of soil present. Disinfectant/detergent formulations registered by EPA are used for environmental surface cleaning, **but the actual physical removal of micro-organisms and soil by wiping or scrubbing is probably as important, if not more so, than any antimicrobial effect of the cleaning agent used.**”*

In 2008, the US-CDC adopted *The Guideline for Disinfection and Sterilization in Healthcare Facilities* which presents evidence-based recommendations for healthcare cleaning and disinfecting as well as preferred methods for cleaning, disinfecting and sterilizing medical devices.³⁵ The 2008 CDC Guideline emphasizes Spaulding’s* rational approach categorizing patient care items as critical, semi-critical, and non-critical according to the degree of infection risk involved in their use.³⁵ It categorizes such surfaces as bed rails, bedside tables, patient furniture, and floors as non-critical. However, it also refers to them as high-touch surfaces that could contribute to secondary transmissions by contaminating hands of healthcare workers or by contacting medical equipment that subsequently contacts patients.³⁵

US EPA considers antimicrobial products** to be pesticides, and requires their registration as stipulated under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA).^{28,37} In the US, there are no specific standards for antimicrobial products. The US EPA does not allow manufacturers who add antimicrobials/fungicides to their products to make “health claims” (e.g., prevents spreading germs or harmful micro-organisms),^{108,109} unless registered as a pesticide by the EPA under FIFRA. To obtain registration, an antimicrobial product must not cause “unreasonable adverse effects to human health or the environment,” and its labeling and composition must comply with

* In 1968, Earle H. Spaulding developed an approach to disinfection and sterilization of patient care items and equipment.³⁵

** Except antiseptics and germicides.

FIFRA requirements.³⁷ In addition, manufacturers must provide detailed information on the product's chemical composition, documentation of its effectiveness against specific microorganisms, and any hazards associated with the product's use.³⁷ At the moment, the EPA does not allow anti-microbial products to be marketed as green because of their inherent ability to kill micro-organisms.¹¹⁰ However, the EPA has started to explore possibilities for a policy change to allow green claims for nonporous hard-surface disinfectants and sanitizers; as a first step, the EPA's Office of Pesticide Program (OPP) and its Design for the Environment (DfE) Formulator Program will conduct an internal pilot to evaluate cleaning products that the DfE has already recognized imitating antimicrobial products.¹¹¹ If the results of the internal pilot are beneficial, the EPA anticipates conducting an external pilot with the cleaning industry representatives and distributors.¹¹¹

The most commonly used antimicrobial products in healthcare include disinfectants, sterilizers, sanitizers, antiseptics, and germicides.^{28,37} Disinfection and sterilization are defined in Section III. Sanitizers reduce, but not necessarily eliminate, microorganisms from the inanimate environment to levels considered safe by public health codes or regulations (e.g., products for food items, carpet sanitizers, air sanitizers, laundry additives, in-tank toilet bowl sanitizers).³⁷ Antiseptics and germicides are used to prevent infection and decay by inhibiting the growth of microorganisms; because antiseptics and germicides are used in or on living humans or animals, they are considered drugs and generally not antimicrobials, thus, approved and regulated by the US Food and Drug Administration (FDA).³⁷

More than 5,000 antimicrobial products are currently registered with the EPA and available in the market. Nearly 60% of these products are registered to control infectious microorganisms in the healthcare sector.³⁷ Not surprisingly, there have been concerns about the overuse of antimicrobials in healthcare facilities. In a typical hospital, about 45-65% of the facility space is considered to belong to low-infection-risk zones (e.g., areas belonging to exterior maintenance, administra-

tion, accounting, records, human resources, patient registration and waiting, shops, carpentry, mail, printing, materials management, hallways); approximately 25- 45% is considered medium-infection-risk zones (e.g., areas such as public restrooms, nursery, outpatient clinics, diabetes clinics, and respiratory clinics, physical therapy, and cardiac rehabilitation); and about 10% is thought to be high-infection-risk zones (emergency, labor and delivery, morgue, surgery).¹¹² The determination of zones begins with the patient risk and moves outward into lower risk areas or zones. The Practice Greenhealth Guide stated that *more is not better with disinfection: excess product use increases occupational and environmental risks without improving infection prevention and control effectiveness.*²⁷

VI. SYSTEMS APPROACH

A comprehensive systems approach that includes both the influences of the broader society in which healthcare is being delivered as well as the individual healthcare facility is needed to identify effective points of intervention for more healthy, safe, and environmentally sound cleaning. The idea behind the systems approach is that there are relevant interdependencies and interrelationships between representatives inside of and external to a workplace/organization that create change. Various scientists and policy makers have used a systems approach to conceptualize their cases.¹¹³⁻¹¹⁷ For cleaning in healthcare, the systems approach is needed to identify and balance all of the influences, overt or subtle, that ultimately affect the choice of cleaning products and practices. Only with this broader understanding will effective and continuously improving cleaning strategies be achieved.

While intra-hospital relationships related to cleaning are recognized fairly readily (e.g., groups and individuals involved in procurement, use, disposal, infection preventionists, clinical staff, administrators), there are other powerful external driving forces for selecting cleaning products and practices that must be considered. For example, hospital infection prevention and control practices are likely to be influenced by the Centers for Medicare & Medicaid Services (CMS) recent plan to stop paying additional funds for certain preventable medical errors or conditions that result in serious consequences for the patient, including specific HAI. Another related issue is the intensive interest in HAI in general and the consumer's awareness of multi-drug resistant organisms (MDROs) in light of the heavy media coverage on MDROs like *Methicillin-resistant Staphylococcus aureus* (MRSA). Consequently, these influences bring further skepticism towards green cleaning products and practices.

An opposing influence is the widespread adoption of the Leadership in Energy and Environmental Design (LEED) certification program (see Section VII), which includes guidance for the design and operation for high-performance green buildings. The LEED for Existing Buildings (EB) Rating System also helps building owners and operators measure the green performance of existing operations, including whole-building cleaning strategies. The LEED supports green cleaning products and practices. Currently there is very little information describing cleaning from this macro perspective. However the most effective strategies for cleaning vis-à-vis the three safeties—environment, patient, and employee—will be attained only with this broader view.

Several groups have developed methods to apply a systems approach to cleaning at the level of the healthcare facility. Stephen Ashkin, president of a consulting firm specializing in green cleaning, says “*the plan matters*” and poses the following questions: (i) How is the facility defined for cleaning purposes? (ii) Are all tasks at one level of cleaning? (iii) Are different cleaning standards needed for different areas—i.e. high infection risk; medium infection risk, and low infection risk areas?¹¹²

Ideally, one would have a clear understanding of the appropriate level of cleanliness and how to achieve it (Table I). In reality, healthcare facilities are faced with a dizzying array of cleaning products and methods. Many of these cleaning products may not be provided with adequate guidance on how to achieve the desired cleaning outcome and what the tradeoffs might be.

Table I: Achieving the Desired Cleanliness

	Considerations
What is the desired state of cleanliness?	<p>What level of cleanliness is warranted or desired?</p> <p>How would it be measured?</p> <p>How will we know when the desired level is attained?</p>
What is the current state of cleanliness?	<p>What is the baseline level?</p> <p>What needs to be prevented, removed or inactivated in a particular area (e.g., soil, grease, bacteria, odors, etc.)?</p>
How can the gap be closed , between the current cleanliness and the desired state?	<p>What types of cleaning products or methods are effective for moving from the baseline condition to the desired outcome?</p> <p>What are the cleaning products/methods that address specific needs (e.g., removal of soil, grease, bacteria, odors)?</p> <p>What constraints exist (e.g., physical limitations, occupied space, food preparation surfaces)?</p> <p>How does one find, evaluate and select the products or practices?</p> <p>How does one assess and weigh the merits and shortcomings of the alternative products and practices?</p>

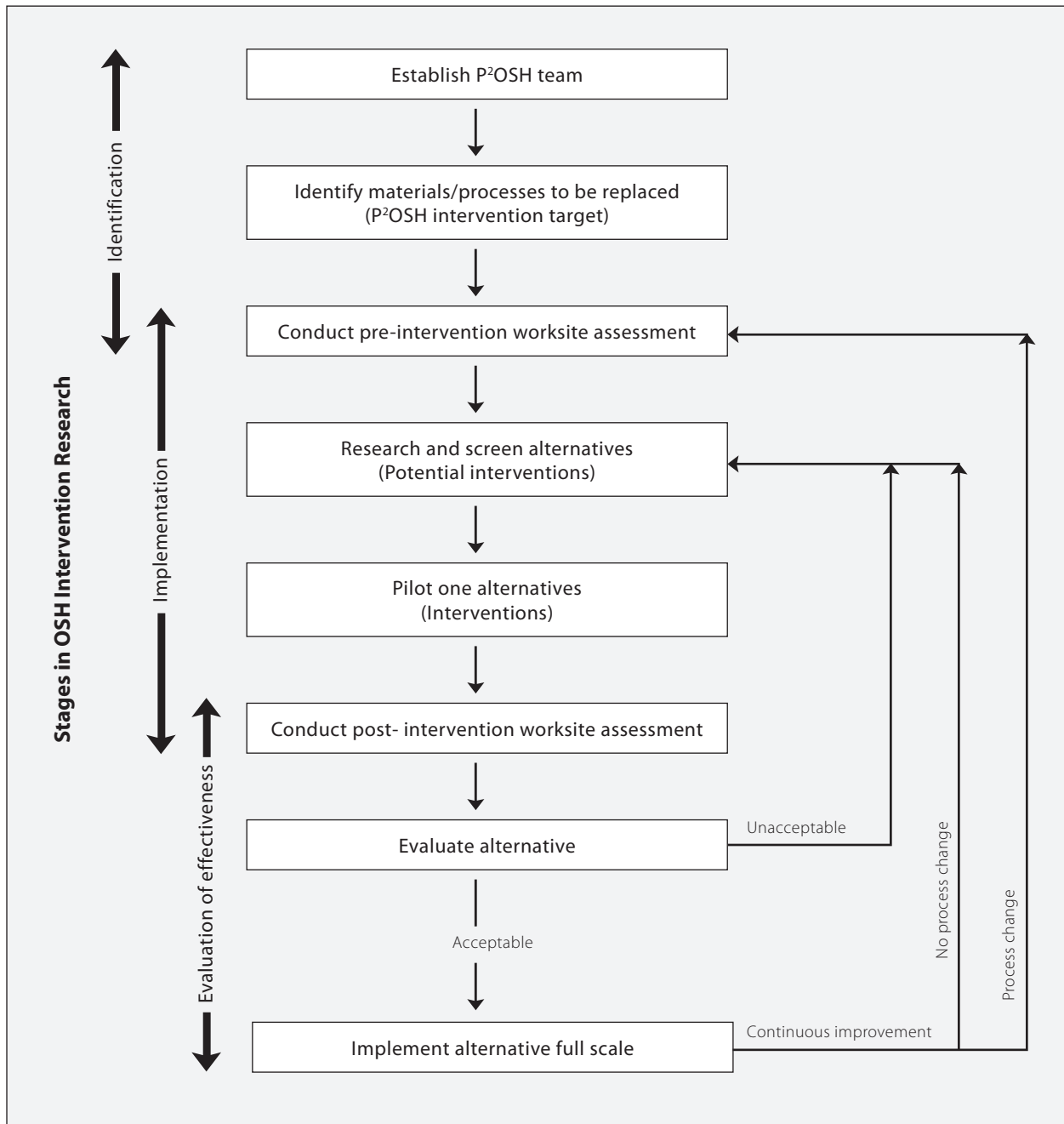
SHP experience with a systems approach to changing practices in hospitals

The SHP developed a participatory strategy for working with hospital staff (administrators, clinicians, clinical laboratory managers and technicians, facilities managers and housekeeping) to assess the use of hazardous materials and practices and to identify and implement safer, more environmentally sound alternatives. The approach is called the Pollution Prevention-Occupational Safety and Health alternatives assessment, implementation and evaluation strategy (P²OSH strategy) which integrates environmental and occupational safety and health.⁷ An integrated strategy is essential because workplace changes in materials and practices cannot be maintained without accounting for the work functions and without getting employee input and buy-in early in the change process. Lessons learned from conducting green cleaning and other pollution prevention activities in US hospitals indicate that focusing on the environment without accounting for the workplace often will not be effective. A successful green cleaning program must (i) be fully supported by the management, and (ii) involve administrators, clinicians, infection preventionists, safety officers, housekeeping/

environmental services, and clinical laboratory personnel to evaluate the infection prevention and control, occupational health, and environmental performance of the new cleaning program.

The integrated P²OSH strategy was developed over the past decade in response to hospital workers' observations that pollution prevention solutions can inadvertently introduce new occupational health problems, and vice versa. This is sometimes referred to as "risk shifting," when a solution in one area causes problems in another. Because occupational and environmental hazards arise from the same sources, user-friendly and sustainable solutions require an integrated systems approach. Few alternative products can be categorized in absolutes of "good" or "bad" with respect to the environment and health. Hence, P²OSH is the process by which one considers the merits and shortcomings of alternative products. In this way, the hospital can make an informed choice of the alternative that best suits its situation. When a new alternative becomes available, perhaps offering more benefits and fewer shortcomings, the process to implement and evaluate it is repeated in a cycle of continuous improvement. Thus training of hospital staff focuses on gaining skills that can be used long after the original alternative substitution is accomplished.

Figure 1: The Sustainable Hospitals Program P²OSH alternatives assessment and implementation strategy⁷



Practice Greenhealth approach

Practice Greenhealth has used a systems approach and developed a 10-step green cleaning program.²⁷ It was designed for busy employees at healthcare facilities who don't have a lot of time to spend reading background material. The Guide includes policy development, selection of products, staff training, standardized operations, cleaning equipment and supplies, and the program monitoring.²⁷ The Practice Greenhealth approach includes the following steps²⁷:

- **Step 1:** Form a team and gain commitment;
- **Step 2:** Review current products and practices (conduct inventories of cleaning products, equipment, policies, and operations);
- **Step 3:** Evaluate and categorize facility areas (identify high risk, medium risk, and low risk care areas, patient rooms);
- **Step 4:** Determine evaluation criteria for products and operations (review product attributes, GPO contracts, certified products, and changes in operations);
- **Step 5:** Select products (e.g., general, toilet bowl, carpet, and glass cleaners have been certified under Green Seal GS-37 and GS-40 products; floor strippers and waxes; and types by usage of disinfectants);
- **Step 6:** Develop a pilot plan (pilot area(s), pilot evaluation criteria, feedback solicitation, changes in work processes, pre-implementation and post-implementation surveys for facility staff, patients and visitors);
- **Step 7:** Execute the pilot (incl. training and feedback);
- **Step 8:** Evaluate the pilot (post-pilot surveys for staff, patients, visitors)
- **Step 9:** Celebrate success (develop press releases, case studies, and materials for future green cleaning projects); and
- **Step 10:** Expand your efforts by institutionalizing the program (e.g., facility's cleaning chemical purchasing standards excluding products containing toxic chemicals in favor of safer products successfully used).

Management and the team

Any systems approach, program, or management system requires two crucial features: (i) commitment of management and (ii) involvement of worker representatives affected by the change. Both the above SHP and Practice Greenhealth approaches prioritize the support of management and careful selection of team members because the strength and cohesion of the team defines the success of future steps.

Who should be included as members of the green cleaning team? At a minimum, the team should consist of representatives from operational areas affected by the green cleaning program, including (not limited to): management/administration, clinical staff (at least one physician, nurse, nurse aide), infection preventionists, safety officers, occupational and environmental officers, operations and facilities personnel, housekeeping/environmental services, purchasing department staff, and laboratory personnel. Marketing, community relations, and GPO representatives may also play useful roles in green cleaning teams.¹¹²

While the team serves as the working group for moving green cleaning forward, the role of management cannot be understated. Most improvement activities consist of a series of successes and obstacles, and steps backward are as common as progress. It is the responsibility of management to reinforce the process and provide the resources that allows the team to move forward. These resources include not only the obvious manpower and finances, but space, time, and moral support.

VII. GREEN MOVEMENTS IN THE HEALTHCARE SECTOR

LEED for Healthcare

Many factors are prompting the healthcare sector to develop and implement sustainable and green initiatives, including green cleaning programs. One of the most visible and influential factors is the impending launch of the new *Leadership in Energy and Environmental Design (LEED) for Healthcare*²⁹ certification program by the US Green Building Council (USGBC) that is tailored to healthcare facilities. This evolved from the USGBC's LEED Green Building Rating System, developed in the mid-1990s.³⁰ Efforts began in 2002 for the healthcare version, which led to the collaboration of the contributors to the Green Guide for Health Care sustainable design toolkit (GGHC) and the USGBC, resulting in the development of *LEED for Healthcare*²⁹ expected to be finalized and launched in the second quarter of 2009.²⁰ It is expected that LEED for Healthcare will become a de facto standard for healthcare facilities, similar to the widespread acceptance of the original LEED for New Construction standard for green buildings. "Environmentally Preferable Cleaning" is a part of the Environmental Services (ES) operations credit of the GGHC²⁹ and is divided into three specific subsections: policy development, products and materials, and cleaning equipment. The credit rating requirements have been outlined for all three subsections. The GGHC recommends extensively cleaning products and materials certified by the US Green Seal and Canadian Environmental Choice.

Green cleaner certification programs

Several organizations offer green certification of cleaners to meet recognized green standards. This has proven to be a powerful force in the transition to green cleaning practices. Green Seal, the most visible of the US organizations, is an independent, non-profit organization that evaluates and certifies green products. Green Seal has developed two standards for cleaning products: GS-37¹¹⁸ for industrial and institutional cleaners and GS-40¹¹⁹ for industrial and institutional floor-care products. The GS-37 standard was revised in April 2008 with new requirements regarding human health and environment, including:¹²⁰ prohibiting astmagens; including additional inhalation exposure criteria with inhalation toxicity limits; prohibiting carcinogens, mutagens, reproductive toxins, phthalates (a group of endocrine disrupters), and 2-butoxyethanol; tightening VOC content limits to provide additional in-door air protection (1% in glass and carpet cleaners); increasing acute oral toxicity limits; inclusion of bioaccumulation criteria; disclosure of fragrance use; and other. Over 150 manufacturers attained the earlier GS-37 certification (pre-April 2008) for their institutional cleaning products and 75 manufacturers have floor products with GS-40 certification. (See Appendix C)

In addition to Green Seal, other well-recognized green product certification programs include the Canadian Environmental Choice (also called EcoLogo) program, the US EPA's Design for the Environment (DfE) Formulator Program, Cradle-to-Cradle, the Nordic Swan, EcoLabel (European Union), and Blue Angel (Germany).¹⁹ Appendix C provides a very short list of selected sources that are useful to start identifying and choosing industrial green cleaning products.

Many facility managers trust that certified products are healthier for building occupants and the environment.¹¹⁰ However, as noted earlier, one group of products, cannot be certified as green. The US EPA prohibits manufacturers or distributors from promoting, labeling, or marketing disinfectants or any other antimicrobial pesticides as green (see the subsection entitled *Cleaning, disinfecting, and antimicrobials products* of Section V) and stipulates that registration under FIFRA is sufficient assurance of safety and effectiveness and that any additional claims may be misleading.¹¹⁰ Disinfectant users, including hospitals, are seeking safer disinfectants than FIFRA-registered ones and as a result, cleaning industry representatives are discussing with the EPA how to promote safer disinfectants.¹¹⁰ The EPA is exploring possibilities for a future policy change for nonporous hard-surface disinfectants and sanitizers (the subsection of *Cleaning, disinfecting, and antimicrobials products* of Section V).¹¹¹ At the moment, hydrogen peroxide or hydrogen peroxide-peracetic acid are considered a more benign disinfectant than those containing chlorine or phenolic compounds, or 2-butoxyethanol.^{28,55,110} The Canadian Environmental Choice Program (EcoLogo) has developed certification criteria for disinfectants and disinfectant-cleaners (Standard CCD-166). The Standard lists numerous prohibited and restricted components as well as toxicity and degradability requirements.¹²¹

VIII. MOVING UPSTREAM TOWARDS NON-CHEMICAL ALTERNATIVES

Successful green cleaning programs should move upstream in the cleaning process towards non-chemical or less toxic alternatives by identifying new technologies, building materials, and work practices without compromising infection prevention and control goals. The **INFORM, Inc.** report “Cleaning for Health” has suggested that the use of hazardous chemicals could be reduced by 13% if cleaning staff used fewer chemicals, substituted less toxic chemicals, increased the use of entry mats, and avoided aerosol products.^{28,55} The use of microfiber mops and cloths has been shown as effective and safe¹⁰³ while reducing noise pollution from vacuums.

The entire building and its operational design should be considered for environmentally friendlier cleaning. In her white paper to the American Society for Healthcare Engineering Annual Conference, Bartley discusses good practices and recommends heeding the “three safeties (i.e., patient, employee, environmental safety)” principle with such practices as¹⁰⁸:

- (i) Provide private patient rooms. From the infection prevention and patient safety perspective, private patient rooms have been associated with reduced medication errors, falls, and HAIs.
- (ii) Focus on water. Routine maintenance and prompt response to water leaks prevent moisture and consequent fungal formation inside the buildings. Also, sink designs can reduce splashing and waterborne pathogen infection risks.¹²²
- (iii) Reduce waste by implementing recycling and take-back programs; and (iv) Use microfiber mops with detergents instead of cotton mops with disinfectants.

Other environmentally friendly cleaning strategies include: choosing surface materials that are easy to maintain and clean with the greenest products available to minimize worker or patient exposure to cleaning and disinfecting products; designing heating, ventilation, and air conditioning (HVAC) systems that remove airborne contaminants; designing rooms, floors, toilets/bathrooms so that they can be cleaned with a minimum of chemicals; and organizing waste manage-

ment.¹²³ For example, HVAC- systems in healthcare facilities can be designed to maintain comfortable indoor temperature and humidity to control odors, remove air contaminants, and minimize the risk for transmission of airborne pathogens such as *M. tuberculosis*.³⁶ Studies report ultraviolet germicidal irradiation (UVGI)* technology as an effective method in the fight against infections in healthcare, however, there are safety tradeoffs (i.e., ultraviolet radiation exposure).¹²⁴⁻¹²⁵ The CDC guidelines recommend UVGI as a supplemental air-cleaning measure but it cannot replace HEPA filtration systems which are considered at least 99.97% efficient for removing particles greater than 0.3 micrometers (µm).³⁶ The UVGI technology is said to be effective in reducing the transmission of airborne bacterial and viral infections, for example, in hospitals, but has only a minimal inactivating effect on fungal spores.³⁶

Many cleaning experts recommend focusing on exterior facility maintenance (i.e., keeping the contaminants out of the facility) and entryway systems and maintenance (i.e., capturing the contaminants at entryways).^{27,112} Cleaning technologies that remove soil, dust, mold, and allergens non-chemically are the most preferable. For example, over 80% of the soil enters through shoe soles, hence, proper high-performance matting systems in entranceways are needed to capture, trap and retain the soils.¹²³ A high-performance matting system allows the soil and contaminants to fall beneath the surface of the mat, preventing tracking into the facility and reducing the need for chemical cleaning. The USGBC-LEED EB standard awards one point (of the necessary 32) to facilities that have an effective, high-performing matting system in place.¹²³ Another effective tool that complements and reduces chemical cleaning is the use of vacuum cleaners with true HEPA filtration, designed to capture fine particulate matter and dust through a multistage filtration process.¹²³

* the use of ultraviolet radiation to kill or inactivate microorganisms.

There are truly promising reports from healthcare facilities using microfiber mops.^{7,21-24} As earlier indicated, investigation by Rutala shows that the microfiber mop can sequester and remove microorganisms with a detergent cleaner—it is not necessary to use disinfectants. These mops provide a safer, greener, and effective method of cleaning. Microfiber mops demonstrated superior microbial removal compared with cotton string mops (95% vs 68%, respectively).²⁴ The microfiber mop is lightweight, compact, and offers ergonomic, infection prevention and control, as well as inventory management benefits compared to a conventional mop and bucket system. In microfiber mopping, a fresh cleaning pad soaked in cleaning solution is used for each room. The soiled pad is then set aside for laundering, maintaining the cleanliness of the virgin cleaning solution and preventing cross contamination of rooms.¹⁰³ The design of the microfiber system eliminates the need to mix, transport, and refresh large buckets of cleaning solution, eliminating lifting and carrying of heavy buckets and minimizing the use of cleaning chemicals and water.¹⁰³ An additional benefit of microfiber mopping is that patients are happier because microfiber mopping is quieter, faster and less intrusive.²²

Last but not least, proper cleanliness as well as infection prevention and control start with hand hygiene. *Prevention Strategist*^{*} described how money-saving technologies like motion-sensitive lights, doors, faucets, soap and paper towel dispensers, etc can also reduce infections since germs on patients' and healthcare workers' hands are not spread around.¹²⁶

Christopher Tricozzi^{**} makes a useful analogy that summarizes our approach to green cleaning. He noted in a roundtable discussion^{***} that green cleaning is not only about cleaning chemicals and that healthcare administrators should view all the different elements of green cleaning as “*the spokes on a wheel*.”¹²³

*“As long as all the spokes are strong and sturdy, the wheel works fine. But when one is missing or is not performing correctly, the integrity of the entire wheel may be in jeopardy.”*¹²³

* A publication of the Association for Professionals in Infection Control and Epidemiology (APIC)

** Industry representative from Crown Mats and Matting

*** Organized by the Infection Control Today Magazine: <http://www.infectioncontroltoday.com/articles/green-cleaning-roundtable.html>

Green cleaners are only one spoke of the wheel. To achieve the most successful outcome, cleaning products need to be considered together with all other contributors to a clean healthcare setting. Otherwise, one of the fundamental three safeties—patient, employee, environmental—will be compromised.

IX. CONCLUSIONS AND RECOMMENDATIONS

The knowledge gaps pertaining to attaining and maintaining cleanliness in healthcare settings include the following:

Cleaning in general

- We know that the use of some cleaning products is related to asthma and asthma-like symptoms. What we lack are adequate data on which specific ingredients cause asthma or other health effects.
- Studies have shown that respiratory and dermal exposures result from a combination of factors including the cleaning products used, ambient conditions, physical space, and the way tasks are performed (e.g., sequential toilet, mirror and floor cleaning). There is limited information about how cleaning tasks generate respiratory and dermal exposures.
- There is a need to develop a universal standard to test cleaning and/or disinfection effectiveness in different laboratories and workplaces. No single product will work for every situation and process-specific testing is a necessity before switching to a new product.
- It is important to have a comprehensive analysis of the broad system of cleaning, including its decision-makers, their roles, and responsibilities at various levels of work organization. A such analysis currently does not exist.

Green cleaning

- While we found many general descriptions of green cleaning, there is no uniform definition of green cleaning for the healthcare sector. “*Cleaning to protect health without harming the environment*”¹⁰¹ is frequently used; however, it is not adequate for the healthcare sector as it leaves out the concept of cleaning effectiveness, most notably infection prevention and control.¹⁸
- In healthcare it is crucial to understand how cleaning practices support infection prevention and control goals. Our literature search showed that there

are no systematic scientific evaluations publicly available on how effectively green cleaners meet infection prevention and control standards.

- Other public health issues have demonstrated that readily available information rapidly advances the adoption of good practices and lessons learned. For example, significant mercury reduction was achieved in US hospitals over the past decade largely as a result of strong communication on programs to eliminate mercury. However there is no similar publicly available information on green cleaning programs in healthcare facilities with details of how they were implemented and the lessons learned. All that are currently available are rather short reports.^{27,104} We recommend the development of a central national repository providing comprehensive information on green cleaning in hospitals. (see Appendix B)
- While green cleaners offer great promise for human health and the environment, we can find no evidence of comprehensive scientific health studies that examine health risks from green cleaners.

Upstreaming non-chemical alternatives for cleanliness

- Architecture and the use of green building materials are an important avenue for attaining and maintaining cleanliness in healthcare settings. Integrating prevention through design with cleaning methods should be considered as part of a unified system to reduce exposures and promote sustainable solutions;
- Many new materials, technologies and approaches for attaining and maintaining cleanliness are coming onto the market with little information about risks or potential harms. These need to be considered using a systems approach that examines their efficacy for cleaning, as well as infection prevention and control and how these products interact within the broad system of cleaning to avoid risk shifting among patients, workers, and the environment.

New research and educational initiatives could fill many of the gaps listed above. *LEED for Healthcare* is expected to be launched during the 2nd half of 2009 so the period of 2009-2010 is timely for collecting baseline occupational exposure and health data. The baseline data can be compared to the LEED post-implementation data to measure the success. The following recommendations flow from the knowledge gaps. They are not meant to be a definitive list:

- **Qualitative study:** We recommend carrying out a qualitative study on the nature, effectiveness, and impacts of environmentally friendly (green) cleaning programs in selected hospitals by conducting (i) in-depth interviews with key staff members who coordinate or participate in green cleaning teams and (ii) focus groups with janitorial employees in these same hospitals. The SHP's research on sharps injuries in home healthcare¹²⁷ demonstrated that qualitative data provide crucial in-depth information on the nature of the study topic as well as how it is influenced by different circumstances, perspectives, and social forces. These qualitative data are needed to fully define the main influences in the system of cleaning in healthcare and to identify gaps and lessons learned for information rich case studies.
- **Exposure assessment:** The SHP's earlier work on exposure assessment of cleaners attests to the need and offers a baseline for conducting exposure assessment studies to develop improved work practices and cleaning. It is recommended that a study be designed and conducted to assess worker exposures with green cleaners and typical work scenarios.
- **Conduct human health studies** on green cleaning products focusing on asthma and other health effects.
- **Collaborate with infection preventionists and microbiologists** to design studies and standard methods to evaluate how effectively green cleaners meet the infection prevention and control goals.
- **Clearinghouse on green cleaning:** A freely accessible, online central repository of information about green cleaning is a necessary and powerful force for identifying and sharing best practices, creating a driving force for the development and promulgation of up-to-date and scientifically based information, and provide mentoring for hospitals lacking in resources. Two important characteristics of this clearinghouse are that information is free and scientifically based. What the SHP has found is that over time a repository like this amasses a collection of useful information from different sources that complements and builds upon itself.
- **How-to guidance:** We recommend that information about the selection and use of green cleaners be developed into a series of 2-page factsheets for frontline workers. While journal articles are important for communicating to the scientific community, frontline workers have informed the SHP that terse and cogent how-to guides are useful for understanding and getting buy-in for improvements to their practices. The SHP currently has over two dozen fact sheets on various health and safety topics and these are some of our most requested products for conferences, hospital outreach and educational events. One of these, "10 Reasons to Use Microfiber Mopping", presents a broad overview of considerations and cautions for hospitals considering this alternative.
- **Case studies:** In addition to articles and factsheets, the SHP recommends the use of case studies to serve as practical overviews of implementing new products or practices. The case studies differ from the factsheets in that they are more detailed, comprehensive, and useful to a broader audience within the healthcare setting. The SHP's "Case Study: Are Microfiber Mops Beneficial for Hospitals?"²³ is an example of a systematic examination of environmental, safety and health aspects of microfiber mopping.
- Train janitors, housekeepers, unions and labor groups on the systems approach to green cleaning.
- Develop materials on health and environmental aspects of cleaning for hospital administrators and managers.

LIST OF REFERENCES

1. Clapp, R, Culver, A, Donahue, S, Fuller, T, Hoppin, P, Jacobs, M, Sutherland, L. *Risks to Asthma Posed by Indoor Health Care Environments: A Guide to Identifying and Reducing Problematic Exposures*. Health Care Without Harm. 2007. Available at: <http://www.noharm.org/details.cfm?type=document&ID=1315>. Accessed: 04/02/09.
2. Massawe, E, Geiser, K, Ellenbecker, M, Marshall, J. *Health, safety, and ecological implications of using biobased floor-stripping products*. J Environ Health. 2007. 69(9):45-52, 76-7.
3. Surface Solutions Laboratory, Toxics Use Reduction Institute (TURI), University of Massachusetts Lowell. *VA Hospital Floor Finish Stripping using Biobased Products*. University of Massachusetts Lowell. 2007.
4. Surface Solutions Laboratory, Toxics Use Reduction Institute (TURI), University of Massachusetts Lowell. *VA Hospital Hard Surface Cleaning using Biobased Products*. University of Massachusetts Lowell. 2007.
5. Surface Solutions Laboratory, Toxics Use Reduction Institute (TURI), University of Massachusetts Lowell. 2006. *Cleaner-Solutions Database*. Available at: http://www.turi.org/laboratory/cleanersolutions_database. Accessed: 01/23/09.
6. Surface Solutions Laboratory, Toxics Use Reduction Institute (TURI), University of Massachusetts Lowell. *Ten ways to find safer and greener cleaners*. 2006. TURI website. http://www.turi.org/laboratory/cleaning_chemistry_basics/ten_tips_to_find_safer_cleaners. Accessed: 04/02/09.
7. Quinn, MM, Fuller, TP, Bello, A, Galligan, CJ. *Pollution prevention—occupational safety and health in hospitals: alternatives and interventions*. J Occup Environ Hyg 2006. 3(4):182-93; quiz D45.
8. Hoppin, P, Donahue, S. *Improving Asthma Management by Addressing Environmental Triggers: Challenges and Opportunities for Delivery and Financing*. Symposium Edition. Asthma Regional Council of New England. 2004.
9. Hoppin, P, Jacobs, M, Ribble, M. *Enhancing Asthma Management Using In-Home Environmental Interventions: A Review of Public Health Department Programs*. Asthma Regional Council of New England. 2006.
10. Hoppin, P, Jacobs, M, Stillman, L. *Investing in Best Practices for Asthma: A Business Case for Education and Environmental Interventions*. Asthma Regional Council. 2007. <http://www.sustainableproduction.org/downloads/InvestinginBestPracticesforAsthma.pdf>. Accessed: 04/02/09.
11. Toxics Use Reduction Institute (TURI), University of Massachusetts Lowell. *Current community grant projects*. 2009. TURI website. Available at: http://www.turi.org/community/grants/further_information/current_projects. Accessed: 04/02/09.
12. Dancer, SJ. *Mopping up hospital infection*. J Hosp Infect. 1999. 43(2):85-100.
13. Klevens, RM, Edwards, JR, Richards, CL, Jr., Horan, TC, Gaynes, RP, Pollock, DA, Cardo, DM. *Estimating health care-associated infections and deaths in U.S. hospitals, 2002*. Public Health Rep. 2007. 122(2):160-6.
14. Klein, E, Smith, DL, Laxminarayan, R. *Hospitalizations and deaths caused by methicillin-resistant Staphylococcus aureus, United States, 1999-2005*. Emerg Infect Dis. 2007. 13(12):1840-6.
15. Bello, A. *Assessment of Exposures to Cleaning Product Ingredients Used for Common Cleaning Tasks*. Doctoral dissertation. Department of Work Environment. University of Massachusetts Lowell. 2008.
16. Office of the Federal Environmental Executive. *Green cleaning pollution prevention calculator*. US Environmental Protection Agency.OFEE website. Available at: <http://www.ofee.gov/janitor/index.asp>. Accessed: 04/02/09.
17. US Federal Register. The White House. *The President's Executive Order 13101—Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition*, Executive Order 13101. 1998. Available at: <http://www.epa.gov/epp/pubs/13101.pdf>. Accessed: 04/02/09.
18. Beaver, M. *Healthcare facilities hesitantly embrace green cleaning principles and products*. Infection Control Today 2007. 05/31/07):05/31/07. Available at: <http://www.infectioncontroltoday.com/articles/399/77h1614381641757.html>. Accessed: 04/02/09.
19. US Environmental Protection Agency, Environmentally Preferable Purchasing Program, Office of Pollution Prevention and Toxics. *Cleaning products pilot project*. Washington DC: 1997. Available at: <http://www.epa.gov/epp/pubs/cleaner.pdf>. Accessed: 04/02/09.
20. Furness, DA. *LEED rules studied for health care: Green Building Council focusing on benefits to patients, environment*. North Bay Business Journal. 12/15/08. Available at: <http://www.northbaybusinessjournal.com/article/20081215/BUSINESSJOURNAL/812140246>. Accessed: 04/02/09.
21. U.S. Environmental Protection Agency, Program, RPP. *Using Microfiber Mops in Hospitals*. 2002. Available at: http://www.textileinnovations.com/PDF/using_microfiber_mops_hospitals.pdf. Accessed: 01/23/09.
22. Sustainable Hospitals Program (SHP), Lowell Center for Sustainable Production. *10 reasons to use microfiber mopping*. 2003. Factsheet on SHP website. Available at: <http://www.sustainablehospitals.org/PDF/tenreasonsmop.pdf>. Accessed: 04/02/09.
23. Desa, J, Bello, A, Galligan, C, Fuller, T, Quinn, M. *Case study: are microfiber mops beneficial for hospitals* 2004. Sustainable Hospitals Project (SHP), Lowell Center for Sustainable Production. .SHP website. Available at: <http://www.sustainablehospitals.org/PDF/MicrofiberMopCS.pdf>. Accessed: 04/02/09.
24. Rutala, WA, Gergen, MF, Weber, DJ. *Microbiologic evaluation of microfiber mops for surface disinfection*. Am J Infect Control. 2007. 35(9):569-73.
25. US Federal Register. US Department of Health and Human Services, Centers for Medicare and Medicaid Services. *Proposed Changes to the Hospital Inpatient Prospective Payment Systems and Fiscal Year 2009*, CMS-1390-P. 2008. Available at: <http://edocket.access.gpo.gov/2008/pdf/08-1135.pdf>. Accessed: 04/02/09.
26. Carling, PC, Parry, MF, Von Beheren, SM. *Identifying opportunities to enhance environmental cleaning in 23 acute care hospitals*. Infect Control Hosp Epidemiol. 2008. 29(1):1-7.
27. Hospitals for a Healthy Environment. *H2E's Ten Step Guide to Green Cleaning Implementation*. 2006. Available at: <http://www.h2e-online.org/docs/h2e10stepgreenclean-r5.pdf>. Accessed: 04/02/09.
28. Culver, A, Feinberg, M, Klebenov, D, Musnikow, J, Sutherland, L. *Cleaning for Health: Products and Practices for a Safer Indoor Environment*. INFORM, Inc. 2002. Available at: <http://informinc.org/reportpdfs/chp/CleaningForHealth.pdf>. Accessed: 04/02/09.

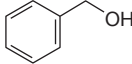

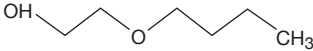
29. Center for Maximum Potential Building Systems, Practice Greenhealth. *Green Guide for Health Care (Green Guide): Version 2.2, Operations Section*. Green Guide for Health Care. 2008.
30. Gunther, R, Vittori, G. *Sustainable Healthcare Architecture*. Hoboken, New Jersey: John Wiley & Sons, Inc, 2008.
31. Minnesota Technical Assistance Program (MnTap), University of Minnesota. *Improving cleaning processes at Olmsted Medical Center*. 2008. Available at: <http://mntap.umn.edu/health/129IS.OMC.2007.pdf>. Accessed: 04/02/09.
32. U.S. Environmental Protection Agency, Environmentally Preferable Purchasing Program. *Cleaning Products Pilot Project*. Toxics OoPPa. Washington DC: 1997. Available at: <http://www.epa.gov/epp/pubs/cleaner.pdf>. Accessed: 01/29/09.
33. US Environmental Protection Agency, Region 9 Janitorial Pollution Prevention Project. *How to Select and Use Safe Janitorial Chemicals*. California EPA. 1999. Available at: <http://www.wrppn.org/Janitorial/05%20Report.pdf>. Accessed: 04/02/09.
34. Practice Greenhealth. *Green cleaning* Practice Greenhealth website. Available at: <http://cms.h2e-online.org/ee/facilities/greencleaning/>. Accessed: 04/02/09.
35. Rutala, WA, Weber, DJ, The Healthcare Infection Control Practices Advisory Committee (HICPAC). *Guideline for Disinfection and Sterilization in Healthcare Facilities*, 2008. US Department of Health and Human Services, Centers for Disease Control and Prevention (CDC). 2008. Available at: http://www.cdc.gov/ncidod/dhqp/pdf/guidelines/Disinfection_Nov_2008.pdf. Accessed: 04/02/09.
36. Sehulster, L, Chinn, R, Arduino, M, Carpenter, J, Donlan, R, Ashford, D, Besser, R, Fields, B, McNeil, M, Whitney, C, Wong, S, Juranek, D, Cleveland, J. *Guidelines for environmental infection control in health-care facilities. Recommendations from CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC)*. US Department of Health and Human Services, Centers for Disease Control and Prevention (CDC). Chicago IL: American Society for Healthcare Engineering/ American Hospital Association 2003. http://www.cdc.gov/ncidod/dhqp/pdf/guidelines/Enviro_guide_03.pdf. Accessed: 04/02/09.
37. US Environmental Protection Agency. *What are antimicrobial pesticides?* 2008. EPA website. Available at: http://www.epa.gov/oppad001/ad_info.htm. Accessed: 04/02/09.
38. Responsible Purchasing Network. *Responsible Purchasing Guide: Cleaners. 2nd Edition*. Center for a New American Dream. 2008. Available at: http://www.responsiblepurchasing.org/purchasing_guides/cleaners/purchasing_guide.pdf. Accessed: 04/02/09.
39. US Green Building Council. *LEED rating systems* 2008. USGBC website. Available at: <http://www.usgbc.org/DisplayPage.aspx?CMSPageID=222>. Accessed: 04/02/09.
40. US Green Building Council. *LEED initiatives in government and schools* 2009. USGBC website. Available at: <http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1852>. Accessed: 04/02/09.
41. Dharan, S, Mourouga, P, Copin, P, Bessmer, G, Tschanz, B, Pittet, D. *Routine disinfection of patients' environmental surfaces. Myth or reality?* J Hosp Infect. 1999. 42(2):113-7.
42. Rutala, WA, Weber, DJ. *Surface disinfection: should we do it?* J Hosp Infect. 2001. 48 Suppl A:S64-8.
43. Engelhart, S, Krizek, L, Glasmacher, A, Fischnaller, E, Marklein, G, Exner, M. *Pseudomonas aeruginosa outbreak in a haematology-oncology unit associated with contaminated surface cleaning equipment*. J Hosp Infect. 2002. 52(2):93-8.
44. Ruden, H, Daschner, F. *Should we routinely disinfect floors?* J Hosp Infect. 2002. 51(4):309; author reply 309-11.
45. Daschner, F, Schuster, A. *Disinfection and the prevention of infectious disease: no adverse effects?* Am J Infect Control. 2004. 32(4):224-5.
46. Daschner, FD, Schuster, A, Dettenkofer, M, Kummerer, K. *No routine surface disinfection*. Am J Infect Control. 2004. 32(8):513-5.
47. Dettenkofer, M, Wenzler, S, Amthor, S, Antes, G, Motschall, E, Daschner, FD. *Does disinfection of environmental surfaces influence nosocomial infection rates? A systematic review*. Am J Infect Control. 2004. 32(2):84-9.
48. Rutala, WA, Weber, DJ. *The benefits of surface disinfection*. Am J Infect Control. 2005. 33(7):434-5.
49. Weber, DJ, Sickbert-Bennett, EE, Vinje, J, Brown, VM, MacFarquhar, JK, Engel, JP, Rutala, WA. *Lessons learned from a norovirus outbreak in a locked pediatric inpatient psychiatric unit*. Infect Control Hosp Epidemiol. 2005. 26(10):841-3.
50. Vitali, M, Agolini, G. *Prevention of infection spreading by cleaning and disinfecting: Different approaches and difficulties in communicating*. Am J Infect Control. 2006. 34(1):49-50.
51. Carling, PC, Briggs, JL, Perkins, J, Highlander, D. *Improved cleaning of patient rooms using a new targeting method*. Clin Infect Dis. 2006. 42(3):385-8. Epub 2005 Dec 29.
52. Goodman, ER, Platt, R, Bass, R, Onderdonk, AB, Yokoe, DS, Huang, SS. *Impact of an environmental cleaning intervention on the presence of methicillin-resistant Staphylococcus aureus and vancomycin-resistant enterococci on surfaces in intensive care unit rooms*. Infect Control Hosp Epidemiol. 2008. 29(7):593-9.
53. Drees, M, Snyderman, DR, Schmid, CH, Barefoot, L, Hansjosten, K, Vue, PM, Cronin, M, Nasraway, SA, Golan, Y. *Prior environmental contamination increases the risk of acquisition of vancomycin-resistant enterococci*. Clin Infect Dis. 2008. 46(5):678-85.
54. Anonymous. *Cleaning of patient rooms, a persistent challenge, prompts innovative methods to evaluate effectiveness*. Premier Safety Share. Available at: <http://www.premierinc.com/quality-safety/tools-services/safety/safety-share/09-08-full-txt.jsp#story-03>. Accessed: 04/01/09.
55. Lehman, D. *Clean and green: Implementing environmentally friendly cleaning practices*. Health Facil Manage 2003. 16(3):48-51.
56. Fisher, JM. *Healthcare and social assistance sector*. J Safety Res 2008. 39(2):179-81.
57. Stewart, AG, Carter, J. *Towards the development of a multidisciplinary understanding of the effects of toxic chemical mixtures on health*. Environ Geochem Health 2008. 21:21.
58. Pohl, HR, Abadin, HG. *Chemical mixtures: evaluation of risk for child-specific exposures in a multi-stressor environment*. Toxicol Appl Pharmacol. 2008. 233(1):116-25. Epub 2008 Jan 31.
59. Wolkoff, P, Schneider, T, Kildeso, J, Degerth, R, Jaroszewski, M, Schunk, H. *Risk in cleaning: chemical and physical exposure*. Sci Total Environ. 1998. 215(1-2):135-56.
60. Cicolella, A. *[Volatile Organic Compounds (VOC): definition, classification and properties]*. Rev Mal Respir. 2008. 25(2):155-63.
61. Nielsen, GD, Larsen, ST, Olsen, O, Lovik, M, Poulsen, LK, Glue, C, Wolkoff, P. *Do indoor chemicals promote development of airway allergy?* Indoor Air. 2007. 17(3):236-55.
62. Air Resources Board California. Office of Administrative Law. *Air Cleaner Regulation AB 2276*. 2008. Available at: <http://www.arb.ca.gov/research/indoor/aircleaners/aircleaners.htm>. Accessed: 04/02/09.
63. Cicolella, A. *Glycol ethers: a ubiquitous family of toxic chemicals: a plea for REACH regulation*. Ann N Y Acad Sci. 2006. 1076:784-9.

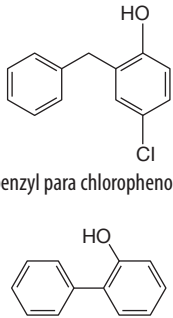
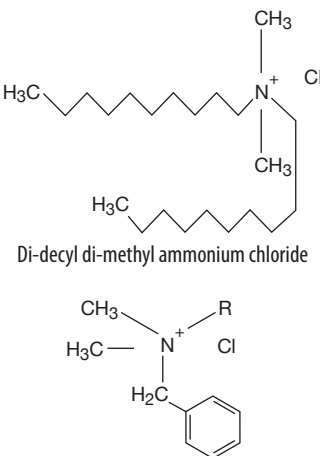
64. Cicolella, A. [Glycol ethers reproductive risks]. *Gynecol Obstet Fertil*. 2006. 34(10):955-63. Epub 2006 Sep 20.
65. Exner, M, Vacata, V, Hornei, B, Dietlein, E, Gebel, J. *Household cleaning and surface disinfection: new insights and strategies*. *J Hosp Infect*. 2004. 56 Suppl 2:S70-5.
66. Singer, BC, Destailhats, H, Hodgson, AT, Nazaroff, WW. *Cleaning products and air fresheners: emissions and resulting concentrations of glycol ethers and terpenoids*. *Indoor Air*. 2006. 16(3):179-91.
67. Starek, A. *Studies on the nature of hemolytic effect induced by ethylene glycol alkyl ethers*. *Acta Pol Pharm*. 2008. 65(4):421-5.
68. Starek, A, Szabla, J. [Ethylene glycol alkyl ethers--the substances noxious to health]. *Med Pr* 2008. 59(2):179-85.
69. National Toxicology Program. *NTP Toxicology and Carcinogenesis Studies 2-Butoxyethanol (CAS NO. 111-76-2) in F344/N Rats and B6C3F1 Mice (Inhalation Studies)*. *Natl Toxicol Program Tech Rep Ser*. 2000. 484:1-290.
70. Purohit, A, Kopferschmitt-Kubler, MC, Moreau, C, Popin, E, Blaumeiser, M, Pauli, G. *Quaternary ammonium compounds and occupational asthma*. *Int Arch Occup Environ Health*. 2000. 73(6):423-7.
71. Vincent, G, Kopferschmitt-Kubler, MC, Mirabel, P, Pauli, G, Millet, M. *Sampling and analysis of quaternary ammonium compounds (QACs) traces in indoor atmosphere*. *Environ Monit Assess*. 2007. 133(1-3):25-30. Epub 2006 Dec 16.
72. Stern, ML, Brown, TA, Brown, RD, Munson, AE. *Contact hypersensitivity response to o-benzyl-p-chlorophenol in mice*. *Drug Chem Toxicol* 1991. 14(3):231-42.
73. Savonius, B, Keskinen, H, Tuppurainen, M, Kanerva, L. *Occupational asthma caused by ethanalamines*. *Allergy*. 1994. 49(10):877-81.
74. Medina-Ramon, M, Zock, JP, Kogevinas, M, Sunyer, J, Torralba, Y, Borrell, A, Burgos, F, Anto, JM. *Asthma, chronic bronchitis, and exposure to irritant agents in occupational domestic cleaning: a nested case-control study*. *Occup Environ Med*. 2005. 62(9):598-606.
75. Andersson, E, Olin, AC, Hagberg, S, Nilsson, R, Nilsson, T, Toren, K. *Adult-onset asthma and wheeze among irritant-exposed bleachery workers*. *Am J Ind Med*. 2003. 43(5):532-8.
76. Medina-Ramon, M, Zock, JP, Kogevinas, M, Sunyer, J, Basagana, X, Schwartz, J, Burge, PS, Moore, V, Anto, JM. *Short-term respiratory effects of cleaning exposures in female domestic cleaners*. *Eur Respir J*. 2006. 27(6):1196-203. Epub 2006 Mar 1.
77. Seigel, J. OSHA: Masks worn in fumes deaths unsafe. *Chicago Tribune*. 02/09/89.
78. Bernstein, JA, Stauder, T, Bernstein, DI, Bernstein, IL. *A combined respiratory and cutaneous hypersensitivity syndrome induced by work exposure to quaternary amines*. *J Allergy Clin Immunol*. 1994. 94(2 Pt 1):257-9.
79. Burge, PS, Richardson, MN. *Occupational asthma due to indirect exposure to lauryl dimethyl benzyl ammonium chloride used in a floor cleaner*. *Thorax*. 1994. 49(8):842-3.
80. de Fatima Macaira, E, Algranti, E, Medina Coeli Mendonca, E, Antonio Bussacos, M. *Rhinitis and asthma symptoms in non-domestic cleaners from the Sao Paulo metropolitan area, Brazil*. *Occup Environ Med*. 2007. 64(7):446-53. Epub 2007 Feb 15.
81. Delclos, GL, Gimeno, D, Arif, AA, Burau, KD, Carson, A, Lusk, C, Stock, T, Symanski, E, Whitehead, LW, Zock, JP, Benavides, FG, Anto, JM. *Occupational risk factors and asthma among health care professionals*. *Am J Respir Crit Care Med*. 2007. 175(7):667-75. Epub 2006 Dec 21.
82. Karjalainen, A, Martikainen, R, Karjalainen, J, Klaukka, T, Kurppa, K. *Excess incidence of asthma among Finnish cleaners employed in different industries*. *Eur Respir J*. 2002. 19(1):90-5.
83. Kogevinas, M, Anto, JM, Sunyer, J, Tobias, A, Kromhout, H, Burney, P. *Occupational asthma in Europe and other industrialised areas: a population-based study*. *European Community Respiratory Health Survey Study Group*. *Lancet*. 1999. 353(9166):1750-4.
84. Kopferschmitt-Kubler, MC, Ameille, J, Popin, E, Calastreng-Crinquand, A, Vervloet, D, Bayeux-Dunglas, MC, Pauli, G. *Occupational asthma in France: a 1-yr report of the observatoire National de Asthmes Professionnels project*. *Eur Respir J*. 2002. 19(1):84-9.
85. Le Moual, N, Kennedy, SM, Kauffmann, F. *Occupational exposures and asthma in 14,000 adults from the general population*. *Am J Epidemiol*. 2004. 160(11):1108-16.
86. Medina-Ramon, M, Zock, JP, Kogevinas, M, Sunyer, J, Anto, JM. *Asthma symptoms in women employed in domestic cleaning: a community based study*. *Thorax*. 2003. 58(11):950-4.
87. Pechter, E, Davis, LK, Tumpowsky, C, Flattery, J, Harrison, R, Reinisch, F, Reilly, MJ, Rosenman, KD, Schill, DP, Valiante, D, Filios, M. *Work-related asthma among health care workers: surveillance data from California, Massachusetts, Michigan, and New Jersey, 1993-1997*. *Am J Ind Med*. 2005. 47(3):265-75.
88. Reinisch, F, Harrison, RJ, Cussler, S, Athanasoulis, M, Balmes, J, Blanc, P, Cone, J. *Physician reports of work-related asthma in California, 1993-1996*. *Am J Ind Med*. 2001. 39(1):72-83.
89. Rosenman, KD, Reilly, MJ, Schill, DP, Valiante, D, Flattery, J, Harrison, R, Reinisch, F, Pechter, E, Davis, L, Tumpowsky, CM, Filios, M. *Cleaning products and work-related asthma*. *J Occup Environ Med*. 2003. 45(5):556-63.
90. Zock, JP, Kogevinas, M, Sunyer, J, Almar, E, Muniozguren, N, Payo, F, Sanchez, JL, Anto, JM. *Asthma risk, cleaning activities and use of specific cleaning products among Spanish indoor cleaners*. *Scand J Work Environ Health*. 2001. 27(1):76-81.
91. Zock, JP, Kogevinas, M, Sunyer, J, Jarvis, D, Toren, K, Anto, JM. *Asthma characteristics in cleaning workers, workers in other risk jobs and office workers*. *Eur Respir J*. 2002. 20(3):679-85.
92. Delclos, GL, Gimeno, D, Arif, AA, Benavides, FG, Zock, JP. *Occupational exposures and asthma in health-care workers: Comparison of self-reports with a workplace-specific job exposure matrix*. *Am J Epidemiol* 2009. 6:6.
93. Gawkrödger, DJ, Lloyd, MH, Hunter, JA. *Occupational skin disease in hospital cleaning and kitchen workers*. *Contact Dermatitis*. 1986. 15(3):132-5.
94. Stingeni, L, Lapomarda, V, Lisi, P. *Occupational hand dermatitis in hospital environments*. *Contact Dermatitis*. 1995. 33(3):172-6.
95. Kumar, R, Chaikumarn, M, Lundberg, J. *Participatory ergonomics and an evaluation of a low-cost improvement effect on cleaners' working posture*. *Int J Occup Saf Ergon* 2005. 11(2):203-10.
96. Andrade, CB, Monteiro, MI. [Aging and work ability of workers of a university hospital's cleaning and hygiene service]. *Rev Esc Enferm USP*. 2007. 41(2):237-44.
97. De Vito, G, Molteni, G, Camerino, D, Bordini, L, Molinari, M, Capodaglio, P. [Aging and work: health aspects in cleaners]. *Med Lav*. 2000. 91(4):387-402.
98. Gamperiene, M, Nygard, JF, Brage, S, Bjerkedal, T, Bruusgaard, D. *Duration of employment is not a predictor of disability of cleaners: a longitudinal study*. *Scand J Public Health* 2003. 31(1):63-8.
99. Unge, J, Ohlsson, K, Nordander, C, Hansson, GA, Skerfving, S, Balogh, I. *Differences in physical workload, psychosocial factors and musculoskeletal disorders between two groups of female hospital cleaners with two diverse organizational models*. *Int Arch Occup Environ Health*. 2007. 81(2):209-20. Epub 2007 Jun 13.

100. Bello, A, Quinn, MM, Perry, MJ, Milton, DK. *Characterization of occupational exposures to cleaning products used for common cleaning tasks-a pilot study of hospital cleaners*. Environ Health. 2009. 8(1):11.
101. OneSource. *OneSource knows green cleaning*. Available at: <http://www.one-source.com/en/green-cleaning.html>. Accessed: 04/02/09.
102. Hospitals for a Healthy Environment. *Success story: Green cleaning. Hackensack University Medical Center greens its cleaning practices and wins environmental award*. STAT Green: The Hospitals for a Healthy Environment Newsletter 2005. 2(8):8. Available at: <http://www.h2e-online.org/docs/h2estat-green80105.pdf>. Accessed: 04/02/09.
103. US Environmental Protection Agency, Region 9 Pollution Prevention Program. *Using microfiber mops in hospitals*. 2002. EPA website. Available at: http://www.textileinnovations.com/PDF/using_microfiber_mops_hospitals.pdf. Accessed: 04/02/09.
104. Anonymous. *New York hospitals implement green cleaning*. Healthcare Purchasing News 2004. Available at: http://findarticles.com/p/articles/mi_m0BPC/is_8_28/ai_n6156514/pg_1?tag=artBody;col1. Accessed: 04/02/09.
105. Crothall Services Group. *The 'greening' of environmental services: Jersey Shore University Medical Center is 'earth & people-friendly'*. Available at: http://www.crothall.com/inside/case_studies/EVS_JSUMC_casestudy.pdf. Accessed: 04/02/09.
106. Crothall Services Group. *Going green and staying clean*. Available at: http://www.crothall.com/inside/case_studies/EVS_Suburban_casestudy.pdf. Accessed: 04/02/09.
107. Latter, C. *Finding a Balance*. Prevention Strategist. Publication of APIC Inc, Washington DC. 2008. 1(2).
108. Bartley, J. *Facility managers dilemmas: crossroads for infection prevention, green, and safety*. White paper. American Society for Healthcare Engineering Annual Conference. American Society for Healthcare Engineering Annual Conference. Washington DC. July 22, 2008.
109. US Environmental Protection Agency. *Consumer products treated with pesticides*. 2008.EPA website. Available at: <http://www.epa.gov/pesticides/factsheets/treatart.htm>. Accessed: 04/02/09.
110. BioCanadian. *Are There Green-Certified Disinfectants?* 2009. Press release on BioCanadian website. Available at: <http://www.biocanadian.com/english/press/tag/green-disinfectants>. Accessed: 04/02/09.
111. The Ashkin Group. *EPA announces "internal pilot" for green disinfectant claims*. Infection Control Today 2009. Available at: <http://www.infectioncontroltoday.com/hotnews/green-disinfectant-claims.html>. Accessed: 04/02/09.
112. Ashkin, SP. *Green cleaning in hospitals: cleaning to protect health without harming the environment* Available at: www.h2e-online.org/pubs/grncleaning.ppt. Accessed: 04/02/09.
113. Wooding, J, Levenstein, C. *The Point of Production: Work Environment in Advanced Industrial Societies*. New York: The Guildford Press, 1999.
114. Hermans, LM. *Dynamic actor network analysis for diffuse pollution in the province of North-Holland*. Water Sci Technol 2004. 49(3):205-12.
115. Timpka, T, Bang, M, Delbanco, T, Walker, J. *Information infrastructure for inter-organizational mental health services: an actor network theory analysis of psychiatric rehabilitation*. J Biomed Inform. 2007. 40(4):429-37. Epub 2006 Nov 17.
116. Williams-Jones, B, Graham, JE. *Actor-network theory: a tool to support ethical analysis of commercial genetic testing*. New Genet Soc. 2003. 22(3):271-96.
117. Markkanen, P, Levenstein, C. *New points of production: home-work and shoemaking in Asia*. New Solut 2004. 14(4):301-18.
118. Green Seal, I. *Green Seal™ Environmental Standard for Industrial and Institutional Cleaners (GS-37)*, 2008. Available at: http://www.greenseal.org/certification/standards/GS37_Industrial_Cleaner_Standard.pdf. Accessed: 04/02/09.
119. Green Seal, I. *GS-40 Green Seal™ Environmental Standard for Industrial and Institutional Floor-Care Products*, 2004. Available at: http://www.greenseal.org/certification/standards/industrial_institutional_floor_care_GS_40.pdf. Accessed: 04/02/09.
120. Green Seal, I. *GS-37 Update: Green Seal™ Environmental Standard for Industrial and Institutional Cleaners*. 2008.Green Seal website. Available at: http://www.greenseal.org/resources/g37_overview.pdf. Accessed: 04/02/09.
121. Environment Canada's Environmental Choice Program. *Certification Criteria Document: CCD-166. Product: Disinfectants and Disinfectant-Cleaners*. 2008. Available at: <http://www.ecologo.org/common/assets/criterias/CCD-166.pdf>. Accessed: 04/02/09.
122. Hota, S, Hirji, Z, Stockton, K, Lemieux, C, Dedier, H, Wolfaardt, G, Gardam, MA. *Outbreak of multidrug-resistant Pseudomonas aeruginosa colonization and infection secondary to imperfect intensive care unit room design*. Infect Control Hosp Epidemiol. 2009. 30(1):25-33.
123. Pyrek, KM. *Green Cleaning and Infection Control: An Expert Roundtable Discusses the Issues*. Infection Control Today 2008. Available at: <http://www.infectioncontroltoday.com/articles/green-cleaning-roundtable.html>. Accessed: 01/23/09.
124. Schafer, MP, Kujundzic, E, Moss, CE, Miller, SL. *Method for estimating ultraviolet germicidal fluence rates in a hospital room*. Infect Control Hosp Epidemiol. 2008. 29(11):1042-7.
125. Leung, M, Chan, AH. *Control and management of hospital indoor air quality*. Med Sci Monit. 2006. 12(3):SR17-23. Epub 2006 Feb 23.
126. Latter, C. *Green by design*. Prevention Strategist. Publication of APIC Inc, Washington DC. 2008. 1(4):36-40.
127. Markkanen, P, Quinn, M, Galligan, C, Chalupka, S, Davis, L, Laramie, A. *There's no place like home: a qualitative study of the working conditions of home health care providers*. J Occup Environ Med. 2007. 49(3):327-37.

APPENDIX A: EXAMPLES OF HAZARDOUS INGREDIENTS IN CONVENTIONAL CLEANING PRODUCTS

The below table is a modified version published by Bello et al in Environmental Health, 2009.¹
At the end, the table by Premier Safety Institute clarifies bleach dilutions with household measurement terms.²

Name	Chemical formula	Physicochemical properties	Respiratory , skin, mucous membrane (eye) effects	Other health effects	Purpose of use in cleaning products
Alcohols	<p>Examples :</p>  <p>Benzyl alcohol</p>  <p>Isopropyl alcohol</p> <p>CH₃CH₂OH Ethanol (ethyl alcohol)</p>	<p>Boiling point (BP): 205 °C</p> <p>BP: 82.5 °C</p>	<p>Isopropyl alcohol: Highly volatile. Irritant to eyes and the upper respiratory tract. Prolonged exposure may cause lung damage.³</p> <p>Ethanol and isopropyl alcohol are absorbed through the skin and can irritate the skin, eyes, upper respiratory tract, and throat.⁴</p>	<p>Benzyl alcohol has been reported as a contact allergen in cleaning products.^{5,6}</p>	<p>Used as solvents and disinfectants in cleaning products.⁴</p>
Ammonia	<p>NH₃</p>	<p>Found in aqueous solutions in the form of ammonium hydroxide.</p> <p>(BP): -33.5 °C</p>	<p>Highly irritating. Inhalation of its vapors can irritate the nose, throat, and lungs, causing wheezing and shortness of breath. Prolonged exposure can cause bronchitis.^{3,7}</p>	<p>No evidence of sensitization was found.¹</p>	<p>Used in glass cleaners.¹</p>
Ethanolamine	<p>H₂N-CH₂-CH₂-OH</p> <p>Ethanolamine (MEA, mono-ethanol amine, 2-aminoethanol),</p>	<p>BP: 170.8 °C</p>	<p>Breathing its vapors can irritate the nose, throat and lungs, causing coughing, wheezing and shortness of breath.³</p> <p>It is a skin irritant and can be absorbed through the skin.⁸ Can cause skin sensitization.³</p>	<p>Exposure to ethanolamine has been associated with occupational asthma.⁹</p>	<p>Used as surfactant in cleaning products.¹ Used in floor care products, general purpose, glass, and bathroom cleaners.¹</p>
Ethylene glycol ethers	<p>Examples :</p>  <p>2-Butoxyethanol (2-BE, ethylene glycol monobutyl ether, butyl "Cellosolve)</p>	<p>2-BE (BP):168 °C</p>	<p>2-BE vapors are irritants to eyes and respiratory tract.¹⁰ Class A3 : Confirmed animal carcinogen with unknown relevance to humans.¹¹</p> <p>2-BE is a skin irritant. Absorbed in the body through skin¹² - an important exposure route.¹³</p>	<p>2-BE is a toxic chemical.⁸ Ethylene glycol alkyl ethers target the central nervous system, blood and blood-forming organs, and reproductive system.¹⁰</p>	<p>Used as solvent in cleaning products to dissolve fatty substances.¹ Mostly used in glass, general purpose cleaners, and floor care products.¹</p>

Name	Chemical formula	Physicochemical properties	Respiratory , skin, mucous membrane (eye) effects	Other health effects	Purpose of use in cleaning products
Inorganic Chlorine compounds	<p>Examples:</p> <p>Bleach: 5.25 - 6.15% solution of sodium hypochlorite.²</p> <p>Na-O-Cl</p> <p>Hydrochloric acid H-Cl</p>	<p>Bleach is highly toxic when mixed with ammonia or ammonium quaternary compounds, generating chloramine gas.⁴ Can form chlorine gas when mixed/ used in conjunction with strong acids (e.g., toilet bowl cleaners).⁴ Fire risk in contact with organic materials.³ Store separately from other cleaning products.</p>	<p>Breathing a high concentration of chlorine can irritate the lungs.⁴ Particularly dangerous for people with heart conditions or chronic respiratory problems such as asthma or emphysema.⁴ Concentrated hypochlorite can cause corrosive damage to the skin and nails. Concentration below 5.25% not corrosive unless exposure occurs over a long period.⁴</p>	<p>Strong tissue irritant.⁸ Concentrated bleach can cause corrosive damage to the eyes and mucous membranes.⁴ Chlorine bleach often manufactured using a mercury cell process, leaving contaminant mercury in the product.⁴</p>	<p>Bleach is a commonly used disinfectant in medical, commercial, and household settings.¹</p>
Oxidizers	<p>Example:</p> <p>H₂O₂ Hydrogen peroxide</p> <p>Most commercial janitorial cleaners do not contain over 10% hydrogen peroxide.⁴</p>	<p>Concentrated solutions are highly reactive and have low flash points.⁴ Explosion hazard and must be stored carefully and away from other combustible materials and other chemicals.⁴</p>	<p>Corrosive to the skin over 50% concentrations, irreversible eye damage over 10% concentrations.⁴ Ready-to-use dilutions contain less than 2% percent hydrogen peroxide - which is not irritating to the skin unless other irritating ingredients are present. At high concentrations, irritates the nose, throat, and lungs.⁴</p>	<p>Classified as "mutagenic," however, no evidence that exposure to the concentrations found in cleaning products would cause mutagenic damage in humans.⁴</p>	<p>Hydrogen peroxide considered more green due to fewer toxic characteristics than, for example quaternary ammonium or chlorine compounds.⁴</p>
Phenols/Chlorinated phenols	 <p>Ortho benzyl para chlorophenol (OBPC)</p> <p>Ortho phenyl phenol (OPP) and p-tert-amylphenol.</p>	<p>OBPC BP: 160-162 °C</p> <p>OPP BP: 286 °C</p>	<p>Irritant to eyes and respiratory tract when inhaled.¹⁴ Even at low concentrations is extremely irritating to the skin. Repeated skin contact can cause dryness, itching and redness. Can penetrate the skin.³</p> <p>Skin irritant. Occupational exposures may happen mostly through dermal contact.³</p> <p>p-tert-amylphenol can be absorbed through the skin.</p>	<p>Sensitivity potential reported from animal studies.¹⁵ OPP is listed as a carcinogen in California.^{4,16}</p>	<p>Phenols are used as disinfectants in cleaning products – many considered effective against tuberculosis.¹⁷</p>
Quaternary ammonium Compounds (quats)	<p>Examples :</p>  <p>Di-decyl di-methyl ammonium chloride</p> <p>N Alkyl dimethyl benzyl ammonium chloride (benzalkonium chloride)</p>	<p>Quaternary ammonium compounds are salts that are soluble in water and alcohol.³</p>	<p>Because quats are not volatile, inhalation exposures can happen through products' aerosolization.¹ Commonly used solutions can cause nose and throat irritation. Benzalkonium chloride is a severe eye irritant.³</p> <p>Limited evidence implicates quats in the development of allergic responses and occupational asthma.^{18,19} Exposures to benzalkonium chloride have been associated with combined respiratory and dermal hypersensitivity.²⁰</p> <p>Benzalkonium chloride is a primary skin irritant in solutions of less than 10%. Exposures to quats may cause allergic reactions to skin.²⁰</p>	<p>Benzalkonium chloride suspected gastrointestinal and liver toxicant, and other quaternary ammonium compounds may have the same attributes.⁴</p>	<p>Used as a low-level disinfectant. High level of disinfection is achieved if different quats and alcohols are mixed.¹ Mostly used in bathroom, floor, and general purpose cleaners.¹</p>

Bleach dilutions clarified with household measurement terms

The Premier Safety Institute provided the CDC Guidelines with bleach dilutions using household measurement terms and equivalent parts per million (ppm) that can be used to translate recommendations for use in the patient care setting for environmental decontamination after cleaning, e.g., for *Clostridium difficile*. Below table presents the Premier Safety Institute's expanded information that includes the bleach in dietary settings consistent with EPA regulations (21 CFR Part 178).²

Bleach solution	Dilution exact	Chlorine (ppm)	Dilution approximate	Household (ppm) approximate	Application
5.25% - 6.15%	Concentrate	52,500 - 61,500	Concentrate	52,500 - 61,500	*Patient Care
5.25% - 6.15%	1:10	5,250 - 6,150	1.5 cups/ 1 gallon	~6000	*Patient Care
5.25% - 6.15%	1:100	525-615	0.25 cup/ 1 gallon	~600	*Patient Care
5.25%	1:200	263	1 tablespoon/ 1 gallon	<200	*Dietary
5.25% - 6.15%	1:1000	53-62	1 teaspoon/ 1 gallon	~50	*Dietary

Source: Premier Safety Institute, <http://www.premierinc.com/quality-safety/tools-services/safety/topics/cdad/cleaning.jsp>

References cited in Appendix A

- Bello, A, Quinn, MM, Perry, MJ, Milton, DK. *Characterization of occupational exposures to cleaning products used for common cleaning tasks-a pilot study of hospital cleaners*. Environ Health. 2009. 8(1):11.
- Premier Safety Institute. *Environmental cleaning*. 2008. Premier Safety Institute website. Available at: <http://www.premierinc.com/quality-safety/tools-services/safety/topics/cdad/cleaning.jsp>. Accessed: 04/01/09.
- National Library of Medicine. *Hazardous Substances Data Bank and ChemIDplus*. Environmental Health and Toxicology, Toxicological Data Network (Toxnet) National Institutes of Health (NIH), Bethesda MD.
- Culver, A, Feinberg, M, Klebenov, D, Musnikow, J, Sutherland, L. *Cleaning for Health: Products and Practices for a Safer Indoor Environment*. INFORM, Inc. 2002. Available at: <http://informinc.org/reportpdfs/chp/CleaningForHealth.pdf>. Accessed: 02/03/09.
- Flyvholm, MA. *Contact allergens in registered chemical products*. Contact Dermatitis 1991. 25(1):49-56.
- Flyvholm, MA. *Contact allergens in registered cleaning agents for industrial and household use*. Br J Ind Med 1993. 50(11):1043-50.
- Basil, AA, Hafiz, OA, Seifeddin, GB, Albar, AA. *Pulmonary function of workers exposed to ammonia*. Int J Occup Environ Health 2001. 7:19-22.
- Lewis, RJ. *Hawley's Condensed Chemical Dictionary*. Twelfth Edition edition. New York, NY: Van Nostrand Reinhold, 1993.
- Savonius, B, Keskinen, H, Tuppurainen, M, Kanerva, L. *Occupational asthma caused by ethanolamines*. Allergy. 1994. 49(10):877-81.
- Starek, A, Szabla, J. [*Ethylene glycol alkyl ethers--the substances noxious to health*]. Med Pr 2008. 59(2):179-85.
- American Conference of Governmental Industrial Hygienist (ACGIH). *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices* Cincinnati, OH 2008.
- Jakasa, I, Mohammadi, N, Kruse, J, Kezic, S. *Percutaneous absorption of neat and aqueous solutions of 2-butoxyethanol in volunteers*. Int Arch Occup Environ Health. 2004. 77(2):79-84. Epub 2003 Aug 12.
- Vincent, R, Cicolella, A, Surba, I, Reieger, B, Poirat, P, Pierre, F. *Occupational exposure to 2-butoxyethanol for workers using window cleaning agents*. Applied Occupational and Environmental Hygiene 1993. 8(6):580-586.
- Stouten, H, Bessems, JG. *Toxicological profile for o-benzyl-p-chlorophenol*. Journal of Applied Toxicology 1998. 18(4):271-9.
- Stern, ML, Brown, TA, Brown, RD, Munson, AE. *Contact hypersensitivity response to o-benzyl-p-chlorophenol in mice*. Drug Chem Toxicol 1991. 14(3):231-42.
- State of California, Environmental Protection Agency, Office of Environmental Health Hazard Assessment. *Safe Drinking Water and Toxic Enforcement Act of 1986. Chemicals known to the State to cause cancer or reproductive toxicity. December 19, 2008* Available at: http://www.oehha.org/prop65/prop65_list/files/P65single121908.pdf. Accessed: 04/03/09.
- Goddard, P, McCue, KA. *Penolic Compounds*. In: Block SS, ed. *Disinfection, sterilization, and preservation*. 5 edition Lippincott Williams & Wilkins, 2001;255-282.
- Purohit, A, Kopferschmitt-Kubler, MC, Moreau, C, Popin, E, Blaumeiser, M, Pauli, G. *Quaternary ammonium compounds and occupational asthma*. Int Arch Occup Environ Health. 2000. 73(6):423-7.
- Burge, PS, Richardson, MN. *Occupational asthma due to indirect exposure to lauryl dimethyl benzyl ammonium chloride used in a floor cleaner*. Thorax. 1994. 49(8):842-3.
- Bernstein, JA, Stauder, T, Bernstein, DI, Bernstein, IL. *A combined respiratory and cutaneous hypersensitivity syndrome induced by work exposure to quaternary amines*. J Allergy Clin Immunol. 1994. 94(2 Pt 1):257-9.

B. APPENDIX B: INFORMATION ON GREEN CLEANING EFFORTS IN HEALTHCARE FACILITIES

In January-February 2009, the SHP team conducted literature and web searches to identify information on healthcare facilities that have implemented green cleaning practices. Despite anecdotal information suggesting widespread implementation of green cleaning efforts, a relatively small number of healthcare facilities were identified through literature and web searches. Most of the existing sources merely indicated the implementation of green cleaning with few details. It is therefore difficult to assess the extent and comprehensiveness of implemented green cleaning efforts. These facilities were identified:

- Dartmouth-Hitchcock Medical Center (Lebanon, NH)¹
- Emerson Hospital (Concord, MA)²
- Good Samaritan Regional Medical Center (Corvallis, OR)³
- Hackensack University Medical Center (Hackensack, NJ)^{4,5}
- Jacobi Medical Center (New York, NY)⁶
- Jersey Shore University Medical Center (Neptune, NJ)⁷
- Kaiser Permanente (Oakland, CA)⁸
- Marianjoy Rehabilitation Hospital (Wheaton, IL)⁹
- McGill University Health Center (Montreal, Quebec)¹⁰
- New York Presbyterian (New York, NY)¹¹
- North Central Bronx (New York, NY)⁶
- Olmsted Medical Center (Rochester, MN)¹²
- Rockingham Memorial Hospital (Harrisonburg, VA)¹³
- Rush University Medical Center (Chicago, IL)¹⁴
- Seattle's Children's Hospital (Seattle, WA)¹⁵
- St. Vincent Hospital (Bridgeport, CT)¹⁶
- State University of New York Upstate Medical University (Syracuse, NY)¹⁷
- Suburban Hospital (Bethesda, MD)¹⁸
- University of California Davis Medical Center (Sacramento, CA)¹⁹

An inquiry to the Practice Greenhealth* listserv (accessible via paid membership and reaching approximately 2,000 members) revealed a few more hospitals reporting use of green cleaners. Perhaps more informative was the greater number of respondents asking us to share our findings about facilities with green cleaning practices. As of February 3, 2009, the additional green cleaning facilities identified via Practice Greenhealth listserv are the following:

- Lexington Medical Center (West Columbia SC)
- Sequoia Hospital (Redwood City, CA)
- St. John's Riverside Hospital (Yonkers, NY)

In summary, our search revealed challenges that healthcare facilities seeking to implement green cleaning practices would also encounter, include:

- Although there is anecdotal evidence of green cleaning becoming widespread in healthcare, these claims cannot be supported by literature or web searches;
- There is no publicly available (free-of -charge) central repository of healthcare facilities' green cleaning efforts;
- Facilities do not seem to be systematically collaborating or sharing their practices;
- The most useful sources we found included MnTAP intern summary¹², H2E Newsletter of 2005⁴, and the EPA fact sheet on microfiber mopping¹⁹ which provided some information about cost savings (pre- and post-implementation comparisons of financial impacts of green cleaning) as well as health and environmental benefits. However, we did not find any detailed documentation to serve as a model, provide guidance, or allow one to assess the effectiveness of green cleaning programs.

* Practice Greenhealth is a membership and networking organization for the healthcare community institutions (e.g., hospitals, healthcare systems, businesses, and other) committed to sustainable and eco-friendly practices.

References cited in Appendix B

1. Mollenkamp, B. *Green Cleaning: Housekeepers Continue to Embrace Philosophy*. HousekeepingSolutions 2005. April 2005 (Available at: <http://www.cleanlink.com/hs/article.asp?id=2759>. Accessed: 01/27/09).
2. Green Guide for Health Care™. *Green Guide for Health Care™ Announces New Senior Director*. Press Release email to GGHC listserv members. Communication 01/27/09: 01/27/09.
3. Hogue, T. *Seeking sustainability: Hospital hosts a program to create environmentally sound spaces*. Gazette-Times. 11/16/05. Available at: http://www.gazettetimes.com/articles/2005/11/17/news/top_story/news01.txt. Accessed: 01/29/09.
4. Hospitals for a Healthy Environment. *Success story: Green cleaning. Hackensack University Medical Center greens its cleaning practices and wins environmental award*. STAT Green: The Hospitals for a Healthy Environment Newsletter 2005. 2(8):8. Available at: <http://www.h2e-online.org/docs/h2estat-green80105.pdf>. Accessed: 04/02/09.
5. The Deirdre Imus Environmental Center for Pediatric Oncology®. *Greening the Cleaning®*. Hackensack University Medical Center Website. Available at: <http://www.dienviro.com/index.aspx?lobid=958>. Accessed: 02/05/09.
6. Anonymous. *New York hospitals implement green cleaning*. Healthcare Purchasing News 2004. Available at: http://findarticles.com/p/articles/mi_m0BPC/is_8_28/ai_n6156514/pg_1?tag=artBody;col1. Accessed: 04/02/09.
7. Crothall Services Group. *The 'greening' of environmental services: Jersey Shore University Medical Center is 'earth & people-friendly'*. Available at: http://www.crothall.com/inside/case_studies/EVS_JSUMC_casestudy.pdf. Accessed: 04/02/09.
8. Practice Greenhealth. *Practice Greenhealth Environmental Excellence Awards*. 2008. Available at: http://www.practicegreenhealth.org/page_attachments/0000/0116/2008AwardsProgram.pdf. Accessed: 01/30/09.
9. McLeister, D. *Suburban Hospitals "Greening" Their Facilities* The Business Ledger. 01/07/08. Available at: <http://www.thebusinessledger.com/Home/Archives/CommentaryViewpoints/tabid/86/newsid415/209/Suburban-Hospitals-Greening-Their-Facilities-/Default.aspx>. Accessed: 01/30/09.
10. Anonymous. *Enviro-Solutions press release*. 2005. Available at: <http://www.alturasolutions.com/McGillHealth.pdf>. Accessed: 01/30/09.
11. NewYork-Presbyterian, the University Hospital of Columbia and Cornell. *NewYork-Presbyterian Goes Clean & Green: Hospital Uses Cleaning Products That Are Better for Patients and the Environment* 2008. NewYork-Presbyterian. Available at: <http://www.nyp.org/news/hospital/hospital-green-initiaves.html>. Accessed: 01/27/09.
12. Minnesota Technical Assistance Program (MnTap), University of Minnesota. *Improving cleaning processes at Olmsted Medical Center*. 2008. Available at: <http://mntap.umn.edu/health/129IS.OMC.2007.pdf>. Accessed: 04/02/09.
13. Thompson, D. *RMH Makes the Switch to Green Cleaning Products*. 2008. Rockingham Memorial Hospital. Available at: <http://www.rmhonline.com/Home/News/tabid/241/articleType/ArticleView/articleId/77/Default.aspx>. Accessed: 01/27/09.
14. Judkis, M. *America's Best Hospitals, Green Edition*. U.S. News & World Report. 07/16/08. Available at: <http://www.usnews.com/blogs/fresh-greens/2008/07/16/americas-best-hospitals-green-edition.html>. Accessed: 01/30/09.
15. Atkinson, W. *Seattle Children's Hospital revitalizes green procurement strategies*. AllBusiness Purchasing 2008. Available at: <http://www.allbusiness.com/company-activities-management/operations/11604477-1.html>. Accessed: 04/03/09.
16. Anonymous. *Hospitals go green*. Connecticut Post. 08/19/08. Available at: http://www.connpst.com/health/ci_10247920. Accessed: 04/02/09.
17. Palmateer, P. *Survey: Green-building methods working for health-care facilities*. CNY Business Journal (1996+). 06/15/07. Available at: http://findarticles.com/p/articles/mi_qa3718/is_20070615/ai_n19430148. Accessed: 01/27/09.
18. Crothall Services Group. *Going green and staying clean*. Available at: http://www.crothall.com/inside/case_studies/EVS_Suburban_casestudy.pdf. Accessed: 04/02/09.
19. US Environmental Protection Agency, RPPP. *Using microfiber mops in hospitals*. 2002. EPA website. Available at: http://www.textileinnovations.com/PDF/using_microfiber_mops_hospitals.pdf. Accessed: 04/02/09.

C APPENDIX C: SELECTED SOURCES FOR CHOOSING INDUSTRIAL GREEN CLEANING PRODUCTS

This section provides examples of green cleaning product types and categories recognized by three well-known certifiers of North America: Green Seal, EPA's Design for Environment (DfE) Formulator Program, and Environment Canada's Environmental Choice Program. Also, UMASS Lowell's web-based Cleaner-Solutions Database helps to select cleaners or replace solvents.

Green Seal

Green Seal certified cleaning products/services fall under two main categories: (i) household cleaning products and (ii) facility operations and maintenance. The latter includes the following four subcategories: floor finishes and strippers (GS-40 standard); hand soaps and hand cleaners (GS-41A standard); institutional cleaning products (GS-37 standard); paper towels (GS-1 standard), napkins and tissue papers (GS-9 standard).

Institutional cleaning products

Green Seal has certified institutional cleaning products for over 150 manufacturers that comply with an earlier GS-37 standard. These manufacturers and products are available at:

<http://www.greenseal.org/findaproduct/i&i-cleaners.cfm>
In 2008, Green Seal revised its GS-37 and the products need to be re-certified according to the revised standard by August 29, 2009.

Floor finishes and strippers

Green Seal has certified floor finisher and stripper products for over 75 manufacturers that comply with GS-40 standards. These manufacturers and products are listed at:

http://www.greenseal.org/findaproduct/floor_care.cfm

EPA's Design for Environment (DfE) Formulator Program

DfE categorizes cleaning products into two major categories: (i) consumer products and (ii) institutional/ industrial cleaning products. Both categories include general cleaners, floor care products, and laundry detergents. In addition, automatic dishwasher products and graffiti removers are included in the institutional/ industrial cleaning products category. The DfE logo on a product means that the DfE scientific review team has reviewed all of the product ingredients for potential human health and environmental effects according to currently available information, EPA's predictive models, and expert judgment.

Institutional/ Industrial Cleaning Products:

General cleaner and floor care products

Over 140 manufacturers of general cleaning products and about 50 manufacturers of floor care products recognized under the EPA's DfE Formulator Program are listed at: <http://www.epa.gov/dfe/pubs/projects/formulat/formparti.htm#iiclean>

Environment Canada's Environmental Choice Program (EcoLogo)

For professional purchasers, EcoLogo lists about 40 cleaning and janitorial product types. "Industrial cleaners" is one of the product types and has been divided into 19 different product criteria which include: (i) biologically based cleaning and degreasing compounds (CCD-110 standard), disinfectant and disinfectant cleaners (CCD-166 standard), and floor care products (CCD-147 standard).

Biologically based cleaning and degreasing compounds

About 30 manufacturers of comply biologically based cleaning and degreasing compounds that with CCD-110 standard: http://www.ecologo.org/en/seeourcriteria/details.asp?ccd_id=335#results

Disinfectants and Disinfectant Cleaners:

Four manufacturers of four disinfectants/disinfectant cleaners that comply with the CCD-166 standard are listed at: http://www.ecologo.org/en/seeourcriteria/details.asp?ccd_id=391#results.

Floor care products

Over 20 manufactures of floor care products complying that comply with the CCD-147 standard are listed at: http://www.ecologo.org/en/seeourcriteria/details.asp?ccd_id=372#results

Toxics Use Reduction's (TURI's) CleanerSolutions database

The Surface Solutions Laboratory (SSL) of TURI has been gathering information on the performance of industrial cleaning products from the testing performed at the SSL. To use this information effectively, the "CleanerSolutions" Database was created. Its web-based interface is available at <http://www.cleansolutions.org/>. The database is field-searchable by surface contaminants, surface substrates, cleaning equipment, solvents replaced, and vendor product data.

When choosing an alternative it is important that you do not shift the risk from the worker to the environment or from the environment to the worker. You want to select a product that is safer for one or the other; ideally it would be best if the product is safer for both as compared to the current cleaning product. To help make this selection process easier, the lab conducts a preliminary screening of products for health and safety issues using the lab's five environmental indicators:

- volatile organic compounds (VOCs);
- global warming potential (GWPs);
- ozone depletion potential (ODPs);
- Hazardous Material Information System/ National Fire Protection Association (HMIS/NFPA); and
- pH.

Each indicator is assigned a value up to ten points. Individual indicator points are then combined (with equal weighting) to give a safety score out of 50 points. A higher score implies a potentially safer product. It is important to note that the indicators used by the SSL are not the only indicators that can be used for evaluating risk hazards associated with these products. However, the SSL indicators do cover a broad range of hazards and provide the user with a good starting point.

All of the previously mentioned sources for choosing industrial green cleaning products require products be tested for performance as well as for safety. The lab has and continues to test products for each of the programs.

Health Care Without Harm
1901 N. Moore Street, Suite 509
Arlington, VA 22209
www.noharm.org

Global Health and Safety Initiative
5957 Chabot Crest
Oakland, CA 94618
www.globalhealthsafety.org

Lowell Center for Sustainable Production
University of Massachusetts Lowell
One University Ave.
Lowell, MA 01854
www.sustainableproduction.org/

