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PRACTICAL GUIDE TO ANTIMICROBIAL STEWARDSHIP IN HOSPITALS

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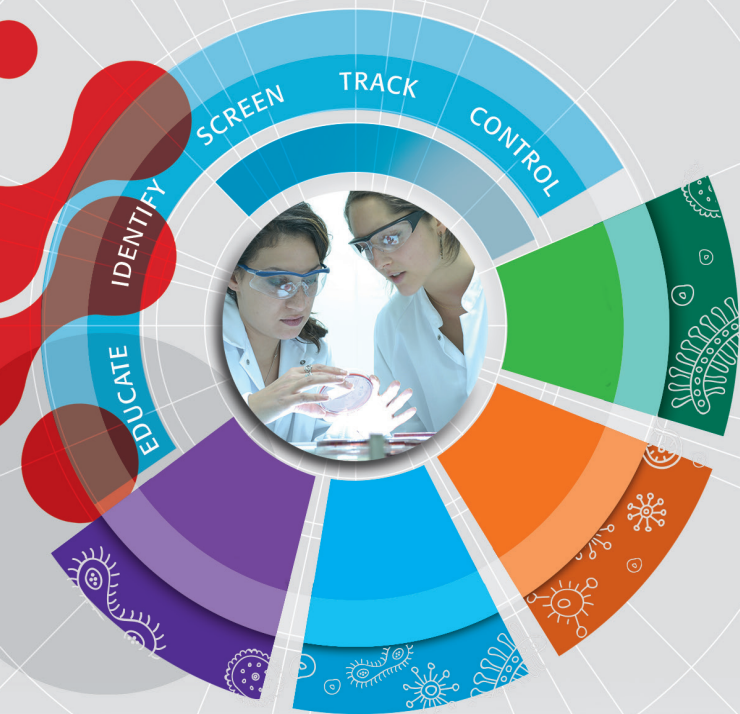**Fax : (800)** 968-9494
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PRACTICAL GUIDE TO

ENVIRONMENTAL INFECTION CONTROL

IN HOSPITALS

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PREFACE

The hospital/healthcare environment has been recognised as an infection risk for patients for at least a hundred years. As far back as 1860, Florence Nightingale wrote that "the greater part of nursing consists in preserving cleanliness". Although rigorous adherence to hygienic practice and environmental cleanliness remains strictly enforced for surgery, standards of general hospital hygiene declined after the introduction of antibiotics and the development of the misguided perception that infection had now become less of a threat.

However, infection is an increasing risk to patient safety due to the increasing complexity of modern medicine, the increasing vulnerability of patients compromised by extremes of age, immunosuppression, major surgery and intensive care, and the emergence of multi-drug resistant (MDR) pathogens.

The spread of resistance genes between bacteria and the worldwide emergence of extremely MDR pathogens is now recognised as a global public health emergency that threatens our ability to treat hospital infections and deliver safe and effective healthcare *(Boucher et al, 2009; European Commission, 2011; World Economic Forum report, 2014)*. The control of cross-infection is important not only for the reduction of patient infection but also to reduce the spread of MDR pathogens and their resistance genes.

In the hospital setting, air, water, medical devices and dry surfaces are all potential sources of contamination and infection.

This practical booklet aims to provide an overview of the various types of environmental transmission of hospital infection and its control, as well as reviewing the recommended practices for optimum bacteriological sampling.

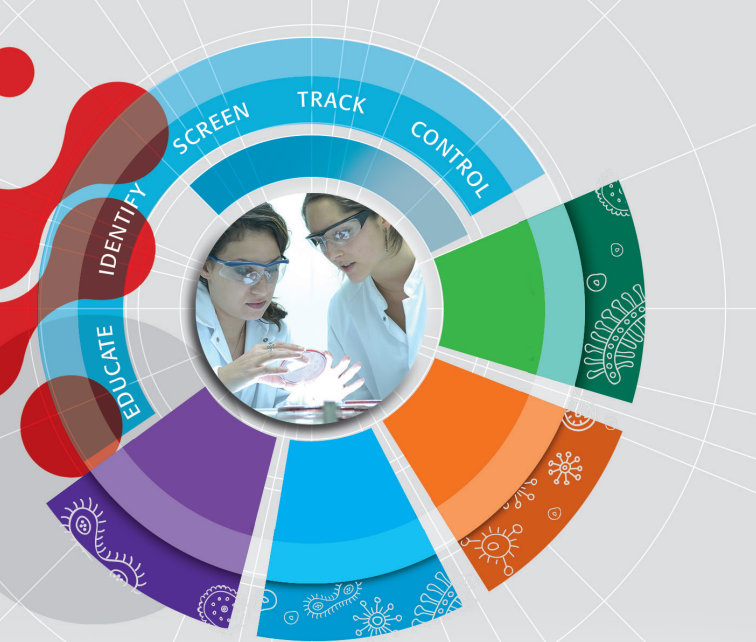**Professor GL French, MD FRCPath DipHIC**

TRACK

SCREEN

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CONTROL

TABLE OF CONTENTS

INTRODUCTION

The hospital environment may be contaminated with various environmental pathogens and with more virulent organisms transmitted from colonized or infected patients or staff.

Infection may occur by direct inoculation into wounds or other sites. Alternatively, patient skin and mucous membranes may first become colonized with subsequent invasive infection when patient defences are compromised.

Infection control therefore includes the prevention of contamination and colonisation as well as direct infection.

Transmission routes are complex and often involve the environment, either directly or indirectly. Environmental routes and sources include:

- Air
- Water
- Medical devices and equipment
- Environmental surfaces
- Food and drink

Figure 1.

Potential routes of transmission of nosocomial infection involving the environment [*Adapted from Otter et al, 2011*]
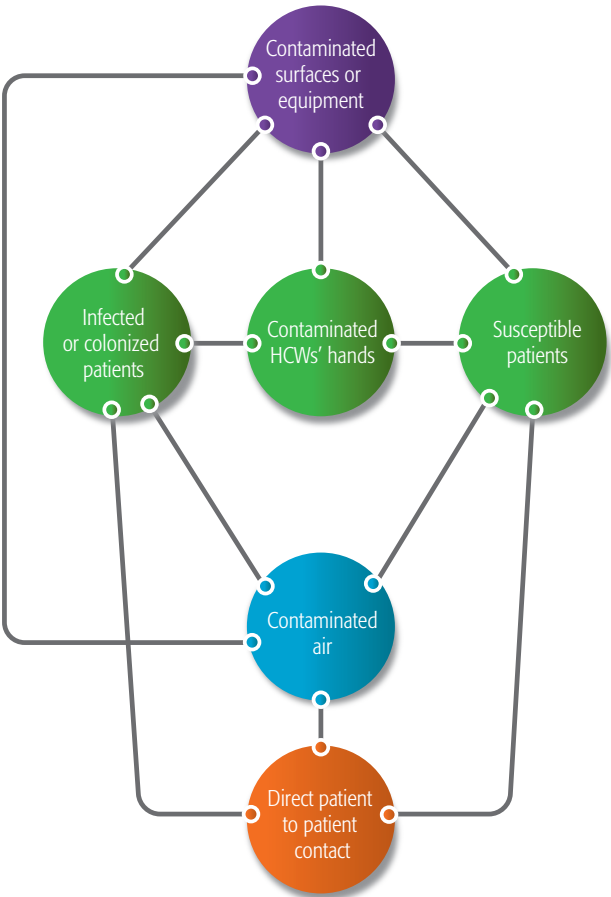
AIRBORNE TRANSMISSION

Airborne organisms can be inhaled, fall directly onto wounds or instruments or survive on surfaces and then be indirectly transmitted to patients. Some pathogens are especially likely to be shed from patients or carriers, resist drying, survive in dust or droplets and then be spread via the air.

The main airborne organisms include:
- *Staphylococcus aureus*
- Coagulase negative Staphylococci (CoNS)
- *Streptococcus pyogenes*
- *Acinetobacter* spp
- *Mycobacterium tuberculosis* (TB)
- Norovirus
- Influenza
- Middle East Respiratory Syndrome coronavirus (MERS-CoV)
- *Clostridium* spores
- *Legionella* spp.
- *Aspergillus* spp.

Staphylococcus aureus

Methicillin-sensitive (MSSA) and methicillin-resistant (MRSA) strains are the major pathogen of surgical wounds, skin and soft tissue infection.

MSSA is a commensal of nose, perineum and other skin sites in about 30% of normal people and is shed on skin squames that float in the air before settling and surviving in dust. Air movement stirs up dust and *S. aureus* can then be transmitted to wounds and instruments.

MRSA is carried much less frequently but spreads widely amongst hospital patients. It is mainly transmitted from colonized and infected patients through healthcare workers' hands, but environmental contamination and airborne spread may also be involved.

Coagulase negative staphylococci (CoNS)

These are low virulence organisms that colonize the skin of normal people. They also are shed into the air and may settle on wounds and surgical instruments, leading to prosthetic infections, especially in orthopaedic and cardiac surgery.

Streptococcus pyogenes

This organism is carried in the throats of about 5% of healthy people and causes wound and skin and soft tissue infection with a similar epidemiology to *S. aureus*.

PREVENTION AND CONTROL MEASURES

These measures involve the systematic implementation of **standard hygiene and cleaning precautions** *(CDC, 2003; WHO, 2008)* for the prevention and control of surface contamination. The control of air contamination in high risk areas such as operating theaters involves strict environmental cleaning, frequent air changes and air filtration (see box below). In implant surgery, additional protection of the wound and surgical instruments from CoNS is provided by delivery of ultraclean air from special ventilation canopies or hoods.

CONTROL OF AIRBORNE TRANSMISSION IN OPERATING THEATERS AND OTHER HIGH RISK ENVIRONMENTS
(Dharan & Pittet, 2002; Hoffman et al, 2002; CDC 2003)

Transmission of airborne infections can be prevented by:

- **Repeated air changes**, air filtration and reduction of air turbulence.
- **Keeping staff to a minimum** throughout an operation.
- **Maintaining air flows** directed from clean areas such as theaters, intensive care units and treatment rooms (relatively positive pressure) to less clean general areas (relatively negative pressure).
- **Applying stricter measures** for higher risk environments. For example, six air changes/hr are recommended for general wards, 10/hr for critical areas, 15/hr for day case theaters and 25/hr for general theaters.
- **Using laminar flow filtered air** via canopies (ultra clean ventilation, UCV) for prosthetic implant surgery.

Although there are **no agreed standards for bacterial air sampling or its frequency**, many authorities agree on monitoring when:

- **A surgical theater is newly commissioned;**
- **After building works or refurbishment** *(Hoffman et al, 2002)*;
- **Monitoring of adherence to cleaning practices is recommended.**

OPERATING THEATER AIR QUALITY

- **Empty operating theater:**
  < 35 colony-forming units (cfu)/m³, with
  < 1 colony of Clostridium perfringens or *S. aureus* per m³
- **During an operation**, total air counts: **< 180 cfu/m3** averaged over 5 minutes.

(*Consensus from Dharan & Pittet, 2002; Hoffman et al, 2002; CDC, 2003*)

Acinetobacter species

(*Peleg et al, 2008; Tacconelli et al, 2014*)

Gram-negative bacteria have less resistance to drying than Gram-positives and are generally not transmitted via air. The exception is *Acinetobacter* spp. These non-fermenting Gram-negative coccobacilli are widely distributed environmentally in soil and water and also colonize the skin and mucous membranes in about 25% of normal people.

Acinetobacter baumannii is the most frequently isolated *Acinetobacter* and the most likely to acquire multiple antibiotic resistance. It is the commonest cause of hospital *Acinetobacter* outbreaks. Recent isolates of these organisms may be highly MDR and such strains have caused major outbreaks and serious, difficult to treat infections in immunocompromized patients, particularly in intensive care units.

*Acinetobacter*s can survive for weeks or months on dry surfaces and be transmitted via dust, contaminated equipment and aerosols from contaminated air conditioning.

Hospital outbreaks originate from contaminated environmental sources or follow hand transmission from the skin of colonized patients. Outbreaks may be with single epidemic strains, usually from an environmental source, or with multiple distinct isolates associated with a complex mixed epidemic and endemic epidemiology.

A. baumannii is found in nearly 50% of respiratory cultures of all *A. baumannii* positive patients and isolates are increasingly carbapenem resistant *(Munoz-Price et al, 2013)*.

PREVENTION AND CONTROL MEASURES

Environmental control focuses on:
• Strict attention to hand washing and disinfection,
• Effective environmental cleaning,
• Isolation of colonized and infected patients.

Extremely MDR *Acinetobacters* can cause more difficult-to-treat or even untreatable infections. These MDR pathogens require enhanced control procedures to prevent their spread in high risk units. This involves the very strict application of standard procedures, enhanced environmental cleaning, identification of asymptomatic carriers by patient screening and isolation of colonized and infected patients in negative pressure rooms, with filtered air if necessary.

Endemic infection is particularly difficult to control and is often related to extensive environmental contamination. Typing of patient and environmental isolates may be needed to identify and eliminate sources and routes of transmission. Regular environmental cleaning is recommended to prevent outbreaks, but temporary closure of affected units for cleaning may be needed to control endemic infection *(Tacconelli et al, 2014)*.

Tuberculosis

The most common form of tuberculosis (TB) is pulmonary or respiratory TB. Such patients, who often cough up *M. tuberculosis* in sputum, are said to have 'open TB', i.e. transmissible to others. Pulmonary TB patients are often nursed in hospitals, where they pose a risk of transmission via the airborne/inhalation route to other patients, staff and visitors. The immunocompromized are especially vulnerable to infection, including those with HIV/AIDS. Many TB outbreaks in hospitals have been reported in the literature and the emergence of multi-drug resistant tuberculosis (MDR-TB) makes this a particularly important disease to control in healthcare facilities.

PREVENTION AND CONTROL MEASURES

(Hannan et al, 2000; CDC, 2005; NICE, 2011)

• **Identify infected patients:** this is essential as undiagnosed patients with open TB can spread TB widely in institutions.
• **Isolate infected patients** until judged to be non-infectious, with reinforced air isolation precautions (specific mask).
• **Assess risk** for drug resistance and HIV for all patients with TB. If MDR TB is known or suspected, special precautions should be implemented (see page 10).

- **Isolate patients with suspected open respiratory TB**, especially from immunocompromized patients. They should be nursed in single rooms, either with negative pressure or vented to the outside of the building. Perform aerosol-generating procedures such as bronchoscopy, sputum induction or nebuliser treatment in an appropriately ventilated area.
- **Use of masks** (particulate respirators), gowns and barrier nursing techniques is recommended for healthcare workers caring for patients or people suspected of having infectious TB, or during aerosol-generating procedures associated with a high risk of TB transmission.
- **Inpatients** with open respiratory TB should wear a surgical mask whenever they leave their rooms until they have had two weeks' drug treatment.

> ## MULTI-DRUG RESISTANT TUBERCULOSIS
>
> MDR-TB is a serious and potentially untreatable infection and **special precautions** should be implemented to prevent its spread.
>
> - **Negative-pressure rooms** with continuously monitored air flows for patients with known or suspected MDR TB, until they are judged non-infectious.
> - **FFP3 masks** for staff and visitors while the patient is considered infectious. Masks should meet the standards summarized by the Health and Safety Executive guidelines (2013). Staff who are likely to nurse infected patients should be trained in the use of FFP3 masks and have their mask fit tested.

Middle East Respiratory Syndrome (MERS) and other virulent viral respiratory infections

Since April 2012, cases of severe and often fatal acute respiratory tract infections with a novel coronavirus (Co-V) have been reported from the Middle East. The reservoir is thought to be bats, but it appears to have spread to humans mainly via camels. However, knowledge of the epidemiology of MERS is still limited.

This virus is similar to, but distinct from, the coronavirus that caused the global outbreak of Severe Acute Respiratory Syndrome (SARS) in 2002-3. Many lessons learnt during the SARS outbreak can be applied to the new outbreak of MERS. In particular, although inhalation protection was important, transmission was probably largely via droplet spread via

hands and environmental contamination. Outbreaks were often brought under control by stringent application of standard infection prevention and control (IPC) procedures, including hand washing *(Shaw, 2006)*.

MERS appears to be less transmissible than SARS but has a higher case fatality rate (40 - 50%). Spread is via respiratory droplets. Although MERS may cause limited human-to-human transmission with close contact (in families and healthcare workers caring for MERS cases), so far it has not caused larger community outbreaks.

MERS is a current threat, but at different times other virulent viral respiratory infections emerge as potential pandemics, including SARS and avian and swine influenza. The prevention of airborne and other environmental transmission of these infections, as well as severe infections with common strains of influenza, follows the same principles as outlined here for MERS.

PREVENTION AND CONTROL MEASURES

As there are no effective anti-virals for MERS, the main protection is the implementation of **strict standard IPC practices** at all times.

Detailed guidance and up-to-date advice on the changing epidemiology, diagnosis and management of MERS is given on the websites of the WHO (World Health organisation), CDC (Centers for Disease Prevention and Control USA) and PHE (Public Health England).

The principles of control are as follows:

- **Staff should be educated** and alerted to the potential risk of a patient with MERS being admitted, especially from the Middle East.

- **Strict, standard IPC practice** must be maintained by all staff at all times (regardless of the presence of any potential MERS patients), including non-clinical staff such as cleaners and porters.

- **Possible cases should be identified** and reported promptly to local public health authorities and managed according to local guidelines. Diagnostic samples should be collected and handled in accordance with local public health authorities and laboratories guidance.

- **Enhanced protection** (negative pressure isolation and use of personal protective equipment [PPE, in this case appropriate FFP3 masks]) must be used for the care of suspected and confirmed cases (after appropriate training).

- **The most likely scenario** is that an unsuspected case is admitted to an Intensive Care Unit (ICU) with respiratory failure thought to be due to other causes. ICU staff must be alerted about such cases, educated as to the risks and the appropriate IPC actions, and have mask fit testing and training completed.

Aspergillus

Spores of the fungus *Aspergillus* spp. are widespread in the environment and can be released into the air in high concentrations during demolition and building work. These spores do not usually harm healthy people, but may cause disseminated and fatal disease in immunosuppressed patients, especially neutropenics. Hospital building works therefore pose a risk to patients, especially those in oncology/haematology and intensive care units.

There is no consistent relationship between airborne *Aspergillus* spore counts and invasive infection, even in neutropenic patients. Several hospital outbreaks have been associated with nearby building works and care must be taken to reduce dust exposure during construction by containment, vacuuming and damping.

PREVENTION AND CONTROL MEASURES DURING BUILDING WORKS

- **Bone marrow transplant patients** are normally protected from airborne infections, including those from *Aspergillus*, by being routinely nursed in **sealed, positive-pressure single rooms** with high-efficiency particulate air (HEPA)-filtered air.
- **Other types of immunocompromized patients** are normally nursed in less protected environments. If spore contamination is likely to be difficult to contain, vulnerable patients should be moved to safe areas during construction work.
- **General recommendations** to reduce the risk of *Aspergillus* exposure during on-site construction include the following (*CDC, 2003; UK Department of Health Estates and Facilities, 2013*):
  - Involve the IPC team in the planning process from the beginning.
  - Implement a planned contamination-control programme when building work is planned.
  - Seal windows in areas accommodating susceptible patients.
  - Use floor-to-ceiling barriers that completely enclose the work area.
  - Use dampening procedures to reduce dust formation.
  - Use vacuum cleaners with HEPA filters on exhausted air.

Norovirus

Norovirus is a highly contagious cause of diarrhoea and vomiting that is usually community-acquired. In hospitals, rapid transmission can produce large outbreaks involving both patients and staff and may

lead to ward closures. The main transmission route is person-to-person spread by faeces and vomitus via hands. However, vomiting may be sudden and projectile, sometimes leading to widespread environmental contamination. The virus can survive in the environment for hours to weeks and environmental contamination may play a role in indirect spread. There is some evidence that the virus can be transmitted in air during vomiting and can infect other people in close proximity by the airborne route *(Marks, 2000, 2003)*. Nevertheless, air is a minor transmission route and does not require special control, except that isolation in side rooms rather than in bays or the open ward is recommended *(Harris, 2013)*.

PREVENTION AND CONTROL MEASURES

The prevention and control of norovirus infection in hospitals depends largely on the following **four key actions** *(CDC Guidelines, 2011)*:

- **Keeping symptomatic patients** and staff out of the hospital where possible.
- **Enforcing strict contact isolation** of patients until 48 hours after symptoms have cleared.
- **Restricting patient movement**.
- **Reinforcing hand decontamination** and environmental cleaning.

Clostridium spores

Clostridial spores are shed in faeces and can survive in the environment for months or even years. Transmission of *Clostridium difficile* spores, leading to diarrhoea and sometimes pseudomembraneous colitis, is primarily person-to-person via the faecal-oral route.

Spores of *Clostridium perfringens* from a previous infected surgical patient can theoretically transfer in the air of operating theaters to open surgical wounds and cause gas gangrene in a subsequent patient; this is, however, rare in modern surgery. Any gas gangrene cases should obviously be placed last on the list of surgery patients and appropriate environmental cleaning performed.

PREVENTION AND CONTROL MEASURES

Main control measures for Clostridial spores are by **contact isolation** with **enhanced hand hygiene** and **environmental cleaning**.

Standard operating theater control measures of repeated air changes and filtration and environmental cleaning are normally sufficient to prevent exogenous *C. perfringens* infection.

In hospitals, environmental water contamination has led to many hospital outbreaks. These include:

- *Legionella* **outbreaks** from contaminated general water supplies and air conditioning.
- *Pseudomonas* **outbreaks** associated with medical devices (see page 17), in particular fiber optic endoscopes (disinfection failure), or hydrotherapy pools.
- **Outbreaks of Gram-negative opportunists** in high dependency units due to contamination of tap water and humidifiers.

Legionella

Legionnaires' disease is a potentially fatal pneumonia caused by *Legionella* bacteria. It is the most well-known and serious form of a group of diseases known as Legionellosis. Everyone is susceptible to infection but the risk is higher in those over 45 years, smokers, heavy drinkers, people suffering from chronic respiratory or kidney disease, diabetes, lung and heart disease, and those with impaired immunity.

Legionella commonly contaminate hospital water systems, including cooling units, evaporative condensers, hot and cold water supplies and spa pools, especially where water is stored or re-circulated and where there are high levels of scale, sludge and biofilms.

Legionella survive at low temperatures, multiply between 20-45°C and are killed by higher temperatures. At optimum temperatures, they multiply to high numbers in water systems and people are infected by inhaling highly contaminated aerosols. This often occurs when showers or taps that have been unused for a period - allowing organisms to multiply in the stagnant pipes - are turned on. Infection usually occurs as outbreaks in air conditioned buildings and patients in hospitals are particularly vulnerable because of their underlying medical conditions.

PREVENTION AND CONTROL MEASURES *(WHO, 2007)*

The risk of *Legionella* outbreaks can be reduced **by installing safe water systems** and equipment and **implementing preventative maintenance programmes**. There are extensive regulatory requirements for the control of *Legionella* and hospitals should be compliant with local/national guidance.

The principles of prevention and control are as follows:

- **Hospitals should produce a *Legionella* policy** (involving medical, nursing, laboratory professionals and IPC teams) to assess the risk of contamination, implement appropriate risk-reduction programmes, monitor compliance and contamination rates, rapidly identify cases and investigate and control outbreaks should they occur.
- **A named person should be managerially responsible** for the control systems and measures adopted and should report to appropriate authorities.
- **The water system installation and preventive maintenance programme** should:
  - avoid water stagnation;
  - store and distribute cold water below 25 °C and ideally below 20 °C;
  - maintain hot water temperatures at a high enough level to kill *Legionella* while avoiding scalding. This should be above 50°C; 60°C is usually recommended.
  - include a programme of descaling and biocide treatment;
  - include regular flushing of taps and showers regardless of routine use;
  - monitor *Legionella* concentrations and implement additional treatment cycles to maintain safe levels if concentrations rise.

Multi-Drug Resistant Gram-negative bacteria
(CDC, 2003; Tacconelli et al, 2014)

Many Gram-negative opportunistic pathogens can survive and proliferate in wet environmental sites such as hospital water systems and taps, ice machines, water baths sink drains and hydrotherapy pools, and may sometimes spread from these reservoirs to cause infections in patients.

These water organisms include the non-fermenting bacteria *Pseudomonas*, *Serratia*, *Acinetobacter* and *Flavobacterium* species that are inherently antibiotic resistant and have the ability to acquire multiple resistance factors.

Multi-drug-resistance Gram-negative bacteria may contaminate and survive in supposedly sterile solutions or clean water reservoirs associated with hospital equipment. Outbreaks of antibiotic-resistant infections may therefore occur when there are failures of sterilization of injectable solutions or breakdowns in the maintenance, decontamination and disinfection of hospital equipment, such as arterial pressure monitoring systems, endoscopes, suction apparatus, humidifiers, nebulizers, ventilators and breast pumps. Similarly, MDR *Klebsiella*, *Serratia* and *Enterobacter* species may contaminate and survive in cold hospital food or enteral feeds given to compromized patients.

MDR Gram-negative organisms tend to be relatively resistant to disinfectants and bacteriostatic agents. Contamination of disinfectants and multiple-use medications may lead to outbreaks of antibiotic-resistant infections, such as post-operative endophthalmitis caused by *Pseudomonas aeruginosa* and *Burkholderia cepacia* associated with contaminated eye drops *(CDC, 1996; Lalitha et al, 2014)*.

PREVENTION AND CONTROL MEASURES

The prevention and control of infection with MDR Gram-negative bacteria in wet environmental sources depends on standard preventive measures:

- **Disinfectants** should be freshly prepared in newly sterilized bottles and ideally for single patient use only.
- **Standing water sources** (ice machines, water baths, humidifier water) should be replaced regularly and the containers cleaned. Where appropriate, disinfectant can be added to suppress bacterial growth.
- **There are specific guidelines** on control of contamination of specific items and facilities such as:
  - hydrotherapy pools (see page 34);
  - expressed breast milk (*NICE 2010*);
  - renal dialysis water (see page 35);
  - fiber-optic endoscopes (see page 17).
- **In other cases**, appropriate cleaning and disinfection between each patient use is effective.
- **Disinfection of large equipment** such as ventilators and incubators in hydrogen peroxide rooms is a useful additional control.

In the hospital setting, infection outbreaks may frequently be associated with medical devices, in particular fiber optic endoscopes.

Wherever possible, medical devices should be disposable and single use. If this is not possible, appropriate decontamination protocols should be in place for all re-useable items.

All medical equipment should be decontaminated by specialised trained staff in certified and externally audited departments.

Fiber optic endoscopes

Fiber optic endoscopes are examples of medical devices that are introduced into both sterile and non-sterile body sites and which can cause infection if they are contaminated.

Because they are heat sensitive, fiber optic endoscopes have to be chemically disinfected. This is less reliable than autoclaving and failures of such disinfection have led to endoscope-associated infections, usually with water-borne MDR Gram-negative bacteria, especially *Pseudomonas* spp.

Some outbreaks have been with environmental *Mycobacteria* spp. that may contaminate mains water supplies and are relatively resistant to disinfectants. Stringent systems must therefore be in place to ensure the safe decontamination of these endoscopes.

PREVENTION AND CONTROL MEASURES

(Department of Health, England, 2013; BSG Report, 2014; ASG & SHEA 2011)

Decontamination of fiber optic endoscopes is a specialist procedure that should be performed only by trained personnel in accredited units.

There are often local regulatory requirements and different instruments and automated washer-disinfectors (AWDs) may have different manufacturer's operational procedures.

After cleaning, flexible endoscopes can be disinfected by special chemical solutions in AWDs, followed by rinsing and drying cycles. An enzymatic treatment is also commonly used to remove biofilms.

Successful disinfection depends on:
- **Correct operation** of the AWD.
- **Use of an appropriate disinfectant** at the correct concentration and exposure times.
- **Use of clean water** for the final rinse.

The following is a summary of common control measures but local policies should be consulted for more detail.
- **Control systems** should be in place to ensure effective cleaning, processing and tracking.
- **If process failures** or possible instrument/device-associated outbreaks occur, potentially contaminated items should be recalled, outbreak organisms typed, sources and transmission routes of infection investigated and system breakdowns rectified.
- **The most effective method of sterilisation** is by high temperature/high pressure autoclaves (for heat-resistant items such as metal surgical instruments and rigid endoscopes).
- **Flexible fiber optic endoscopes** are heat labile and cannot be autoclaved; they are usually reprocessed by high level disinfection rather than sterilisation. This process of high level chemical disinfection using peracetic acid is now performed in AWDs, which control the disinfection process and perform a final rinse of the endoscope with water.
- **Rinse water for gastro-intestinal endoscopes** (which make contact with mucous membranes, secretions and excretions but do not usually penetrate sterile areas of the body) needs to be only of potable quality.
- **Rinse water for endoscopes which enter sterile body cavities** (such as arthroscopes) needs to be of a higher standard.
- **Final rinse water from AWDs** should have a low microbial count. It should not present a potential hazard to the patient either through infection, or by an erroneous diagnosis due to contamination of aspirated samples for culture.

Microbiological Monitoring of AWDs include:

- **a weekly test** of the quality of the final rinse water. This involves measurement of total bacterial viable counts (TVCs) expressed as colony-forming units (cfus) per 100 mL.
- **quarterly and annual tests** that include the prolonged incubation needed to identify any contaminating mycobacteria.

> **Safe bacterial TVCs** are usually considered to be **<10 cfu per 100 mL**.
>
> **Safe mycobacterial counts** are usually considered to be **no mycobacteria per 200 mL**.

If higher TVCs are found up to 100 cfu per 100mL, the AWD should go through a self-disinfection cycle.

If the TVCs remain high, or if the initial sample count is >100 cfu per 100 mL, the machine should be removed from service until remedial action has returned the TVCs to normal.

Microbiological results should be monitored sequentially to identify normal variation and take early action if abnormal trends occur. During investigations of poor results, collection of water samples prior to the final treatment process (supply water and break tank water) should be considered. In addition, filters, pipework and pumps should be checked and replaced if necessary.

For disinfection measures, see page 27.

DRY SURFACE TRANSMISSION

Until recently, infection control has tended to focus on patients' endogenous flora as the major source of healthcare-associated infection, with the main route of transmission from infected and colonized patients being staff hands. Contaminated hospital equipment, medicines, and water supplies have also been recognised as other common sources of hospital outbreaks.

In contrast, the dry hospital surface environment has only recently been considered as a potentially important source of healthcare-associated infection and as playing a role in the transmission of multi-drug resistant organisms *(Boyce, 2007; Otter et al, 2011, 2013. Weber et al, 2010, 2013; Gebel et al, 2013; Tacconelli et al, 2014)*.

THERE IS INCREASING EVIDENCE OF THE IMPORTANT ROLE THE ENVIRONMENT PLAYS IN HOSPITAL INFECTIONS:
(Carling et al, 2013)

Important hospital pathogens can survive on dry surfaces for prolonged periods

The major hospital pathogens, methicillin-resistant and -sensitive *Staphylococcus aureus* (MRSA, MSSA), vancomycin-resistant and sensitive *Enterococcus* spp. (VRE, VSE), *Clostridium difficile, Acinetobacter* spp., and norovirus may survive for months on dry surfaces (**Table 1**). Gram-negative organisms other than *Acinetobacter* tend to be less resistant to drying but *Pseudomonas aeruginosa* and *Klebsiella* spp. can also survive for long periods and this may contribute to cross-infection.

Survival of hospital pathogens on dry hospital surfaces.
[*Adapted from Otter et al, 2013*]

Organism	Survival time
Clostridium difficile (spores)	> 5 months
Acinetobacter spp	3 days to 11 months
Enterococcus spp including VRE	5 days to > 46 months
Pseudomonas aeruginosa	6 hours to 16 months
Klebsiella spp	2 hours to > 30 months
Staphylococcus aureus, including MRSA	7 days to > 12 months
Norovirus (and feline calicivirus)	8 hours to > 2 weeks

The surface environment around colonized or infected patients is frequently, and often extensively, contaminated with hospital pathogens.

(*Weber et al, 2013*)

The proportion of surface samples from rooms occupied by infected or colonized patients contaminated with the infecting pathogen has been reported as 1 to 64% for MRSA, 7 - 70% for VRE, 3 - 74% for *C. difficile* and 3 - 50% for *Acinetobacter* spp. Some studies have isolated multiple strains of some pathogens, such as MRSA, from the room environment that differ from the organism affecting the most recent occupant, indicating that pathogens from previous patients can survive in rooms for prolonged periods.

Contact with room surfaces or medical equipment by staff frequently leads to contamination of hands and/or gloves

Studies show that staff hand contamination in isolation rooms occurs at similar rates for both direct patient contact and surface environmental contact (**Table 2**).

Table 2.

Transfer of pathogens from surfaces to the hands of health care personnel.
[*Adapted from Otter et al, 2013*]

Direct patient contact	Contact with environmental surfaces only
	52% of 44 HCP acquired VRE on their hands or gloves
45% of 50 HCP acquired MRSA on their gloved hands	45% of 50 HCP acquired MRSA on on their gloved hands
50% of 30 HCP acquired *Clostridium difficile* on their gloved hands	50% of 30 HCP acquired *C. difficile* on their gloved hands
Compliance with hand hygiene: 80%	Compliance with hand hygiene: 50%

HCP: Health care personnel.

Figure 2.

Overview of common routes of transmission of health care-associated pathogens and potential environmental disinfection strategies.
[*Adapted from Donskey, 2013*]
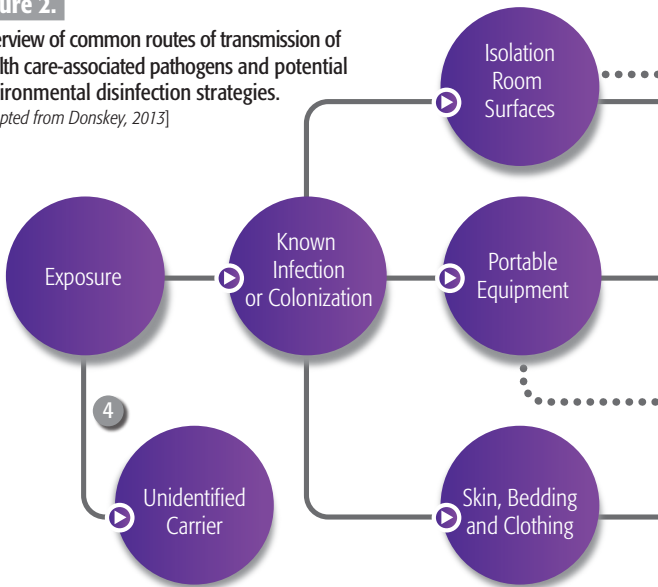
Patients colonized or infected with health care-associated pathogens shed organisms onto their skin, clothing, and nearby environmental surfaces. Susceptible patients may acquire pathogens through direct contact with surfaces or equipment or via the hands of health care personnel. Four sources of transmission and potential environmental disinfection strategies to interrupt transmission are shown:

1. contamination of surfaces after terminal cleaning of isolation rooms resulting in risk of acquisition by patients subsequently admitted to the same room (intervention: improve terminal room cleaning and disinfection);

The risk of staff hand contamination appears to depend on the level of environmental contamination. 'High touch surfaces' are those that are frequently touched and are the most heavily contaminated.

The same observation was made by Morgan *et al*. *(Crit Care Med, 2012)*: MDR *A. baumannii* was transmitted in one out of three interactions of staff with colonized patients. Environmental contamination with an MDR bacterium was the most predictive factor in healthcare worker contamination. A high association was also seen between *A.baumannii* environmental contamination of patient rooms and positive patients *(Munoz-Price et al., 2013)*.

Therefore, although pathogen transfer between patients most commonly occurs via the hands of staff, contaminated hospital surfaces can be directly or indirectly involved in the transmission pathways. (**Figure 2**).
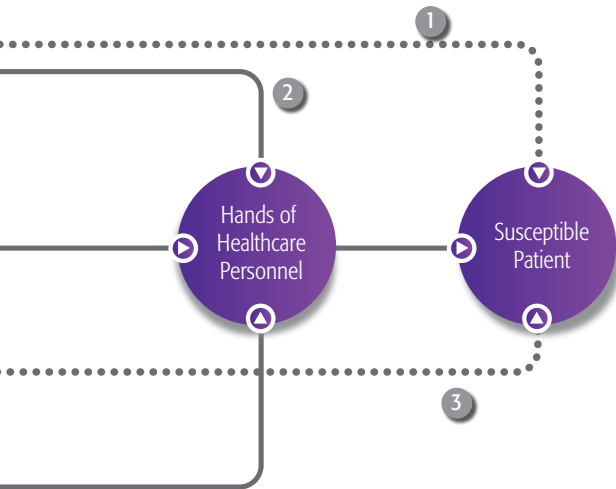
2. contamination of surfaces in isolation rooms resulting in risk for contamination of health care personnel hands (intervention: daily disinfection of high-touch surfaces);

3. contamination of portable equipment (intervention: disinfection of portable equipment between patients or use of disposable equipment in isolation rooms);

4. contamination of surfaces in rooms of unidentified carriers of health care-associated pathogens (intervention: improve cleaning and disinfection of all rooms on high-risk wards or throughout a facility).

A patient admitted to a room previously occupied by a patient colonized or infected with a nosocomial pathogen has an increased risk of acquiring that pathogen through colonization or infection

This has been shown for MRSA, VRE, *C. difficile*, *P. aeruginosa* and *Acinetobacter* (**Figure 3**) and is important evidence that contaminated environmental surfaces are sources of hospital cross-infection.

Figure 3.

Chart showing the increased risk associated with the prior room occupant.
[*Adapted from Otter et al, 2013*]

Difference in risk
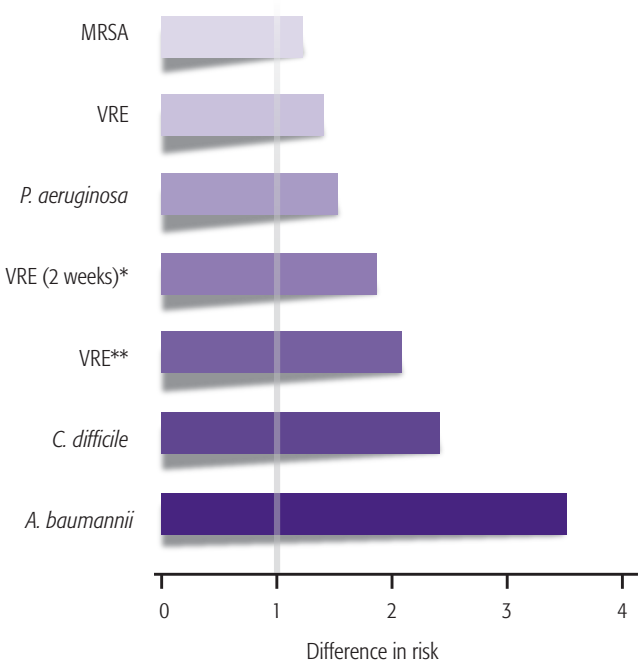
*Any patient infected or colonized with VRE in the two weeks prior to admission.
**The immediate prior room occupant was known to be infected or colonized with VRE.

Improved environmental cleaning of wards and terminal cleaning of isolation rooms leads to decreased infection rates

This has been shown in several studies where environmental ward cleaning with hypochlorite was associated with a reduction in *C. difficile* infection, and in other studies where improvements in the frequency or quality of environmental cleaning was associated with reductions in MRSA and VRE infection rates. *(Donskey et al., 2013)*.

Similarly, improved terminal cleaning of isolation rooms after a colonized patient is discharged and before the next, non-colonized, patient is admitted has been shown to reduce infection rates. Passaretti *et al*. used hydrogen peroxide vapor (HPV) for the terminal disinfection of isolation rooms that had been used for previous patients infected or colonized with multidrug-resistant organisms (MDROs):

- HPV decontamination reduced the proportion of rooms contaminated with MDROs by 35%.
- Patients admitted to rooms decontaminated with HPV were significantly less likely to acquire any MDRO (64% reduction) than patients admitted to rooms disinfected with standard methods.
- There was a significant 80% reduction in the risk of acquiring VRE from the prior occupant and non-significant reductions in the risk of acquiring MRSA, *C. difficile* and MDR-Gram Negative bacilli.

STRATEGIES TO REDUCE AND CONTROL ENVIRONMENTAL SURFACE CONTAMINATION

Improvements in cleaning quality

Numerous studies have shown that environmental cleaning in hospitals often falls below acceptable standards and conventional cleaning processes produce only a 50% reduction in surface contamination rates *(Otter et al, 2011; Weber et al, 2013)*.

However, improved cleaning can reduce infection rates as shown below:

- 66% reduction in VRE acquisition rates following a 75% improvement in thoroughness of environmental cleaning *(Hayden et al, 1996)*.
- 50% and 28% reduction in MRSA and VRE acquisition respectively as a result of an 80% improvement in cleaning practices *(Datta et al, 2011)*.

Educational or training programmes, together with feedback on cleaning effectiveness, can improve the quality of cleaning, leading to a reduction in contamination and, in some cases, to a reduction in infection rates *(Donskey, 2013)*.

In recognition of the importance of environmental contamination for nosocomial infection, the Centers for Disease Control and Prevention (CDC) has produced a tool kit to help hospitals comply with their 2004 guidance and improve environmental cleaning (see below).

PRACTICAL TOOL KIT BY CDC

A tool kit has been developed by the **Centers for Disease Control and Prevention** (CDC) *(Guh & Carling, 2010)* to help hospitals comply with the 2003 CDC recommendation to "implement procedures that ensure consistent cleaning and disinfection of surfaces closely approximated to the patient and likely to be touched by the patient and health care workers." *(Sehulster et al, 2004)*.

This tool kit describes two levels of single room terminal decontamination:

- **Level 1** - comprises basic interventions to optimised disinfection cleaning practices, procedures and staff education and practice.

- **Level 2** - all elements of Level 1 plus objective monitoring of practice, by measuring 'cleanliness' (a measurement of surface bioburden) or 'cleaning' (a measure of how well cleaning is done):

  - **Bioburden** can be measured by swab and other cultures and adenosine triphosphate (ATP) bioluminescence. However, no universally accepted standards of cleaning and cleanliness have yet been accepted *(Carling, 2013)*.

  - **Cleaning** can be assessed by direct practice observation and the use of fluorescent markers.

Testing for environmental contamination

Bacteriological sampling

Routine bacteriological sampling of environmental surfaces is not routinely indicated. However, sampling may be required to:

- **Identify** an environmental source of an outbreak;
- **Confirm** the efficacy of disinfection or cleaning procedures;
- **Monitor** adherence to cleaning practices.

- **Swab cultures** can identify pathogens and provide quantitative measurement of contaminating pathogens. More time is required to take swabs and then plate them out than to use direct agar contact plates (see below). This technique is therefore mainly employed in research studies of cleaning effectiveness or to identify specific pathogens and help clarify the epidemiology during outbreaks.
- **Direct agar contact cultures** use agar-coated plastic slides or contact plates to directly sample environmental surfaces. The number of colonies growing on the agar surface can be used to quantitate the bacterial burden.

Other methods for assessment of environmental contamination and effectiveness of cleaning

- **Fluorescent gel** can be used to assess the thoroughness of cleaning practice. The gel is applied covertly to mark surface areas to be cleaned but theoretically cannot be seen by the cleaners. After cleaning, ultraviolet light can show how much of the gel has been removed and therefore how thoroughly cleaning has been performed. This method has been used successfully in educational programmes to improve cleaning practice.
- **Adenosine triphosphate (ATP) bioluminescence technology** detects the presence of organic debris, including viable and nonviable bacteria, on surfaces. Semi-automated ATP systems have been used widely to monitor surface contamination in the food industry and have recently been applied in healthcare settings. However, because of the generally low level of contamination on healthcare surfaces and the detection by ATP of non-viable material, the sensitivity and specificity of these systems are only around 57%. The method is therefore of limited use for critical monitoring of the hospital environment *(Mulvet et al, 2011)*. It may have a role in monitoring the effectiveness of cleaning practice.

Use of surface disinfectants

For disinfection and sterilization purposes, medical devices and equipment can be divided into critical, semi-critical and non-critical according to the degree of risk for infection *(CDC, Rutala & Weber, 2008)*.

Critical devices enter sterile tissue, and include surgical instruments, vascular and urinary catheters and implants. Critical devices have a high risk for infection if contaminated. These devices should be sterile single-use items or multi-use items sterilised by autoclaving between use.

Heat sensitive items such as fiber optic endoscopes should be disinfected by high level chemical disinfection; because of the potential risks associated with this method, processing should be carefully regulated and monitored (see pages 17-18).

Semi-critical devices come into contact with mucous membranes or non-intact skin, and include anaesthesia equipment and devices used in respiratory therapy, some endoscopes, laryngoscope blades and cystoscopes. These can have high-level chemical disinfection (removal of bacteria and viruses but not spores) after cleaning.

Non-critical devices come into contact with intact skin but not mucous membranes and include bedpans, blood pressure cuffs, stethoscopes, crutches and computers. These can be cleaned with standard cleaning materials or disinfectant wipes. The potential for patient to patient transmission of MDR hospital pathogens has led to the increasing use of disposable blood pressure cuffs and tourniquets.

Hospital surfaces such as floors or bedside tables are classified as non-critical items. Many therefore consider that cleaning with detergent is sufficient *(Ruden & Daschner, 2002)*, while others routinely use a disinfectant *(Rutala & Weber, 2002, 2008)*. The potential for transmission of MDR pathogens has led to the implementation of special disinfection procedures for beds after use by known colonized or infected patients, including steam cleaning or hydrogen peroxide decontamination.

There is increasing evidence for terminal disinfection of single rooms previously occupied by patients colonized with an MDR pathogen or the cleaning of a ward or bed area during or after an outbreak of *C. difficile* or norovirus infections.

Furthermore, with the increasing recognition of the importance of environmental contamination, routine disinfection of floors and other surfaces is becoming more widely practiced, although the evidence that this reduces infection rates is limited.

The most common surface disinfectants are phenols and quaternary ammonium compounds, but these are not active against spore-forming pathogens, such as *C. difficile*, or viruses, such as norovirus. Hypochlorites have often been used instead, which are effective for viruses but have variable activity against spores. New sporocidal compounds are under investigation.

Disinfection should be an integrated part infection prevention and control with appropriate standards and controls *(Gebel et al, 2013)*. There is a need to:

- **Define standard principles** for cleaning and disinfection.
- **Ensure compliance** with these principles by measures such as written standard operating procedures, adequate training and suitable audit systems.
- **Develop test procedures** to assess the efficacy of surface disinfectants in different situations.

Improvements in surface materials and design

The effectiveness of surface cleaning can be improved by designing hospital surfaces, furniture, fittings and equipment that resist contamination and are easy to clean. Many surface materials now incorporate anti-bacterials to reduce surface contamination, but there is limited evidence so far that they have a significant impact on infection rates. However, one study has recently shown the use of copper coated surfaces in hospital rooms to reduce the rate of healthcare-associated infections by more than 50% *(Salgado et al, 2013)*.

Use of new technologies for surface decontamination

Due to the problems with conventional cleaning and terminal disinfection, several new decontamination methods have been introduced. These include automated systems using ultraviolet light or hydrogen peroxide vapour (H_2O_2) *(Otter et al, 2013)*. Automation can eliminate some of the failures of practice often seen with manual cleaning methods and the systems have been referred to as 'No Touch Disinfection' (NTD). H_2O_2 systems have been shown to be effective in reducing the risk of patient acquisition of MDR pathogens as well as environmental contamination *(Passaretti et al, 2013; Mitchell et al, 2014)*. The limitations of these H_2O_2 systems are that they require rooms to be vacated and sealed before disinfection, and they are expensive.

MANAGEMENT & ORGANIZATION

Healthcare environments are liable to become contaminated with potential pathogens, many of which are now increasingly multi-drug resistant (MDR). This situation must be managed by the hospital Infection Control Committee (ICC) that reports to the main Hospital Board, either directly or via Risk Management and Clinical Governance. The ICC should have multidisciplinary representation, including from Microbiology, Nursing, Medicine, Surgery, Housekeeping, Estates, Endoscopy and Sterile Supply (Figure 4). In larger hospitals, consideration should be given to having a separate decontamination subcommittee of the ICC.

Education and training programs should be set up to ensure that staff are aware of and understand the problems of hospital infection and the importance of environmental hygiene in its prevention and control. Audits should be conducted to ensure the education is effective.
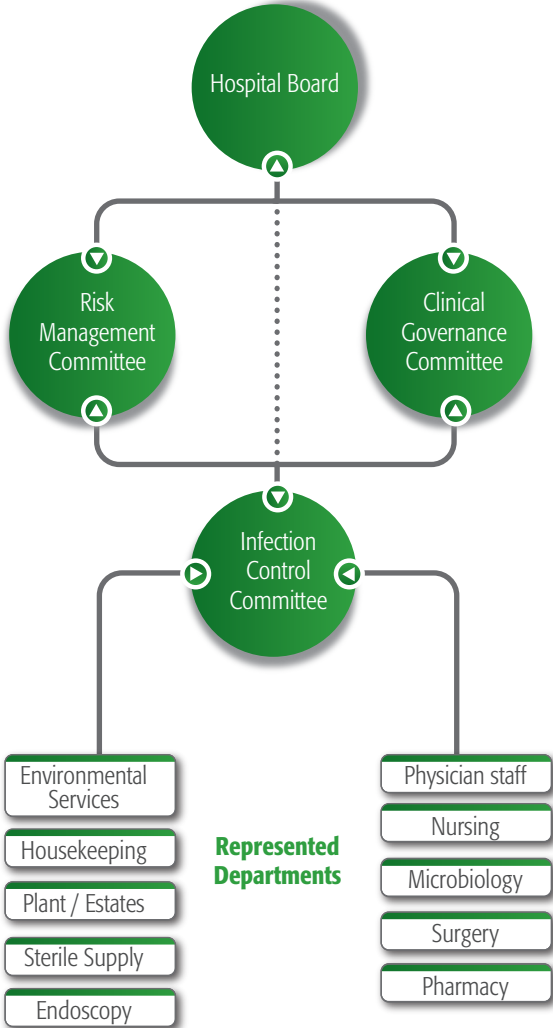
Written policies based on published guidelines and regulatory requirements should be produced and regularly updated for all major issues of concern. Compliance with these policies should be audited.

Surveillance systems should be in place to ensure the early detection of healthcare-associated infection and the possible occurrence of outbreaks. If a transmission or outbreak is suspected, the sources and routes of transmission should be investigated, with organism identification and typing where necessary. An incident group may need to investigate the possible outbreak and implement appropriate interventions to bring it under control.

Initial investigations may indicate environmental sources. If so, appropriate investigations, including environmental sampling, should be implemented. Once an environmental incident has been identified and controlled, appropriate changes to policies and practices should be made to ensure prevention of a recurrence.

Figure 4.

Example of Environmental Control Pathway and Organization within the Hospital Setting.

Hospital Board

Risk Management Committee

Clinical Governance Committee

Infection Control Committee

Represented Departments

Environmental Services

Housekeeping

Plant / Estates

Sterile Supply

Endoscopy

Physician staff

Nursing

Microbiology

Surgery

Pharmacy

BACTERIOLOGICAL SAMPLING OF THE ENVIRONMENT

When sampling the hospital environment, careful thought must be given to the nature and purpose of the sampling, and whether quantitative or qualitative results are needed. Before sampling, it is also important to decide what actions will be taken in response to the results. This may be difficult because in many cases there are no defined standards for microbial contamination.

Air sampling

Air sampling is usually undertaken to assess air quality in areas such as operating theaters, positive-pressure single rooms, pharmacy sterile units and sterile supply units.

Before sampling, it should be decided:
• What organisms are to be targeted;
• What culture media are to be used;
• The volume of air or time to be sampled;
• The need for quantitative or qualitative results;
• What actions might be taken with different results.

Air sampling may be passive or active:

• **For passive sampling**, several agar plates are simply exposed in the area for a defined period of time (usually 30 minutes or up to four hours). After exposure, plates should be stored at 1 - 8ºC and processed the same day or at least within 24 hours of collection. Culture should be at 30 +/- 1°C for 3 days for bacteria and 22.5°C/- 2.5°C for 5 days for yeasts and molds. The results are calculated as the number of colonies that appear over a unit of time. Results may be affected by air movements and activity, which need to be controlled.

• **Active sampling** uses mechanical air samplers, which draw in known volumes of air onto culture media or filters. Numbers of microbes present per unit volume of air can then be calculated accurately. The use of mechanical air samplers ensures measurement standardisation and result traceability.

Total microbial counts may be assessed and/or yeast and molds can be enumerated separately, using appropriate selective agars.

Microbial air sampler (SAMPL'AIR™)

Air sample testing target results

There are no standard accepted targets for active air sampling. The CDC recommends assaying only molds for control of aspergillosis. It also recommends particle counting for assessment of the effectiveness of air filtration. The figures below are consensus figures. The targets are given for unsatisfactory results that require remedial action.

OPERATING THEATER AIR QUALITY (ACTIVE AIR SAMPLING)

Tested on commissioning or following any refurbishment work
- Aerobic Colony Count **< 10 cfu per m³**

Test in empty rooms
- Aerobic Colony Count **< 35 cfu per m3**

Tested during a surgical operation
- Aerobic Colony Count **< 180 cfu per m3**

Water sampling

In most countries, the only statutory requirements for water quality testing are for drinking water. However, guidance on water testing is given in several documents addressing best practice:

- General guidance *(CDC, 2003; Tacconelli et al, 2014)*;
- Control of *Legionella* *(UK Health and Safety Executive, 2000; World Health Organization, 2007)*;
- Endoscopy rinse water *(Department of Health, England, 2013; BSG Report, 2014; ASG & SHEA 2011)*;
- Swimming and hydrotherapy pools *(WHO, 2006; HPE, 2008; Pool Water Treatment Advisory Group, 2009)*;
- Renal dialysis water *(UK Renal Association, 2009)*.

These have been summarized by Public Health England *(PHE, 2013)*.

Samples must be collected aseptically into sterile bottles. In general, neutralizing agents are added during water testing to neutralise the effect of any disinfectant (including chlorine) that may be in the sample and may prevent the growth of any contaminating organisms. The appropriate neutralizer should be chosen for each specimen and detailed recommendations can be obtained from guidance documents.

Water sample collection
(refer to the guidelines listed above)

Tap water
- **Quality of water delivered from the tap:** the tap should not be sanitised and the sample taken from the first portion of water delivered.
- **Quality of water before reaching the tap:** clean and disinfect the tap with sodium hypochlorite solution (1% available chlorine) and run for 2 – 3 minutes before sampling. Collect the sample aseptically into a sterile 1L or 500 mL bottle containing neutralizer (20 mg/L sodium thiosulfate).

Hydrotherapy pool water
Normally, a single sample of pool water (or several samples in larger pools) is taken from an area where the water velocity is lowest and away from fresh water inlets or outlets. Samples should also be taken from the balance tank and skimmers, and swabs from inside/behind any jets and from the lid or pool cover if used.

- Wipe the outside of a sterile 500 mL bottle containing neutralizer (120 mg/L sodium thiosulfate) with an alcohol wipe.
- Aseptically open the bottle and immerse it in the pool and fill with water.
- Recap and shake to disperse the neutralising agent.

If *Legionella* testing is required, collect a separate 1L sample in the same way.

Sampling water for *Legionella* testing
NOTE: When investigating water for *Legionella*, it is essential that an assessment is made of the risks involved and the protection needed before samples are collected.

Sampling should be done as part of a risk assessment and review of the whole water system. Water should be sampled from areas where *Legionella* are likely to multiply, such as the warmest parts of a cold system, the coolest parts of a hot system, or areas where there is low usage/stagnation.

For pools and taps (pre-flush samples), see above.

For showers, collect a 1 litre sample as follows:

- Before turning on, adjust the temperature setting to the midpoint for non-thermostatic taps and the normal use temperature (35°C to 43°C) for thermostatic taps.
- Detach the shower head and gently fill a sterile sample bottle containing neutralizer.
- Recap and shake to distribute the neutralising agent.

For routine testing of water systems to ensure the continuing effectiveness of preventative maintenance programmes, culture media or 'dip slides' coated with an appropriate *Legionella* agar can be used.

Renal unit dialysis water and fluids

Samples should be taken from points expected to have the highest bacterial load, such as the end of the distribution loop or the last machine in a dead-end system. If the sample is to be collected from a tap used solely for sampling, disinfect the outlet as described above. The samples should be collected aseptically into sterile, pyrogen-free bottles.

Automated washer-disinfector (AWD) rinse water

For bacterial and mycobacterial testing, 100 mL final rinse water is taken in duplicate from the appropriate port with aseptic technique during the final cycle.

Water Sample Processing

Water samples (except for *Legionella*) should be stored between 1 and 8°C and submitted to the laboratory for testing, ideally the same day, but at the latest within 24 hours of collection.

Water samples for *Legionella* testing should be stored at an ambient temperature (approximately 20°C), in the dark, and returned to the laboratory for processing as soon as possible, preferably the same day but at the latest within 24 hours.

Quantitative analysis of water specimens is usually done by passing the samples through sterile filter membranes of < 0.45 µm pore size and culturing on an appropriate selective or non-selective agar plate at 28 - 32°C. Colony counts are performed after 48 hours and 5 days. The test should be performed in duplicate.

For quarterly mycobacterial testing of AWD rinse water, the filtering method is the same but a mycobacterial agar should be used for culture and the incubation prolonged for 28 days.

Water sample testing target results

The targets are given for satisfactory results requiring no further action.

Hydrotherapy water samples

Tested weekly

• *Escherichia coli*	0 cfu / 100 mL
• Total coliforms at 37°C	0 cfu / 100 mL
• *Pseudomonas aeruginosa*	0 cfu / 100 mL
• Aerobic Colony Count	0-10 cfu / mL

General water systems for *Legionella*

Tested according to a preventative maintenance programme
and during suspected outbreaks

• *Legionella* spp.	0-100 cfu per L

Tap water in units caring for compromized patients

Tested according to a preventative maintenance programme
and during suspected outbreaks

• *Pseudomonas aeruginosa* and other *Pseudomonas*	0 cfu per 100 mL

Renal dialysis fluid and water used for the preparation of dialysis fluid

Tested monthly

• Aerobic Colony Count	0-50 / mL
• Endotoxin /mL	< 0.125 EU / mL

Renal dialysis ultrapure fluid and water used for the preparation of ultrapure fluid

Tested monthly

• Aerobic Colony Count	< 10 per 100 mL
• Endotoxin /mL	< 0.03 IU per mL

Endoscopy washer disinfector final rinse water

Tested weekly

• Aerobic Colony Count	< 1 / 100 mL

Tested quarterly

|	
• Environmental mycobacteria	0 / 200 mL

cfu = colony forming unit   EU = Endotoxin unit

[For details of alert levels and action levels see PHE 2013]

Surface sampling

Surface sampling usually requires moisture, and a sterile diluent such as saline or buffered peptone water is used. Appropriate neutralizers must be used if disinfectant residues are likely on the surface to be sampled.

- **Quantitative sampling** involves swabbing a known area (using a sterile template) in a standardized way in order to compare results from different sites, or from the same site at different times or using an agar contact plate.

- **Qualitative sampling** is appropriate when investigating the source of an outbreak. In this case, the larger the area sampled, the better the chance of detecting the pathogen of interest.

- **Swabbing** can be done with cotton-tipped swabs but wipes or sterile sponges are more convenient for larger areas and generally achieve a more efficient recovery of micro-organisms.

- **Organisms** are extracted from the swab or wipe or sponge in saline or other suitable fluid and transferred to appropriate agar plates (e.g. Trypcase Soy agar and Sabouraud Chloramphenicol agar).

- **After incubation** (usually at 30 +/- 1°C for 3 days for bacteria and 22.5°C +/- 2.5°C for 5 days for yeasts and molds), the colonies are counted and the surface bioburden calculated using the number of colony forming units per unit area. Colonies on contact plates or slides are counted directly and a similar calculation made, based on the area of the slide.

- **There are no standard target values** for surface contamination in healthcare facilities. Qualitative bacteriology is usually done if an outbreak is suspected or to assess the effectiveness of cleaning or for research purposes.

- **In an outbreak context**, it can be useful to detect specific micro-organisms from surfaces using chromogenic media: multidrug-resistant organisms (MRSA, VRE, ESBL, carbapenemases), *P. aeruginosa* or *C. difficile*.
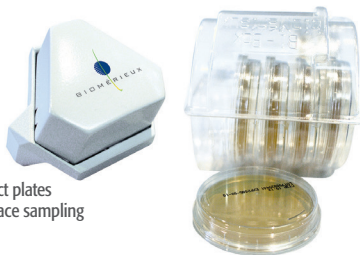
Applicator and contact plates
for standardized surface sampling
(Count-Tact®)
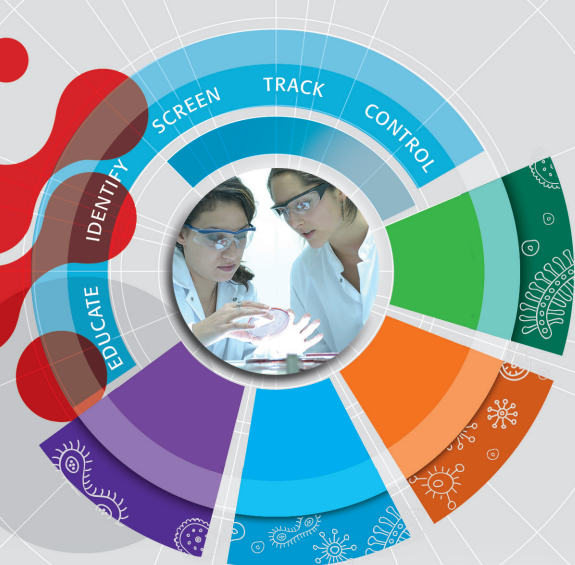
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