Review article **J Bas Res Med Sci 2014; 1(3):1-13.**

Disinfection and general cleaning practices used in health care centers and hospitals

Razieh Amini[1], Rashid Heidari Moghadam[2], Somayeh Soleimani[3], Seyed Vahid Madihi[3], Hoda Jahani[4], Iraj Pakzad[4], Kobra Heidarzadi[4], Negin Karami[5], Zeinab Karimi[4], Ali Hematian[4], Jasem Mohammadi[5], Ali Nazari[6], Eskandar Gholami Parizad[7], Mohammad Hossein Maleki[4], Mansour Amraei[4], Parasto Shahmir[4], Masomeh Asadi[4], Farid Azizi Jalilian[4*]

1. Department of Microbiology, Faculty of Basic Sciences, Hamadan Branch, Azad Islamic University, Hamadan, Iran
2. Department of Ergonomy, Faculty of Health, Hamadan University of Medical Sciences, Hamadan, Iran
3. Department of Microbiology, Farzan Pathobiology Laboratory, Hamadan, Iran
4. Department of Medical Microbiology, Faculty of Medicine, Ilam Uiversity of Medical Sciences, Ilam, Iran
5. Department of Pediatric, Faculty of Medicine, Ilam Uiversity of Medical Sciences, Ilam, Iran
6. Department of Infectious Disease, Faculty of Medicine, Ilam Uiversity of Medical Sciences, Ilam, Iran
7. Department of Environmental Health, Faculty of Health, Ilam Uiversity of Medical Sciences, Ilam, Iran

[*] **Corresponding author:** Tel: +98 8412235714; fax: +98 8412235714
Address: Department of Medical Microbiology, Ilam University of Medical Sciences, Banganànjab Avenue, Ilam, Iran
E-mail: azizifarid@gmail.com
Received 27/11/2013; revised 20/7/214; accepted 13/9/214

Abstract

Improving cleaning and disinfection performance must be taken into account for prevention and control of infection. Health care settings are engaged in a battle against healthcare associated infection (HAIs). 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. There are many cleaning and disinfectant protocols used in health care centers and hospitals. Conventional cleaning and disinfecting methods are not completely effective. On the other hand, some of these products are known or suspected to be associated with eye, skin irradiation, respiratory disorders and allergies. Concerns about adverse human health effects of conventional cleaning and disinfecting products have led to the development of new methods to achieve better results and less adverse effects. Some of these procedures may reduce human health effect as well as reduce costs.

Keywords: Disinfection, infection, resistant, hospital, conventional

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. 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 decision[1] 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., *Clostrium difficile*) has intensified interest in cleaning and disinfection in healthcare facilities (1, 2).

There are various cleaning and disinfection practices used in the hospitals but none of these cleaning practices gives 100% result. Health care-associated infections (HAIs) are infections that occur as a result of health care Interference in any health care setting where care is delivered. Factors that increase the risk for the development of HAIs include:

■ Increased age
■ Greaterawareness
■ Increasing numbers of immune-compromised clients/patients/residents
■ Complex treatments
■ Increasinguse of antimicrobial agents in hospitals and institutional health care settings, creating a largereservoir of resistant microbial strains$_3$
■ Infrastructure renovations and repairs to aging hospitals and long-term care homes creating the risk of fungal diseases caused by dust and spores released during demolition and construction (4, 5). In addition, overcrowding and pressures to move more patients through the health care system can challenge the cleaning of environment (6). The reduction in number of microorganisms from the health care environment is accomplished by cleaning and disinfection.

The Environment of the Health Care Setting: The environment of the health care setting has been shown to be a reservoir for infectious agents such as bacteria (e.g., methicillin resistant *Staphylococcus aureus* (MRSA), vancomycin resistant enterococci (VRE), *Clostridium difficile, Acinetobacter baumannii, Pseudomonas* spp., *Stenotrophomonas*), viruses (e.g., influenza, respiratory syncytial virus - RSV, norovirus, rotavirus, astrovirus, sapovirus, rhinovirus- '*common cold*') and fungi (e.g., *Aspergillus* spp., *Fusarium spp., Penicillium* spp., *Stachybotrys spp.*, *Mucoraceae*). However, the presence of microorganisms alone on objects and items in the health care environment is not sufficient to demonstrate that they contribute to infection.

Table1. Persistence of clinically relevant organisms on dry inanimate surfaces (7).

Serotype No.	Micro- organisms	Duration of persistence (range)
1.	Acinetobacter spp.	3days - 5 months
2.	Clostridium dicile (spores)	5 months
3.	Escherichia coli	1.5 hours - 16 months
4.	Enterococcus spp, including VRE	5 days - 4 months
5.	Influenza virus	1 – 2 days
6.	Norovirus and feline calici virus	8 hours – 7 days
7.	Staphylococcus aureus, including MRSA	7 days – 7 months

Principles of cleaning and disinfecting environmental: Health care settings are complex environments that contain a large diversity of microbial flora, many of which may constitute a risk to the clients/patients/residents, staff and visitors in the environment. Transmission of microorganisms within a health care setting is intricate and very different from transmission outside health care settings and the consequences of transmission may be more severe. High-touch environmental surfaces of the health care setting hold a greater risk than public areas of non-health care organizations. There are many ways disease can be transmitted. Transmission Involves:

a) Presence of an infectious agent (e.g. bacterium, virus, fungus) on equipment, objects and surface in the health care environment.

b) A mean for the infectious agent to transfer from patient-to-patient, patient-to-staff, staff-to-patient and staff-to-staff.

c) Presence of susceptible clients/patients/residents, staff and visitors. In the health care setting, the role of environmental cleaning is important because it reduces the number and amount of infectious agents that may be present and may also eliminate routes of transfer of Microorganisms from one person/object to another, thereby reducing the risk of infection.

Different ways by which disease spreads: There are a number of different ways by which disease can be spread. These ways or areas should be considered first for the spread of disease. These areas are as follows:

A. Frequency of Contact with Surfaces:

All surfaces in a health care setting have the potential to harbor pathogenic microorganisms. The potential for exposure to pathogens is based on the type of activity involving the frequency of contact with a contaminated surface. For example, a conference room table would have less potential for exposure to pathogens than the doorknob in a client/patient/room. High-touch surfaces will require more frequent cleaning regimen. Most, if not all, environmental surfaces will be adequately cleaned with soap and water or a detergent/disinfectant, depending on the nature of the surface and the type and degree ofcontamination (8).

1. High-touch Surfaces: High-touch surfaces are those that have frequent contact with hands. Examples includedoorknobs, elevator buttons, telephones, call bells, bedrails, light switches, computer keyboards, monitoring equipment, haemodialysis machines, wall areas around the toilet and edges ofprivacy curtains. High-touch surfaces in care areas require more frequent cleaning and disinfection than minimal contact surfaces.[9] Cleaning and disinfection are usually done at least daily and more frequently ifthe risk of environmental contamination is higher (e.g., intensive care units).

2. Low-touch Surfaces: Low-touch surfaces are those that have minimal contact with hands. Examples include floors, walls, ceilings, mirrors and window sills. Low-touch surfaces require cleaning on a regular (but not necessarily daily) basis, when soiling or spills occur, and when a client/patient/resident is discharged from the health care setting.[9]many low-touch surfaces may be cleaned on a periodic basis rather than a daily basis if they are also cleaned when visibly soiled.

B. Vulnerability: Different populations of clients/patients/residents have differing vulnerabilities based on their susceptibility to infection. In some populations, such as bone marrow transplant or burn patients, susceptibility to infection is very high and may be impacted by their environment. The frequency of cleaning may be higher in areas with vulnerable client/patient/resident populations.

1. More Susceptible: These are clients/patients/residents that are more susceptible to infection due to their medical condition or lack of immunity. These include those who are immune-compromised (e.g., oncology patients; those in transplant and chemotherapy units; neonates (level 2 and 3 nurseries); those who have severe burns, i.e., requiring care in a burn unit); and those undergoing invasive or operative procedures (e.g., haemodialysis).

2. Less Susceptible: For the purpose of risk stratification for cleaning, all other individuals are classified as less susceptible.

C. Contamination of Items and Surfaces in the Health Care Environment: The probability that a surface, piece of equipment or care area will be contaminated is based on theactivity in the area, the type of pathogens involved and the microbial load.

1. Heavy Contamination: An area is considered to be heavily contaminated if surfaces and/or equipment are exposed to copious amounts of blood or other body fluids (e.g., birthing suite, autopsy suite, cardiac catheterization laboratory, burn unit, haemodialysis unit, Emergency Department, bathroom if the client/patient/resident has diarrhea or is incontinent).

2. Moderate Contamination: An area is considered to be moderately contaminated if surfaces and/or equipment are contaminated with blood or other body fluids as part of routine activity (e.g., patient/resident room, bathroom if client/patient/resident is continent) and the contaminated substances are contained or removed (e.g., wet sheets). All client/patient/resident rooms and bathrooms should be considered to be, as a minimum, moderately contaminated.

3. Light Contamination: An area is considered to be lightly contaminated or not contaminated if surfaces are not exposedto blood, other body fluids or items that have come into contact with blood or body fluids (e.g., lounges, libraries, office).

Depending on cleaning, disinfection and sterilization, healthcare devices and equipment are designated as:

■Critical
■Semi-critical
■Non-critical

Critical Items:

■ Requires sterilization
■ Includes items that enter sterile tissue or the vascular system
■ Examples include surgical instruments and accessories, biopsy forceps, cardiac and urinary catheters, implants, needles.

Semi-Critical Items:

■ Require minimum high level disinfection (or sterilization)
■ Include items in contact with non-intact skin or mucous membranes
■Examples include respiratory therapy equipment, anesthesia equipment, flexible and laryngoscopes, bronchoscopes, GI endoscopes, cyst scopes, vaginal ultrasonic probes.
■ Cleaning process must precede high-level disinfection Non-Critical Items
■ Require intermediate-level or low-level disinfection
■ Include items in contact only with intact skin
■Examples include BP cuffs, stethoscopes, durable mobile patient equipment.

High-touch surfaces in health care settings: High-touch surfaces which may exhibit environmental contamination in health care settings can be divided into three categories:

Critical: e.g. Patient bathroom, Bedpan, Commode.

Semi Critical: e.g.Patient room, Door Handles, Light switches

Non Critical: e.g. Transport items (wheelchair), Nursing station, ECG cart.

Cleaning agents and disinfectants: Cleaning is the removal of foreign material (e.g., dust, soil, organic material such as blood, secretions, excretions and microorganisms) from a surface or object. Cleaning physically removes rather than kills microorganisms, reducing the organism load on a surface. It is accomplished with water, detergents and mechanical action. The key to cleaning is the use of friction to remove microorganisms and debris. Thorough cleaning is required for any equipment/device to be disinfected, as organic material may inactivate a disinfectant. This may be accomplished through a two-step process involving a cleaner followed by a disinfectant, but is more commonly accomplished in the health care setting through a one-step process using a combined cleaner/disinfector product. Disinfection is a process used on inanimate objects and surfaces to kill microorganisms. Disinfection will kill most disease-causing microorganisms but may not kill all bacterial spores. Only sterilization will kill all forms of microbial life.

Detergents and cleaning agents: Detergents remove organic material and suspend grease or oil. Equipment and surfaces in the healthcare setting must be cleaned with approved hospital-grade cleaners and disinfectants. Equipment cleaning/disinfection should be done as soon as possible after items have been used. A variety of products from a number of suppliers can be used to achieve effective cleaning. It is important to follow the manufacturer’s instructions when using cleaning agents.

Disinfecting products used in the health care setting:

a) Must be approved by Environmental Services, Infection Prevention and Control and Occupational Health and Safety.

b) Must be used according to the manufacturers’ recommendations for dilution, temperature, water hardness and use.

c) Must be used according to the product’s Material Safety Data Sheet (MSDS).

Disinfectants: Disinfectants rapidly kill or inactivate most infectious agents. Disinfectants are only to be used to disinfect and must not be used as general cleaning agents, unless combined with a cleaning agent as a detergent disinfectant.

a. Choosing a disinfectant: The following factors influence the choice of disinfectant (16):

a) The disinfectant must have a drug identification number (DIN) from Health Canada.

b) The nature of the item to be disinfected;

c) The innate resistance of expected microorganisms to the inactivating effects of the disinfectant.

d) The amount of organic soil present.

e) The type and concentration of disinfectant used.

f) Duration of contact time required for efficacy at the usual room temperature of the health care setting.

g) If using a proprietary product, other specific indications and directions for use.

h) Occupational health considerations.

i) Many surface disinfectants contain quaternary ammonium compounds (QUATs), phenolics, hydrogen peroxide or sodium hypochlorite’s which can cause skin and respiratory irritation.

-Disinfectants are one of the leading allergens affecting health care providers[26];

- Staff will be more likely to use products that are non-toxic and not irritating.

- Environmental protection:

- Consider products that are biodegradable and safe for the environment;

ii. Many disinfectants (e.g., QUATs) may be hazardous both during manufacture and when they are discharged into the waste stream, as they are not readily biodegradable (26)

b. Using disinfectants: When using a disinfectant:

a) It is most important that an item or surface is free from visible soil and other items that might interfere with the action of the disinfectant, such as adhesive products, before a disinfectant is applied, or the disinfectant will not work; most disinfectants lose their effectiveness rapidly in the presence of organic matter.

b) A hospital-grade disinfectant may be used for equipment that only touches intact skin; examples include intravenous pumps and poles, hydraulic lifts, blood pressure cuffs, monitors and sensor pads, electrocardiogram (ECG) machine/cables and crutches.

c) It is important that the disinfectant be used according to the manufacturer's instructionsfor dilution and contact time;commonly used in health care settings with their recommended concentrations and contact times.

d) Minimizing the contamination levels of the disinfectant solution and equipment used for cleaning; this can be achieved by ensuring proper dilution of the disinfectant, frequently changing the disinfectant solution and by not dipping a soiled cloth into the disinfectant solution (i.e., no 'double-dipping').

e) Personal protective equipment must be worn appropriate to the product(s) used.

f) There should be a quality monitoring system in place to ensure the efficacy of the disinfectant over time (e.g., frequent testing of product).

Hazardous ingredients in conventional cleaning products: The below table (Table 2) is a modified version published by Bello et al in Environmental Health, 2009 (10). At the end, the table by Premier Safety Institute clarifies bleach dilutions with household measurement terms (11).

Table 2. Hazardous ingredients in conventional cleaning products (11).

Product Name	Examples	Physicochemical properties	Respiratory , skin, mucous membrane (eye) effects	Other health effects	Purpose of use in cleaning products
Alcohols	Benzyl alcohol C_6H_6OH Isopropyl alcohol $CH_3CH_2CH_2OH$ Ethanol (ethyl alcohol) CH_3CH_2OH	Boiling point (BP): 205 °C BP: 82.5 °C	Isopropyl alcohol: Highly volatile. Irritant to eyes and the upper respiratory tract. Prolonged exposure may cause lung damage (12). Ethanol and isopropyl alcohol are absorbed through the skin and can irritate the skin, eyes, upper respiratory tract, and throat (19).	Benzyl alcohol has been reported as a contact allergen in cleaning products (13, 14).	Used as solvents and disinfectants in cleaning products (12).
Ammonia	NH_3	Found in aqueous solutions in the form of ammonium hydroxide. (BP): -33.5 °C	Highly irritating. Inhalation of its vapors can irritate the nose, throat, and lungs, causing wheezing and shortness of breath. Prolonged exposure can cause bronchitis (12, 16).	No evidence of sensitization was found (10).	Used in glass cleaners (1).
Ethanolamine	OH H_2N Ethanolamine (MEA, mono-ethanol amine, 2-aminoethanol),	BP: 170.8 °C	Breathing its vapors can irritate the nose, throat and lungs, causing coughing, wheezing and shortness of breath (12). It is a skin irritant and can be absorbed through the skin (17). Can cause skin sensitization (12).	Exposure to ethanolamine has been associated with occupational asthma (18).	Used as surfactant in cleaning products (10). Used in floor care products, general purpose, glass, and bathroom cleaners (10).
Ethylene glycol ethers	OH O CH3 2-Buthoxyethanol (2-BE, ethylene glycol monobutyl ether, butyl "Cellosolve)	2-BE (BP):168^{O}C	2-BE vapors are irritants to eyes and respiratory tract (19). Class A (3): Confirmed animal carcinogen with unknown relevance to humans (20). 2-BE is a skin irritant. Absorbed in the body through skin (21) - an important exposure route (22).	2-BE is a toxic chemical (17). Ethylene glycol alkyl ethers target the central nervous system, blood and blood-forming organs, and reproductive system (19).	Used as solvent in cleaning products to dissolve fatty substances (10). Mostly used in glass, general purpose cleaners, and floor care products.

Table 2 (Continued). Hazardous ingredients in conventional cleaning products (11).

In organic Chlorine compounds	Bleach: 5.25 - 6.15% solution of sodium hypochlorite. Na-O-Cl Hydrochloric acid H-Cl	Bleach is highly toxic when mixed with ammonia or ammonium quaternary compounds, generating chloramine gas(13).Can form chlorine gas when mixed/ used in conjunction with strong acids (e.g., toilet bowl cleaners) (13).Fire risks in contact with organic materials (17).Store separately from other cleaning products.	Breathing a high concentration of chlorine can irritate the lungs (13). Particularly dangerous for people with heart conditions or chronic respiratory problems such as asthma or emphysema (13). Concentrated hypochlorite can cause corrosive damage to the skin and nails. Concentration below 5.25% not corrosive unless exposure occurs over a long period (13).	Strong tissue irritant (17). Concentrated bleach can cause corrosive damage to the eyes and mucous membranes (13). Chlorine bleach often manufactured using a mercury cell process, leaving contaminant mercury in the product (13).	Bleach is a commonly used disinfectant in medical, commercial, and household settings (10).
Oxidizers	H_2O_2 Hydrogen peroxide Most commercial janitorial cleaners do not contain over 10% hydrogen peroxide (4).	Concentrated solutions are highly reactive and have low flash points (13).Explosion hazard and must be stored carefully and away from other combustible materials and other chemicals(13).	Corrosive to the skin over 50% concentrations, irreversible eye damage over 10% concentrations(13).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, irritate the nose, throat, and lungs(13).	Classified as “mutagenic,” however, no evidence that exposure to the concentration found in cleaning products would cause mutagenic damage in humans(13).	Hydrogen peroxide considered more green due to fewer toxic characteristics than, for example quaternary ammonium or chlorine compounds (13).
Phenols/chlorinated phenols	Ortho benzyl parachlorophenol (OBPC) Ortho phenyl phenol (OPP) And p-tert-amylphenol.	OBPC BP: 160-162 °C OPP BP: 286 °C	Irritant to eyes and respiratory tract when inhaled (23). Even at low concentrations is extremely irritating to the skin. Repeated skin contact can cause dryness, itching and redness. Can penetrate the skin (12). Skin irritant. Occupational exposures may happen mostly through dermal contact (12). p-tert-amylphenol can be absorbed through the skin.	Sensitivity potential reported from animal studies.[24]OPP is listed as a carcinogen in California (2, 5, 13).	Phenols are used as disinfectants in cleaning products – many considered effective against tuberculosis (26).
Quaternary ammonium Compounds (quats)	Examples : Di-decyl di-methyl ammonium chloride N Alkyl dimethyl benzyl ammonium chloride (benzalkoniumchloride)	Quaternary ammonium compounds are salts that are soluble in water and alcohol (12).	Because quats are not volatile, inhalation exposures can happen through products' aerosolization (10).Commonly used solutions can cause nose and throat irritation. Benzalkonium chloride is a severe eye irritant (12). Limited evidence implicates quats in the development of allergic responses and occupational asthma (27, 28). Exposures to benzalkonium chloride have been associated with combined respiratory and dermal hypersensitivity (29). Benzalkonium chloride is a primary skin irritant in solutions of less than 10%.	Benzalkonium chloride suspected gastrointestinal and liver toxicant, and other quaternary ammonium compounds may have the same attributes (13).	Used as a low-level disinfectant. High level of disinfection is achieved if different quats and alcohols are mixed (10). Mostly used in bathroom, floor, and general purpose cleaners

New technologies for cleaning and disinfection: Before changing the current methods of cleaning and disinfection in a health care setting, the newer product must be weighed against current products in terms of efficacy, ease of implementation, toxicity, effects on patient care, ergonomic considerations and cost implications. Infection Prevention and Control, Environmental Services and Occupational Health and Safety must be involved in all decision-makings relating to changes in cleaning and disinfection methodologies and products in the health care setting.

A. air disinfection: Disinfectant fogging techniques have been used in some countries for terminal cleaning of rooms, but are not in general use. Toxic gases such as formaldehyde and ethylene oxide have been used in the past,but are not currently recommended due to safety risks and long cycle times. Newer gaseous formulations, such as vapourized hydrogen peroxide (VHP), super-oxidized water and ozone gas, appear to be effective agents in comparison to standard environmental cleaning for microorganisms such as *C. difficile* and MRSA (30-33). Disinfectant fogging is not appropriate for routine cleaning and should be restricted to terminal cleaning of isolation units and rooms involved in uncontrolled outbreaks.

1. Vapourized Hydrogen Peroxide (VHP): Vapourized hydrogen peroxide (VHP) is effective against a wide range of microorganisms, including bacteria, viruses and spores, particularly those of *C. difficile*[32]. It has been used successfully in eradicating *Serratia marcescens* from neonatal intensive care units (31); MRSA from surgical units (30, 35, 36), VRE (37) and *C. difficile* (32, 38, 39). VHP is relatively safe and decomposes to water and oxygen. The vapors are typically delivered by a computer-controlled distribution system that ensures even distribution throughout the room while monitoring gas concentration, temperature and relative humidity. Once decontamination is complete, an aeration unit in the room converts the VHP into water and oxygen. The complete decontamination process takes an average of five hours. A dry-mist hydrogen peroxide system has been used successfully in France to decrease *C. difficile* contamination by 91%, compared to a 50% reduction using sodium hypochlorite. Environmental cleaning with a detergent-disinfectant was performed prior to disinfection. The time required for the dry-mist decontamination was about 1.5 hours (dependant on room volume).[39]

Advantages:

- more effective decontamination compared to routine cleaning
- reduced labor required
- by-products are safe for the environment
- useful for decontaminating soft furnishings and equipment that is difficult to clean
- may be used to decontaminate entire units/wards during outbreaks

Disadvantages:

- time-consuming (average five hours to complete for VHP)
- biological soiling reduces the efficacy of VHP
- air ducts from the room must be sealed prior to decontamination optimal methodology (including exposure time) is still under investigation
- expensive

2. Ozone gas: Ozone is a gas that has bactericidal properties, can be generated cheaply and rapidly dissociates to oxygen. Ozone gas is widely used in water disinfection and has been used successfully to inactivate the feline calicivirus (a surrogate for norovirus) (40) and to eliminate MRSA from the home of a health care provider with eczema.[41] The use of ozone gas as an antibacterial agent in recent studies shows promise for future use in health care settings (31,42). It is, however, toxic at high concentrations, precluding its use in populated areas. It should only be used in areas that may be completely sealed off for the duration of the treatment.

Advantages:

- effectively penetrates all areas of a room, even areas difficult to access or clean by conventional cleaning methods (e.g., fabrics, under beds, inside cracks)
- administration of gas can be controlled from outside the room
- easy and economical to produce
- by-products are safe for the environment
- decontaminates surfaces even if biological material has been dried onto them
- decontaminates a large area quickly (less than one hour for an entire room)

Disadvantages:

- toxic at high concentrations
- area to be decontaminated must be sealed off from other areas until ozone levels return to safe limits

3. Super-oxidized water: Super-oxidized water has hypochlorous acid as its principal ingredient, which is safe to use, is not harmful to the environment[33] and has a broad spectrum of activity that includes spores. Many formulations have a long shelf life and are safe for the environment.[43]The use of super-oxidized water as a disinfectant fog shows promise (33), but require more study before applying it to the health care environment.

B. Ultraviolet irradiation (UVI): The use of ultraviolet irradiation (UVI) in the health care setting is limited to destruction of air borne organisms or inactivation of microorganisms on surfaces. UVI inactivates microorganisms at wavelengths of 240 to 280 nm (42). Bacteria and viruses are more easily killed by UVI than are bacterial spores.

Germicidal effectiveness of UVI is influenced by (44, 45)

a) Amount and type of organic matter present;
b) Wavelength of ultraviolet light;
c) Air mixing and air velocity;
d) Temperature and relative humidity;
e) Type of microorganisms present; and
f) Ultraviolet light intensity, which is affected by distance and cleanliness of lamp tubes.

If UVI is used in a health care setting, warning signs should be posted in the affected area to alert staff, clients/patients/residents and visitors of the hazard. A schedule for replacing ultraviolet lamps should be developed according to the manufacturer's recommendations. UVI intensity should be regularly monitored (46).

1. UVI disinfection of the air: Several studies have demonstrated that UVI is effective in killing or inactivating *M. tuberculosis* and in reducing the transmission of other infectious agents in hospitals. In the U.S., UVI is recommended as a supplement or adjunct to other TB infection control and ventilation measures in settings in which the need to kill or inactivate *M. tuberculosis* is essential, such as air borne infection isolation rooms (45). UVI is not a substitute for HEPA filtration in airborne infection isolation rooms (45).

2. UVI Disinfection of surfaces: UVI disinfection has been used successfully for final disinfection of isolation units once patients have been treated for infections.[48] Cleaning of visibly soiled surfaces is necessary before UVI disinfection, as ultraviolet light is absorbed by organic materials and its ability to penetrate islow.[47]UVI disinfection of surfaces should not be used alone for disinfection, but may be a good addition to chemical disinfection to lower the bio burden of microorganisms in isolation units and during outbreaks.

Advantages and disadvantages of ultraviolet irradiation (UVI) of surfaces advantages:

- automated method – no manual labor is required
- relatively short exposure time required (40 minutes)
- no residue left following disinfection

Disadvantages:

- destructive effect over time on plastics and vinyl's and fading of paints and fabrics
- low penetrating effect
- less effective in the presence of organic materials
- disinfection does not occur in shadowed areas where the ultraviolet light cannot penetrate
- expensive
- rooms must be vacant during UVI disinfection and a warning sign must be posted
- staff should avoid entry during UVI disinfection

C. Steam vapour: Steam has been used effectively to sterilize medical equipment but has not been used for disinfection of environmental surfaces due to the size and immobility of equipment used to deliver the steam. Recent advancements in technology have dramatically decreased the size of steam generators, making the importable and practical. Saturated steam is composed almost entirely of water in the vapors phase and is hotter and drier than typical steam vapour, which is often laden with small droplets of liquid water. Portable steam generators may be used to clean kitchens, bathrooms, floors, walls and other surface susing steam delivered with a nozzle brush. Steam vapour is applied using a back and forth motion for five to ten seconds. Grease, oil, stains and dirt are easily and effectively extracted and bacteria and viruses are killed. Steam vapour effectively travels through biofilm to kill microorganisms that may be unreachable by the surface application of disinfectants. Portable steam cleaners have demonstrated bactericidal, virucidal, fungicidal and sporicidal activity against *C. difficile* spores in experimental situations.

References

1. Centers for Medicare and Medicaid Services (CMS), HHS. Medicare program: changes to the hospital inpatient prospective payment systems and fiscal year 2009 rates. Fed Regist. 2008; 73(161):48433-9084.
2. 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.
3. Weinstein RA. Nosocomial infection update. Emerg Infect Dis. 1998 Jul-Sep; 4(3):416-20.
4. Sarubbi FA, JrKopf HB, Wilson MB, McGinnis MR, Rutala WA. Increased recovery of Aspergillus flavus from respiratory specimens during hospital construction. Am Rev Respir Dis. 1982; 125(1):33-8.
5. Weems JJ, JrDavis BJ, Tablan OC, Kaufman L, Martone WJ. Construction activity: an independent risk factor for invasive aspergillosis and zygomycosis in patients with hematologic malignancy. Infect Control. 1987; 8(2):71-5.
6. Hardy KJ, Oppenheim BA, Gossain S, Gao F, Hawkey PM. A study of the relationship between environmental contamination with methicillin-resistant Staphylococcus aureus (MRSA) and patients' acquisition of MRSA. Infect Control Hosp Epidemiol. 2006; 27(2):127-32.
7. Kramer A, Scwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. BMC Infect Dis. 2006; 6:130.
8. Carling P. Methods for assessing the adequacy of practice and improving room disinfection. Am J Infect Control. 2013; 41(5 Suppl):S20-5.
9. Sehulster L, Chinn RY. Guidelines for environmental infection control in health-care facilities. Recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC).

MMWR Recomm Rep. 2003; 52(RR-10):1-42.
10. 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):11-8.
11. Young M. Environmental cleaning in sterile processing areas. OR Manager. 2014; 30(9):20-1.
12. Fonger GC, Hakkinen P, Jordan S, Publicker S. The National Library of Medicine's (NLM) Hazardous Substances Data Bank (HSDB): Background, recent enhancements and future plans. Toxicology. 2014; 325(7):209-16.
13. D'Souza RM. Housing and environmental factors and their effects on the health of children in the slums of Karachi, Pakistan. J Biosoc Sci. 1997; 29(3):271-81.
14. Flyvholm MA. Contact allergens in registered chemical products. Contact Dermat. 1991; 25(1):49-56.
15. Flyvholm MA. Contact allergens in registered cleaning agents for industrial and household use. Br J Ind Med 1993;50(11):1043-50.
16. Basil AA, Hafiz OA, Seifeddin GB, Albar AA. Pulmonary function of workers exposed to ammonia. Int J Occup Environ Health. 2001; 7(1):19-22.
17. Lewis, RJ. Hawley's Condensed Chemical Dictionary. Twelfth Edition. New York, NY: Van Nostrand Reinhold; 1993.
18. Savonius B, Keskinen H, Tuppurainen M, Kanerva L. Occupational asthma caused by ethanolamines. Allergy. 1994;49(10):877-81.
19. Starek A, Szabla J. [Ethylene glycol alkyl ethers--the substances noxious to health]. Med Pr. 2008;59(2):179-85.
20. American Conference of Governmental Industrial Hygienist (ACGIH). Treshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices Cincinnati, OH; 2008.
21. 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.
22. Vincent R, Cicolella A, Surba I, Reieger B, Poirot P, Pierre F. Occupational exposure to 2-butoxyethanol for workers using window cleaning agents. Appl Occup Environ Hyg. 1993; 8(6):580-6.
23. Stouten H, Bessems JG. Toxicological profile for o-benzyl-p-chlorophenol. J Appl Toxicol. 1998;18(4):271-9.
24. 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.
25. Pease WS, Zeise L, Kelter A. Risk assessment for carcinogens under California's Proposition 65. Risk Anal. 1990; 10(2):255-71.
26. Goddard P, McCue KA. Penolic Compounds. In: Block SS, ed. Disinfection, sterilization, and preservation. 5 edition Lippincott Williams & Wilkins; 2001.P. 255-82.
27. 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.
28. 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.
29. 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.
30. French GL, Otter JA, Shannon KP, Adams NM, Watling D, Parks MJ. Tackling contamination of the hospital environment by methicillin-resistant Staphylococcus aureus (MRSA): a comparison between conventional terminal cleaning and hydrogen peroxide vapour decontamination. J Hosp Infect. 2004; 57(1):31-7.
31. Sharma M, Hudson JB. Ozone gas is an effective and practical antibacterial agent. Am J Infect Control. 2008; 36(8):559-63.
32. Boyce JM, Havill NL, Otter JA, McDonald LC, Adams NM, Cooper T, et al. Impact of hydrogen peroxide vapor room decontamination on Clostridium difficile environmental contamination and transmission in a healthcare setting. Infect Control Hosp Epidemiol. 2008; 29(8):723-9.
33. Clark J, Barrett SP, Rogers M, Stapleton R. Efficacy of super-oxidized water fogging in environmental decontamination. J Hosp Infect. 2006; 64(4):386-90.
34. Bates CJ, Pearse R. Use of hydrogen peroxide vapour for environmental control during a Serratia outbreak in a neonatal intensive care unit. J Hosp Infect. 2005; 61(4):364-6.
35. Dryden M, Parnaby R, Dailly S, Lewis T, Davis-Blues K, Otter JA, et al. Hydrogen peroxide vapour decontamination in the control of a polyclonal meticillin-resistant Staphylococcus aureus outbreak on a surgical ward. J Hosp Infect. 2008; 68(2):190-2.
36. Jeanes A, Rao G, Osman M, Merrick P. Eradication of persistent environmental MRSA. J Hosp Infect. 2005; 61(1):85-6.
37. Otter JA, Cummins M, Ahmad F, van Tonder C, Drabu YJ. Assessing the biological efficacy and rate of recontamination following hydrogen peroxide vapour decontamination. J Hosp Infect. 2007;67(2):182-8.
38. Shapey S, Machin K, Levi K, Boswell TC. Activity of a dry mist hydrogen peroxide system against environmental Clostridium difficile contamination in elderly care wards. J Hosp Infect. 2008; 70(2):136-41.
39. Barbut F, Menuet D, Verachten M, Girou E. Comparison of the efficacy of a hydrogen peroxide dry-mist disinfection system and sodium hypochlorite solution for eradication of Clostridium difficile spores. Infect Control Hosp Epidemiol. 2009; 30(6):507-14.
40. Hudson JB, Sharma M, Petric M. Inactivation of Norovirus by ozone gas in conditions relevant to healthcare. J Hosp Infect. 2007; 66(1):40-5.
41. de Boer HE, van Elzelingen-Dekker CM, van Rheenen-Verberg CM, Spanjaard L. Use of gaseous ozone for eradication of methicillin-resistant Staphylococcus aureus from the home environment of a colonized hospital employee. Infect Control Hosp Epidemiol. 2006; 27(10):1120-8.
42. Berrington AW, Pedler SJ. Investigation of gaseous ozone for MRSA decontamination of hospital side-rooms. J Hosp Infect. 1998; 40(1):61-5.
43. Landa-Solis C, Gonzalez-Espinosa D, Guzman-Soriano B, Snyder M, Reyes-Teran G, Torres K, et al. Microcyn: a novel super-oxidized water with neutral pH and disinfectant activity. J Hosp Infect. 2005; 61(4):291-9.
44. Jensen PA, Lambert LA, Iademarco MF, Ridzon R. Guidelines for preventing the transmission of Mycobacterium tuberculosis in health-care settings, 2005. MMWR Recomm Rep. 2005; 54(17):1- 141.
45. Rutala WA, Weber DJ. Healthcare Infection Control Practices Advisory Committee (HICPAC).Guideline for Disinfection and Sterilization in Healthcare Facilities; 2008.

46. Rutala WA, Gergen MF, Weber DJ. Microbiologic evaluation of microfiber mops for surface disinfection. Am J Infect Control. 2007; 35(9):569-73.
47. Schafer MP, Kujundzic E, Moss CE, Miller SL. Method for estimating ultraviolet germicidal influence rates in a hospital room. Infect Control Hosp Epidemiol. 2008; 29(11):1042-7.
48. Andersen BM, Banrud H, Boe E, Bjordal O, Drangsholt F. Comparison of UV C light and chemicals for disinfection of surfaces in hospital isolation units. Infect Control Hosp Epidemiol. 2006; 27(7):729-34.
49. Centers for Disease Control and Epidemiology. Recommendations for preventing transmission of infections among chronic hemodialysis patients. MMWR Recomm Rep. 2001; 50(RR-5):1-43.
50. Dettenkofer M, Block C. Hospital disinfection: efficacy and safety issues. Curr Opin Infect Dis. 2005; 18(4):320-5.