WATER QUALITY & HEALTH
A PUBLICATION OF THE WATER QUALITY & HEALTH COUNCIL TO THE CHLORINE CHEMISTRY COUNCIL®

Preventing Healthcare Associated Infections: The Role of Chlorine Products in Risk Reduction

By Barbara M. Soule RN, MPA, CIC
Infection Prevention and Control Professional
Member, Water Quality & Health Council

History

In 1847, the Austrian physician, Dr. Ignaz Semmelweis, demonstrated that puerperal sepsis ("childbed fever") was contagious and that incidents of infection could be dramatically reduced by enforcing appropriate hand hygiene by medical caregivers. In his study, Dr. Semmelweis noticed an alarming difference between the low infection rates in the mothers cared for by midwives in one hospital ward and the higher rates of those attended to by the medical students in another ward. As the head of the Maternity Department at the Vienna Lying-in Hospital in Hungary, Dr. Semmelweis instituted a policy requiring medical students to use a solution of chlorinated lime for washing hands after working on cadavers and before the examination of patients. Once this policy was instituted, the infection rate at the clinic attended by the medical students dropped from approximately 12.24% to 2.38%, comparable to the infection rate in the clinic attended by the midwives.

This example from the history of infection control is one of many that illustrates the benefits of chlorine in preventing and managing healthcare associated infections (HAI)[1,2]

Chlorine and HAIs Today

In contemporary healthcare, the risks for infection are diverse, challenging and increasing. Healthcare-associated infections (HAIs) are acquired by patients, residents and others when receiving treatment for clinical conditions in a variety of healthcare setting. Healthcare workers may also acquire HAIs while providing care or performing other duties within a healthcare setting. According to the latest figures from the U.S. Centers for Disease Control and Prevention (CDC), HAIs account for at least 2 million infections, 90,000 deaths and $4.5 billion in excess health care costs annually.

Some HAIs are associated with specific microorganisms. Others are related to patient care practices and the unique issues of specific care settings. Areas of potential infection risk include the cleaning and disinfection of patient care equipment and environmental surfaces in patient areas, water distribution systems and water quality, decontamination of medical waste and dental therapy equipment. Infection issues exist in all settings across the care continuum from ambulatory clinics to home care and hospice and in acute and long term care.[3,4,5]

Chlorine products are effective in reducing many of today's infection risks, as is evidenced by their use as disinfectants in healthcare settings for over a century.6 Hypochlorites have broad antimicrobial activity (less effective against spore-forming organisms), good stability and rapid killing action. They are available in liquid form (sodium hypochlorite) or solid form (calcium hypochlorite). Household bleach (aqueous solutions of 5.25% to 6.15%) is quite common for cleaning, and other formulations have been effective for routine disinfection in healthcare organizations (HCOs) and during outbreaks. Because these products do not stain or leave toxic residues and are inexpensive and non-toxic at concentrations that disinfect, they are highly desirable disinfectants in the healthcare setting. The few disadvantages of chlorine products include ocular irritation or burns of the GI tract and corrosiveness to metals when used in high concentrations.[6]

In 1968, Earle H. Spaulding addressed a key issue for preventing HAIs when he developed a framework for the disinfection and sterilization of patient care equipment.[7] He proposed that the degree of cleaning, disinfection and sterilization for patient equipment depends on its intended use and contact with the human body. Spaulding's framework consists of three types of healthcare equipment:

- Non-critical
- Critical
- Semicritical

Non-critical or low risk items are those that contact normal intact skin or the environment and do not touch the patient. This category includes bedpans, crutches, blood pressure cuffs, bed rails, walls, floors, some patient furniture, sinks and drains. These items are expected to be clean, but can be contaminated with some microorganisms. For equipment in this category, low-level disinfection can be achieved with a variety of agents, including chlorine at 100ppm (500 parts dilution).

Critical or high risk items include healthcare equipment that enters sterile tissue or the vascular system. Intravenous and urinary catheters, surgical instruments, implants and other invasive devices are in this category. High risk equipment requires sterilization by either chemical or thermal means, such as steam, ethylene oxide, hydrogen peroxide plasma and ozone. Chlorine products are not recommended for sterilization.

The third category, *semi-critical* or intermediate risk, includes those items that do not penetrate the skin or enter sterile body areas, but are in contact with mucous membranes or non-intact skin or other surfaces contaminated with potentially virulent and transmissible organisms. The objective of high-level disinfection is to render the objects free from vegetative organisms with the exception of bacterial spores. Items in this category are respiratory therapy and anesthesia equipment, endoscopes, tonometers and endocavity probes. Semi-critical items present the greatest infection challenges in healthcare organizations. Fortunately, chlorine products have been quite useful in reducing risk with these items. The U.S. Food and Drug Administration (FDA) has approved chlorine for high level disinfection at 650-675 ppm for 10 minutes.[8]

Disinfection for Emerging Pathogens

The potential for emerging pathogens to cause HAIs and the ability of available disinfectants to destroy these organisms remains an ongoing concern.[9] According to the World Health Organization (WHO) emerging pathogens are those that are making their appearance in a human population for the first time or have occurred previously but are increasing in incidence or expanding into areas where they have not previously been reported, usually over the last 20 years. Emerging organisms of concern include *cryptosporidium parvum* and Enterobacter coli 0157:H7 that are transmitted by contaminated food, water, the environment and from one person to another. *Helicobacter pylorus* has been transmitted from inadequately disinfected endoscopes and hepatitis C from percutaneous or mucous membrane exposure to blood via sharps injuries or from contaminated blood products. The SARS coronavirus, newer more resistant strains of *Clostridium difficile*, multi-drug resistant M. tuberculosis and non tuberculous mycobacteria (*Mycobacterium chleonae*), human papilloma virus, prions, norovirus and rotavirus have all caused HAIs. Additionally, the agents of plague, small pox and the hemorrhagic fevers are worrisome because of their easy transmissibility and high level of morbidity among persons should they enter the community or healthcare setting.

It is important to note that, for the most part, standard disinfection and sterilization procedures in HCOs are adequate to disinfect or sterilize instruments or devices contaminated with blood and other body fluids from persons infected with emerging pathogens and bloodborne pathogens.[10]. Exceptions include the human papilloma virus and prions (Creutzfeld-Jakob Disease).[11,12]

The following three emerging pathogens are worthy of mention because of their ability to 1) cause severe healthcare associated gastroenteritis, 2) their relative resistance to chemical disinfection, and 3) the recommended use of hypochlorite-based products during outbreaks or high levels of contamination.

Clostridium difficile

Clostridium difficile, an anaerobic, spore-forming bacterium, has been around for a long time. However, a new strain has emerged recently that appears to be more virulent, more resistant to antimicrobial agents, more difficult to treat and is associated with increased morbidity and mortality.[13.14,15, 16] This strain has caused large outbreaks in Canada, the U.S and other countries. It is responsible for about 15-25 percent of all *C. difficile* associated diarrhea [CDAD] in the U.S. and nearly all pseudomembraneous colitis. These infections have a 10-15 percent mortality rate and add *over a billion dollars per year* to health system costs.[17] The vegetative form of *C. difficile* can live 24 hours and spores can remain viable up to 5 months on surfaces. The patient environment may be highly contaminated depending on whether the patient is incontinent or has CDAD. Significantly, major contamination has been found even when patients are asymptomatic.[18,19,20] Investigators have established correlations between high levels of environmental contamination and the presence of *C difficile* on the hands of healthcare staff or disease in patients.[21,22] It is generally acknowledged that the potential for transmission from environment-to-patient can occur from shared instruments, environmental surfaces, the hands of hospital personnel and infected roommates.

Chlorine surface disinfection is very effective against *C. difficile*. In one study, the use of chlorine at 500-1600 ppm decreased the surface contamination and ended an outbreak.[18] In another study, the incidence of CDAD in bone marrow transplant patients decreased from 8.6 to 3.3 per 1000 patient days when the disinfecting agent for the environment was changed from a quaternary ammonium compound to a 1:10 dilution of hypochlorite solution.[23] Hypochlorite at 1,000 ppm was effective in decontaminating the environment of one ward where over one-third of cultures were positive for *C. difficile*.[24] And acidified bleach at 5,000 ppm inactivated all spores in less than 10 minutes in another study [25].

In the healthcare setting, good hand-washing with soap and water (alcohol-based hand rubs are not recommended with spore-forming organisms), contact precautions (gown and gloves) for those caring for patients with *C. difficile* and thorough and persistent environmental cleaning with an EPA registered disinfectant have been effective in preventing the spread of the organism.[26] During an outbreak or in units with high endemic rates of *C. difficile*, the CDC recommends dilute solutions of sodium hypochlorite (1:10 dilution of bleach) for cleaning the environment.[27]

Norovirus and Rotavirus

Norovirus and rotavirus have emerged as healthcare infection pathogens and have been increasingly implicated in outbreaks in hospitals and rehabilitation centers. These viruses can be transmitted through the fecal-oral route, contaminated food or water and droplets from vomiting. They appear to survive well in the environment and transmission in the hospital can occur through direct contact with contaminated items in patient areas. In a study of norovirus, cultures were positive from commodes, curtains and lockers in the immediate patient care environment.[28] In a pediatric setting, rotavirus was most prevalent on the surfaces in direct contact with children such as play mats and thermometers.[29] One researcher found that a

detergent-based cleaning product failed to eliminate norovirus contamination whereas hypochlorite with detergent at 5000 ppm chlorine was effective.[30] For rotavirus, dilutions of either 2000 ppm or 6000 ppm chlorine resulted in significant reductions on environmental surfaces.[31]

Transmission of these viruses in healthcare organizations can be interrupted or minimized in several ways, including when contact precautions are strictly observed; when there is rigorous environmental cleaning; and when an agent such as a hypochlorite is used to disinfect surfaces.

Protecting Healthcare Setting Water Quality and Water Systems

Overall the health care associated transmission of pathogens from water is relatively low. However, HAI outbreaks have been reported in association with water sources; some with very serious consequences.[3,4]

It is important for health care organizations to maintain a high level of suspicion for all water sources and reservoirs used for patient care because of the potential for direct or indirect transmission of nosocomial pathogens. Healthcare organizations typically have multiple water reservoirs including:

- Water used for dialysis
- Suctioning and ventilator care
- Water birthing tanks
- Whirlpools and therapy tanks for physical therapy
- Ice, including ice machines and ice storage tanks
- Eyewash and shower stations
- Faucets, tubs and showers,
- Water baths for thawing plasma or warming dialysis fluids
- Facility cooling towers
- Dental-unit water stations.[3,4]

Outbreaks from rinsing equipment and patients with potable water have led to infections such as *Mycobacterium chelonae* from otolgic equipment[32], *Pseudomonas paucimobillis* from tracheal suction tubing[33], *Pseudomonas aeruginosa* from endoscopy[34] and rinsing burn patients.[35] Additionally, fungi and mold can result from flood and water leakage in hospitals. When this occurs, it is important to remove the moisture source and clean and dry the area promptly. Diluted bleach solutions can be used for disinfection.

Water disruption in an organization can also result in standing or stagnant water. When water is still, the water treatment designed to minimize microbial growth can be compromised. Scale and sediment can develop in pipes as well as biofilm, which supports microbial growth. When a system is restarted and water is recirculated, it is important to assure that the pipes are disinfected and the water is safe to drink or use for patient care[3]

In one study, 19 cases of nosocomial pulmonary disease occurred from hot water generators and water taps in hospitals.[36] Other environmental water sources in healthcare organizations that have been linked to outbreaks include faucet aerators and showers. There is potential for direct or indirect transmission of organisms from faucets and sinks. One outbreak with hand held showerheads involved *group A streptococcus* and Legionella.[37] Other infections have resulted from bath water contamination which has led to endocarditis, bacteremia and peritonitis with organisms such as

Pseudomonas and *Acinteobacter*.[4]

Chlorine products have proven effective for the disinfection of many of these reservoirs or equipment. For example, the water in pools and large water tanks in hospitals and rehabilitation centers are routinely chlorinated to achieve a free chlorine residual of 0.5 mg/L and a pH of 7.2-7.6 to minimize risk of the multiplication of organisms.[4] Smaller water tanks used in physical therapy departments are drained after each use, disinfected and a chlorine solution of 200-300 mg/L is circulated through the agitator tank where most organisms reside. Ice, ice machines and cold water tanks have been linked with nosocomial epidemics or pseudoepidemincs with organisms such as *Enterobacter*, *Pseudomonas*, *Flavobacterium*, *Mycobacterium*, and *Legionella pneumophila*.[4, 38-41] The CDC has published recommendations for cleaning and disinfecting ice machines.[42]

Legionella

One of the most challenging organisms related to water and environmental contamination is *Legionella*. *Legionella* is a bacterium that grows and multiplies in water systems including the cooling towers associated with health care structures. Outbreaks of *Legionella* healthcare-associated infections have been largely related to poor water maintenance, contaminated potable water, ice machines, aspiration of feeding tubes and the poor design and planning of hospital systems. One study found that *Legionella* could be isolated from more than 50% of potable water supplies and more than 10% of distilled water supplies in hospitals.[3,4,43-45] Symptoms of *Legionella* infection range from mild flu-like infection to severe pneumonia, called Legionnaire's disease. Outbreaks have been reported in acute and long term care throughout the world. Some outbreaks have been so mild as to be unrecognized for years. [46,47]

Legionella is transmitted via aerosolization, not from person to person. Once the organism enters the potable water system of an organization, it can multiply, spread through the water distribution system and contaminate the output areas such as faucets and shower heads.[3,4] A wide variety of environmental treatment options have been recommended and tested to eliminate or contain *Legionella*, including ozone, ultravi olet light, copper/silver ionization, thermal methods (e.g., superheating) and hyperchlorination. The fact is no single method has demonstrated the ability to consistently and permanently eradicate *Legionella* from water systems. The CDC currently recommends diagnostic testing and culturing of water distribution systems and superheating or hyperchlorination.[27] Mono-chloramines have proven encouraging for adequate disinfection[48] and chlorine dioxide is highly useful for reducing biofilm.[49, 50]

Surface Disinfection in Health Care Settings

The issue of surface disinfection in healthcare is currently under debate. The question is the balance between the advantages of disinfectants in preventing infection and the associated risks to health care workers and others from the use of these products, e.g. incorrect dilution with resultant toxic effects, contact dermatitis. Given the environment as one variable of a

complex process for disease transmission, most experts believe that surfaces in patient care areas should be disinfected on a routine basis and particularly when there is visible soil or when spills occur. [51, 52]

For general surface disinfection, the CDC specifies concentrations of chlorine bleach required to disinfect countertops, floors, tonometer heads, needles, syringes, dental appliances, hydrotherapy tanks, water distribution systems and other equipment.53 Many organisms can survive on patient surfaces. Therefore it is imperative in potentially highly contaminated patient care environments that persons responsible for cleaning procedures in any healthcare setting be familiar with these recommendations and the broad disinfection capabilities of chlorine and other cleaning and disinfecting products.

Disinfection in Non-Hospital Healthcare Settings

As healthcare shifts from acute care to long term care, ambulatory clinics, outpatient settings, homes and hospice care providers must deal with communicable diseases, invasive devices and contaminated environments that were formerly largely confined to hospitals. In these settings, it is important to follow the Spaulding scheme for disinfection and sterilization. Although cross infection and epidemics are less prevalent or even rare in these settings, patient care equipment requires constant vigilance to prevent contamination and disease transmission.

A great deal of healthcare is now provided in homes. In home settings, chlorine products are available, inexpensive, easy to use and often recommended for disinfection. For example, tracheostomy tubes can be immersed in a 1:2 dilution of household bleach (6.00% - 6.15% sodium hypochlorite) for adequate disinfection. The patient's immediate care environment can be cleaned with a bleach solution or wiped with bleach impregnated towels.

In outpatient settings, such as an ophthalmology office or clinic, tonometers used to measure eye pressure can potentially transmit herpes simplex virus and adenovirus. Tonometers swabbed with 70% alcohol may not be effectively decontaminated. The CDC recommends disinfecting applanation tonometers with a chlorine solution of 5000 ppm for 5-10 minutes.[27] During outbreaks, daycare centers may consider chlorine products for surface decontamination. Dental offices, emergency departments and clinics may also find towels impregnated with a chlorine ingredient helpful.

Endoscopic procedures are performed in both acute care and ambulatory care settings. Effective cleaning and high level disinfection of endoscopes poses significant challenges for health care providers and many outbreaks have been reported.[54] For example, bronschoscopes have been implicated in multiple outbreaks and pseudo-outbreaks with pseudomonas species and other organisms.[55-59] The complex design of endoscopes, with narrow channels and many small parts, requires that their cleaning, disinfection, drying and storage processes are followed strictly according to the manufacturer's recommendations and evidence-based policy. While the

most commonly used agent for disinfecting endoscopes is 2% glutaraldehyde, recent studies have explored the use of chlorine dioxide.[60-63]

Next Generation Disinfection Targets: New Healthcare Equipment and Technology

Technology constantly changes the tools for providing patient care. In recent years, computers and mobile phones have been used extensively to enhance access to staff, quick retrieval of complex and changing information, and increased productivity. These items can be heavily colonized by organisms and serve as a reservoir for the transmission of pathogens via the hands of healthcare personnel.[64-66] Chlorine can be used as a disinfecting agent. One recent study recommends a daily 5 seconds disinfection regime for healthcare facility computer keyboards when visibly soiled.[65-66]

In summary, the risk of healthcare-associated infections continues to generate world-wide concern. Health professional, researchers, and industry constantly seek better ways to prevent these infections. Chlorine products have proven effective for cleaning and disinfection and have contributed to reduced risk for infections and outbreaks in health care settings.

Much of the content of this paper comes from the ongoing research of William Rutala, PhD, University of North Carolina. The author thanks him for his continued leadership in the field of disinfection and sterilization related to healthcare-associated infections.

References

1. Block, S. S. 1991. Historical review, p. 3-17. *In* S. S. Block (ed.), Disinfection, sterilization, and preservation, 4th ed. Lea & Febiger, Philadelphia, Pa.
2. Biography of Ignaz Philipp Semmelweis. http://www.mindfully.org/Health/Ignaz-Philipp-Semmelweis5mar1865.htm- Accessed Aug, 2006
3. Bartley J. Water issues. In Carrico R (ed): *APIC Text of Infection Control and Epidemiology*. Second Edition. Washington, DC: Association for Professionals in Infection Control & Epidemiology, Inc., 2005:107-1-16
4. Rutala WA, Weber DJ. Water as a reservoir of nosocomial pathogens. Infect Control Hosp Epidemiol. 1997;18;9:609-16.
5. Rutala WA, Weber DJ. Cleaning, disinfection, and sterilization in healthcare facilities. In Carrico R (ed): *APIC Text of Infection Control and Epidemiology*. Second Edition. Washington, DC: Association for Professionals in Infection Control & Epidemiology, Inc., 2005:21-1 to 21-11.
6. Rutala WA, Weber DJ. Uses of inorganic hypochlorite (bleach) in health-care facilities. Clin Microbiol Rev.1997;10;4:597-610.
7. Spaulding EH. Chemical disinfection of medical and surgical materials. In: Lawrence. C, Block SS, editors. Disinfection, sterilization and preservation. Philadelphia 1968. Lea & Febiger.
8. Food and Drug Administration: FDA-cleared sterilants and high level disinfectants with general claims for processing reusable medical and dental devices. May, 2005. www.fda.gov/cdrh/ode/germlab.html. Accessed July 2006
9. Weber DJ, Rutala WA. The emerging nosocomial pathogens

Cryptosporidium, Escherichia coli O157:H7, *Helicobacter pylori*, and hepatitis C: epidemiology, environmental survival, efficacy of disinfection, and control measures. Infect Control Hosp Epidemiol. 2001;22;5:306-15.
10. Rutala WA, Weber JD, Infection control: the role of disinfection and sterilization. J Hosp Infect 1999;43:545-55.
11. Weber DJ. Rutala WA. Managing the risk of nosocomial transmission of prion diseases. Curr Opin Infect Dis. 2002;15:421-5.
12. Centers for Disease Control (CDC). Questions and Answers: Creutzfeldt-Jakob Disease Infection-Control Practices. http://www.cdc.gov/ncidod/dvrd/cjd/infection_control_cjd.htm. Accessed July 2006
13. Oldfield EC 3rd. *Clostridium difficile*-associated diarrhea: resurgence with a vengeance. Rev Gastroenterol Disord. 2006;6;2:79-96.
14. Sunenshine RH, McDonald LC. *Clostridium difficile*-associated disease: new challenges from an established pathogen Cleve Clin J Med. 2006 2006 ;73;2:187-97.
15. McDonald LC, Killgore GE, Thompson A, Owens RC Jr., Kazakova SV, Sambol SP, Johnson S, Gerding DN. An epidemic, toxin gene-variant strain of *Clostridium difficile*. N Engl J Med. 2005 Dec 8;353(23):2433-41.
16. A simple guide to *Clostridium difficile*. http://www.dh.gov.uk Ref Number 5264. Accessed July 2006.
17. Rutala WA, Gergen MF, Weber DJ. Inactivation of Clostridium difficile spores by disinfectants. Infect Control Hosp Epidemiol. 1993;14;1:36-39
18. Kaatz GW, Gitlin SD, Schaberg vDR, et al. Acquisition of *Clostridium difficile* from the hospital environment. Am J Epidemiol 1988;127;6:1289-94.
19. Kim KH, Fekety R, Batts DH, Brown D, Cudmore M, Silva J Jr, et al. Isolation of *Clostridium difficile* from the environment and contacts of patients with antibiotic-associated colitis. J Infect Dis. 1981;1;143;1:42-50.
20. Fekety R, Kim K, Brown D, Batts DH, Cudmore M. Silva J. Epidemiology of antibiotic-associated colitis: Isolation of *Clostridium difficile* from the hospital environment. Am J Med 1981;70:907.
21. Samore MH, Venkataraman L, DeGirolami PC, Arbeit RD, Karchmer AW. Clinical and molecular epidemiology of sporadic and clustered cases of nosocomial *Clostridium difficile* diarrhea. Am J Med. 1996 Jan;100(1):32-40.
22. Fawley WN, Wilcox MH. Molecular epidemiology of endemic *Clostridium difficile* infection. Epidemiol Infect, 2001;126;3:343-50.
23. Mayfield JL, Leet T, Miller J, Mundy LM. Environmental control to reduce transmission of *Clostridium difficile*. Clin Infect Dis 2000;31;4:995-1000.
24. Wilcox MH, Fawley WN, Wigglesworth N, Parnell P, Verity P, Freeman J. Comparison of the effect of detergent versus hypochlorite cleaning on environmental contamination and incidence of *Clostridium difficile* infection. J Hosp Infect. 2003 Jun;54(2):109-14.
25. Perez J, Springthorpe VS, Sattar SA. Activity of selected oxidizing microbicides against the spores of *Clostridium difficile*: Relevance to environmental control. Am J Infect Control 2005;33;6:320-5.
26. McFarland LV, Mulligan ME, Kwok RY, Stamm WE. Nosocomial acquisition of *Clostridium difficile* infection. N Engl J Med. 1989 Jan 26;320(4):204-10
27. Sehulster LM, Chinn RYW, Arduino MJ, Carpenter J, Donlan R, Ashford D, Besser R, Fields B, McNeil MM, 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). Chicago IL; American Society for Healthcare Engineering/American Hospital Association; 2004

29. Green J, Wright PA, Gallimore CI, Mitchell O, Morgan-Capner P, Brown DW. The role of environmental contamination with small round structured viruses in a hospital outbreak investigated by reverse-transcriptase polymerase chain reaction assay. J Hosp Infect. 1998 May;39;1:39-45.
30. Barker J, Vipond IB, Bloomfield SF. Effects of cleaning and disinfection in reducing the spread of Norovirus contamination via environmental surfaces. J Hosp Infect. 2004 Sep;58(1):42-9.
31. Sattar SA, Springthorpe VS, Adegbunrin O, Zafer AA, Busa M. A disc-based quantitative carrier test method to assess the virucidal activity of chemical germicides. J Virol Methods. 2003 Sep;11(1-2):3-12.
32. Lowry PW, Jarvis WR, Oberle AD, Bland LA, Silberman R, Bocchini JA Jr, Dean HD, Swenson JM, Wallace RJ Jr. *Mycobacterium chelonae* causing otitis media in an ear-nose-and-throat practice. N Engl J Med. 1988;319;15:978-82.
33. Crane LR. Tagle, LC, Palutke WA. Outbreak of *Pseudomonas paucimililis* in an intensive care facility. JAMA 1981;246:985-7.
34. Doherty DE, Falko JM, Lefkovitz N. Rogers J, Fromkes J. *Pseudomona aeruginosa* sepsis following retrograde cholangiopancreatography (ECRP). Dig Dis Sci 1982;27:169-70.
35. Kolmos HJ, Thuesen B, Nielsen sV, Lohmann M, Kristoffersen K, Rosdahl VT. Outbreak of infection in a burns unit due to *Pseudomonas aeruginosa* originating from contaminated tubing used for irrigation of patients. J Hosp Infect 1993;24:1-21.
36. Costrini AM, Mahler DA, Gross WM, Hawkins JE, Yesner R, D'Esopo ND. Clinical and roentgenographic features of nosocomial pulmonary disease due to *Mycobacterium xenopi*. Am Rev Respir Dis 1981;123:104-9.
37. Oren I, Zuckerman T, Avivi I, Finkelstein R, Yigia M, Rowe JM. Nosocomial outbreak of *Legionella pneumophila* serogroup pneumonia in a new bone marrow transplant unit: evaluation, treatment and control. Bone Marrow Transplant.2002;30;3:175-9.
38. Newson SWB. Hospital infection from contaminated ice. Lancet 1968;2:620-622.
39. Panwalker AP, Fuhse E. Nosocomial *Mycobacterium gordonae* pseudoinfection from contaminated ice machines. Infect Control 1986; Feb 7;2:67-70.
40. Stout JE, Yu VL, Muraca P. Isolation of Legionella pneumophila from the cold water of hospital ice machines : implications for origin and transmission of the organism. Infect Control 1985;6:4:141-6.
41. Stamn WE, Colella JJ, Anderson RL, Dixon RE. Indwelling arterial catheters as a source of nosocomial bacteremia: an outbreak caused by Flavobacterium species. N Engl J Med 1975;292:1099-1102.
42. Manangan LP, Anderson RL, Arduino MJ, Bond WW. Sanitary care and maintenance of ice-storage chests and ice-making machines in health care facilities. Am J Infect Control 1998;26:111-2.
43. Mermel LA, Josephson SL. Giorgio CH, et. al. Association of Legionnaires disease with construction: contamination of potable water? Infect Control Hosp Epidemiol 1995;16;2: 76-81
44. Yu VL, Liu Z, Stout JE. Goetz A. *Legionella* disinfection of water distribution systems: Principles, Problems and Practice
45. Goetz, A. *Legionella pneumophila*. In Carrico R (ed): APIC Text of Infection Control and Epidemiology. Second Edition. Washington, DC: Association for Professionals in Infection Control & Epidemiology, Inc., 2005 76-1-8.
46. Kool JL. Fiore AE, Kioski CM. et al. More than 10 years of unrecognized

nosocomial transmission of Legionnaires' disease among transplant patients. In Infect Control Hosp Epidemiol.1998;19;12:898-904.
47. Lepine MD, Jernigan DB, Pruckler M. et al. A recurrent outbreak of nosocomial Legionnaire's disease detected by urinary antigen testing: evidence for long term colonization of a hospital plumbing system. ICHE 19;12; 905-10.
48. Heffelginger JD, Kool MD, Fridkin S, Fraser VJ, Hageman MHS, Carpenter J, et al. Risk of hospital-acquired Legionnaires' disease in cities using monochloramine versus other water disinfectants. Infect Control Hosp Epidemiol 2003 24;8:569-74.
49. Srinivasan A. Bova g, Ross T, Mackie K, Paquette N, Merz W, et a. A 17 month evaluation of a chlorine dioxice water treatment system to control *Legionella* species in a hospital water supply. Infect Control Hosp Epidemiol. 2003;24;8:575-79.
50. 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;2:8409.
51. Loret JF, Robert S, Thomas V, Cooper AJ, McCoy WF, Levi Y. Comparison of disinfectants for biofilm, protozoa and Legionella control. J Water Health, 2005;3;4:423-33.
52. Rutala WA, Weber DJ. Surface disinfection: should we do it? J Hosp Infect. 2001;48 Suppl A:S64-8. 42, 43
53. Rutala WA, Weber DJ, and the healthcare Infection Control Practices Advisory Committee Guideline for Disinfeciton and Sterilization in Healthcare Facilities. 2002;92-93.
54. Rutala WA, Weber DJ. Reprocessing endoscopes: United Sates perspective. J Hosp Infect 2004;56;S2:S27-39.
55. Silva CV, Magalhaes VD, Pereira CR, Kawagoe JY, Ikura C, Ganc AJ. Pseudo-outbreak of *Pseudomonas aeruginosa* and *Serratia marcescens* related to bronchoscopes. Infect Control Hosp Epidemiol 2003;24:195-7.
56. Kirschke DL, Jones TF. Craig AS, Chu PS, Mayrnick GG, Patel JA, Schaffner W. *Pseudomonas aeruginosa* and *Serratia marcescens* contamination associated with a manufacturing defect in bronchoscopes. N Engl J Med 2003 16;3:214-20.
57. Corne P, Godreuil S, Jean-Pierre H, Jonquet O, Campos J, Jumas-Bilak E, et. al. Unusual implication of biopsy forceps in outbreaks of *Pseudomonas aeruginosa* infections and pseudo-infections related to bronchoscopy. J Hosp Infect 2005;61;1:20-6.
58. Schelenz S, French G. An outbreak of multidrug-resistant Pseudomonas aeruginosa infection associated with contamination of bronchoscopes and an endoscope washer-disinfector. J Hosp Infect 2000;46;1:23-30.
59. Srinivasan A, Wolfenden LL, Song X, Mackie K, Hartsell TL, Jones HD, et al. An outbreak of *Pseudomonas aeruginosa* infections associated with flexible bronchoscopes. N Engl J Med 2003;348;3:191-2.
60. Isomoto H, Urata M, Kawazoe K, Matsuda J, Nishi Y, Wasa A, et. Al. Endoscope disinfection using chlorine dioxide in an automated washer-disinfector. J Hosp Infect 2006;63:298-305,
61. Srinivasan A, Bova G, Ross T, Mackie K, Paquette N, Merz W, Perl TM A 17-month evaluation of a chlorine dioxide water treatment system to control Legionella species in a hospital water supply. Infect Control Hosp Epidemiol. 2003 Aug;24(8):575-9.
62. Ayliffe G; Minimal Access Therapy Decontamination Working Group. Decontamination of minimally invasive surgical endoscopes and accessories. J Hosp Infect. 2000 Aug;45(4):263-77.

63. Cleaning and disinfection of equipment for gastrointestinal endoscopy. Report of a Working Party of the British Society of Gastroenterology Endoscopy Committee. Gut. 1998;42(4):585-93.
64. Schultz M, Gill J, Zubairi S, Huber R, Gordin F : Bacterial contamination of computer keyboards in a teaching hospital. Infect Control Hosp Epidemiol. 2003 Apr;24(4):302-3.
65. Rutala WA, White MS, Gergen MF, Weber DJ. Bacterial contamination of keyboards: efficacy and functional impact of disinfectants. Infect Control Hosp Epidemiol. 2006 Apr;27(4):372-7. .
66. Brady RR, Wasson A, Stirling I, McAllister C, Damani NN. Is your phone bugged? The incidence of bacteria known to cause nosocomial infection on healthcare workers' mobile phones. J Hosp Infect. 2006 Jan;62(1):123-5.