EVALUATION OF THE UTILISATION OF COPPER WITHIN A CLINICAL ENVIRONMENT

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The Evaluation of the utilisation of Copper within a Clinical Environment

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SUMMARY

The antimicrobial properties of copper have been demonstrated in laboratory investigations. In this study the role of copper in reducing environmental microbial contamination in a busy clinical environment was evaluated. A clinical study which involved a cross-over decision compared three items made from copper to standard clinical NHS items. These included a push plate on a door, a toilet seat and a hot and cold water tap attached to a hand wash basin. The study was designed to assess the efficacy of the copper containing items in reducing environmental microbial contamination. It was clearly demonstrated that the copper had the facility, even in a busy clinical environment to reduce surface microbial contamination. This could have implications for the prevention of spread of infection in the clinical area.

The opinion of both staff and patients regarding the use of the copper items and application was also determined by questionnaire. The results demonstrated that both staff and patients noticed a difference between the copper containing items as compared to standard hospital equipment. However, within two months they treated the copper containing items no differently from the standard equipment. This suggested that the view point of both staff and patients when the study was carried out should not have interfered or influenced the study or the results.

The final section of this study was a laboratory investigation into the antimicrobial activity of copper against staphylococci. Various laboratory methods were used to assess the antimicrobial activity of the copper and in particular to answer the question whether or not copper resistant microorganisms were appearing in a clinical environment during the clinical trial. The results demonstrated that copper resistant microorganisms did not emerge during the study.

A more comprehensive copper study has been designed to evaluate further the antimicrobial activity of copper in fifteen different items held commonly in hospitals. An outline of this study has been given with this thesis.

DEDICATION

For my Daughter

Georgia

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PUBLICATIONS

Casey AL, Adams D, Karpanen TJ Lambert PA, Cookson BD, Nightingale P, Miruszenko L, Elliott TSJ, Shillam, R, Christian. Role of copper in reducing hospital environment contamination, Journal of Hospital Infection (2010) 74, 72 – 77 (Appendix 2)

Poster Presentations

Karpanen TJ, Casey AL, Lambert PA, Cookson BD, Nightingale P, Miruszenko L, Elliott TSJ,. An evaluation of the antimicrobial properties of healthcare fomites (furnishing and equipment) made of copper alloys (Appendix 3).

Casey AL, Lambert PA, , Miruszenko L, Elliott TSJ, Copper for preventing microbial environmental contamination (Appendix 3).

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CHAPTER 1 INTRODUCTION

1.1 Healthcare Associated Infections

Healthcare associated infections (HCAI) cause significant morbidity and mortality in patients, both in the community as well as in the hospital setting. Approximately 300,000 HCAI occur in England per year, accounting for nearly 5,000 deaths (Taylor *et al.*, 2002). Healthcare associated infections in the UK cost the National Health Service approximately one billion pounds each year adding significantly to health costs. Between 15 to 30% of all HCAI are considered to be preventable by the application of strict compliance to national infection prevention and control policies and procedures. Despite the wide availability in the UK of defined policies and associated procedures related to many aspects of infection prevention, at any one time, overall 9% of in-patients in hospitals have a HCAI (Taylor *et al.*, 2002). Similarly, the Centre for Disease Control and Prevention has estimated that between 5 to 10% of hospitalised patients acquire a HCAI in the United States. This equates to approximately two million healthcare associated infections which are associated with nearly 100,000 deaths each year (Klevens *et al.*, 2007).

1.2 Prevention of Healthcare Associated Infection

There are various risk strategies associated with the acquisition and development of HCAI. Indeed it is now well recognised that there are a number of factors which contribute to the risk of a patient acquiring a HCAI. These include the level of complexity of medical procedures, the invasive nature of treatment which patients receive, the increasing age of patients now being treated and also their degree of immunosuppression.

For example, those patients on Intensive Care Units are more susceptible to acquiring HCAI due to the number of invasive techniques used in their care which include the use of indwelling intravascular catheters, urinary catheters and tracheal ventilation systems. All these devices allow microorganisms more ready access into the body. The devices can also subsequently become colonised with microorganisms which subsequently allow an infection to develop. When these infections develop in this group of patients they can result in more serious complications due to their underlying comorbidity (Saint *et l.,* 2002., Yokoe *et al.,* 2008).

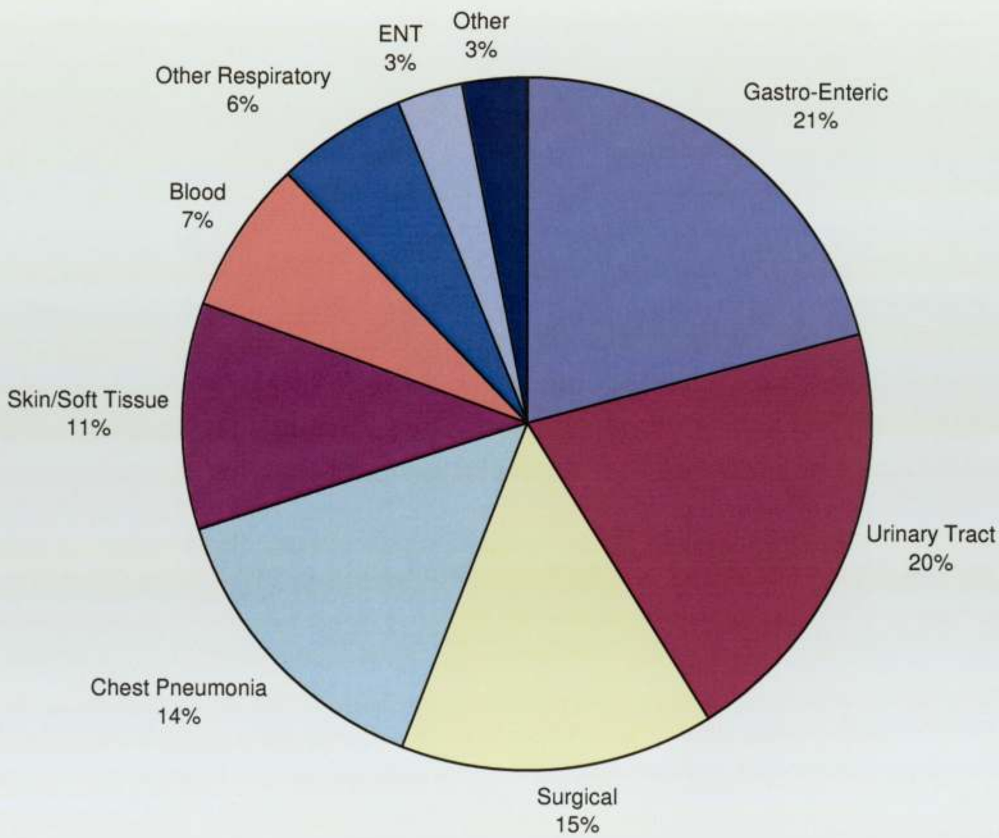
Reducing the incidence of HCAI has become a priority for healthcare providers. This has stimulated the recording of detailed rates of certain infections in hospitals in the UK and also the USA. In the UK monitoring of HCAI is now standard practice and includes determination and notification by all Hospital Trusts of all cases of infections such as meticillin resistant *Staphylococcus aureus* (MRSA) bacteraemia and the number of patients with *Clostridium difficile* which are acquired within hospital. In addition, other infections are now being monitored by many hospitals including surgical site infections (National Institute for Health and Clinical Excellence clinical guideline 74, 2008).

The main types of Healthcare Acquired Infections in terms of site infection is shown in figure 1.1.

Figure 1.1 The main types of Healthcare Acquired Infections

Prevalence of Health Care Associated Infections in the UK

(*Smyth et al., 2006*)



ENT = Ear, Nose and Throat

As shown in figure 1.1 urinary tract infections are the most prevalent infection; followed by surgical site infections and then pneumonia. Blood stream infections, although only accounting for 7% of all infections, have the highest associated mortality, Emmerson *et al.* (1996). Similar trends have been shown in other studies for example Emmerson *et al.* (1996) demonstrated that the commonest infections acquired by patients in hospitals were urinary tract (23.2%) followed by lower respiratory tract infections (22.9%), with surgical wound infections, accounting for 10.7%.

Urinary tract infections are the commonest HCAI's. This is because they are related to the clinical practice of urethral catheterisation which is a common procedure used for many patients. The presence of a urethral catheter allows microorganisms direct access to the urinary bladder via the catheter tubing. Microorganisms in the periurethral area in both males and females can colonise the external surface of the catheter and progress via the urethra into the urinary bladder resulting in infection. Another mechanism by which microorganisms can gain access to the urinary bladder in the presence of a catheter is when a closed drainage system is opened. This occurs for example when the urinary drainage bags are emptied. In this procedure organisms may gain access to the internal surface of a urinary catheter and again allow microorganisms to migrate upwards against the flow of urine resulting finally in contamination, colonisation and infection in the urinary bladder.

Regarding the relatively high prevalence of lower respiratory tract infections these are commonly associated with patients who have a endotracheal tube *in situ*. The presence of this tube allows microorganisms direct access from the patients upper respiratory tract flora to the lower respiratory tract including the bronchi and alveoli. The presence of the tracheal tube allows microorganisms to migrate downwards into the alveoli of the patients lungs and avoids the preventative mechanisms of the bodies defences which include cilia and the presence of macrophages.

Surgical site infections can occur in approximately five percent of patients. Rates of surgical site infections can range from 0.5 to 7.5 infections per 1000 post operative days with rates being highest in surgical procedures where the likelihood of microbial contamination at the surgical site is high for example with large bowel surgery (Surveillance of Health Care associated infections report HPA, 2008).

1.3 Sources of Infection

Infections can arise from two major sources. They can either be endogenous, which is from the patient's own microbial flora, including gastrointestinal carriage, skin commensals and the oral cavity. Alternatively, they can arise from exogenous sources such as health care workers or from the surfaces of fomites, including tables, bedside lockers and ward equipment. The microorganisms from either the patients' own endogenous flora or from the environment can be transmitted via several routes. These include healthcare workers and in particular hand carriage such as from a doctor or nurse to a patient. Alternatively, microorganisms can be sourced directly from the patient's own endogenous source. For example, commensals present on a patient's skin can directly contaminate a surgical operative site which may result in the development of a surgical site infection. Surgical site infections can be sub-divided and related to surgery and the type of operative procedure. Surgery is referred to as "clean surgery" if the operative procedure does not involve any internal organs of the body, which may contain microorganisms such as the large intestine. In comparison, operative procedures involving heavily colonised sites such as the large intestine are referred to as clean contaminated surgery. The numbers of patients who undergo clean contaminated surgery and who subsequently develop sepsis are higher as compared to procedures involving just clean surgery as indicated in the previous section.

1.4 Environmental Microbial Contamination

Environmental contamination can occur from many sources. It can be derived either from healthcare personnel or patients or can be from other vehicles such as air and water. Water contamination includes microorganisms such as *Legionella pneumophila* which can cause legionnaires disease. Other water borne diseases which can occur in the community, include Giardiasis and even salmonella. Air contamination can result in the spread of various microorganisms, for example *Aspergillus fumigatus*. This fungus produces spores which can become airborne and patients can become infected following inhalation of the spores into the alveoli in the lungs. These spores, particularly in immunocompromised patients can germinate and the resulting hyphae can cause a pneumonitis, inflammation in the lungs and infection namely pneumonia. Environmental contamination can also result in outbreaks of infection with many patients acquiring an infection from a point source. For example, *C. difficile* can be spread from an infected patient, to other patients via contamination of the environment, and in particular from commodes and toilets. The Care Quality Commission (CQC) published a report in 2007 following an investigation into outbreaks of *C.difficile* at Maidstone and Tunbridge Wells NHS Trust. The investigation highlighted key issues of concern in care. These included: poor cleaning of equipment including commodes, the lack of hand washing and use of gloves and aprons. The Trust had also no clearly identified process for isolating patients in a timely fashion once symptoms occurred. In addition, the Infection Control Team did not appear to work in conjunction with other Operational Managers to support the decision making process of the Infection Control agenda.

1.5 Methods of Prevention of Healthcare Associated Infections

Many reports have suggested that a significant number of HCAI can be prevented through implementation of evidence based best practices. These practices range from implementation of strict hand hygiene, application of aseptic techniques to appropriate procedures and the use of novel technologies, such as antimicrobial intravascular catheters. A number of improvements to enhance further prevention of infection have resulted in several practices being put together in a "care bundle". The Department of Health launched a delivery program called Saving Lives in June 2005. This programme provided the tools regarding infection prevention for all acute hospitals in England. Implementing the Code of Practice for Prevention and Control of HCA's (Health Care Act, 2006) is a legal requirement for acute hospitals and other care providers. The code of practice states that "effective prevention and control of HCAI has to be embedded into everyday practice and applied consistently to everyone". The Saving Lives programme provides tools and resources for all hospitals to achieve this.

The Saving Lives delivery programme provides a framework for hospitals to reduce HCAI but also highlights specific targets, for example a reduction in MRSA bacteraemias by 50%. The tool enables hospitals to have a comprehensive and prioritised action plan that incorporates national guidance and allows the application and demonstration of good practice.

An example of such an approach is highlighted in a recent review by Marschall *et al.* (2008) where it was applied to the prevention of intravascular catheter related sepsis.

Marschall and colleagues (2008) describe various strategies to prevent central line associated blood stream infections in patients cared for in acute care hospitals. A rationale for selection of independent risk factors associated with these infections was presented. This included factors such as prolonged hospitalisation before catheterisation and prolonged duration of intravascular catheterisation. The authors then outlined detailed strategies to detect and also prevent these infections. Importantly they gave clear guidance of what practices should be included in what they refer to as a prevention bundle. The best practices were divided into components which needed to be considered before insertion of the catheter, at insertion and finally post insertion. The authors clearly identified which precautions should be applied to the patient including the appropriate application of skin antisepsis and that devices should be handled at all times using sterile precautions.

The authors also identify other factors associated with the increased risk of these infections including, not only prolonged hospitalisation and increased duration of catheterisation, but also microbial colonisation at the skin catheter insertion site and the use of the internal jugular vein. The strategies to prevent these infections involve the application of existing defined guidelines, with an established appropriate management infrastructure to allow the training and implementation of such approaches. This approach included adequate staff education, having supportive information technology to collect and collate numbers of infections and having appropriate laboratory support for the timely processing of specimens and production of results. Practical implementation included the education of nurses, doctors and other healthcare personnel. The development and implementation of a checklist was also deemed as being essential together with having all the appropriate equipment available for catheter insertion and subsequent care. Importantly, the authors identify key basic practices for prevention of these infections both at the skin insertion site and the requirement for subsequent care. These include appropriate hand hygiene with the use of antiseptic soap and water or an alcohol based product and the use of gloves. The application of sterile barrier precautions was also highlighted and these include the use of a chlorhexidine based antiseptic for skin preparation. This latter approach with improved skin antisepsis was an initiative to try and eliminate the endogenous source of microorganisms from the patients own skin flora as well as the exogenous source from the attending health care professional both of which may subsequently result in infection.

The use of antiseptic or antimicrobial impregnated intravascular catheters as a preventative measure for catheter related sepsis is another more recent innovation. These antimicrobial devices have clearly resulted in a reduction in catheter associated bacteraemias and their use is now being recommended for high risk patients such as those who have catheters inserted when strict aseptic precautions cannot be applied, as in the emergency room; for patients who have recurrent intravascular catheter related sepsis and for patients who may have a prosthetic device present in their body such as a hip, knee or heart valve (Casey *et al.,* 2008).

1.6 Environmental Surface Contamination

The environment is also an important consideration in terms of the prevention of HCAI. Despite, the lack of direct evidence to demonstrate that environmental contaminants are responsible for HCAI there is some evidence that suggests that the environment may act as a reservoir for some of the pathogens which cause these infections (Aygun *et al*., 2002). It is likely that if a healthcare worker or patient touches a surface which is contaminated with microorganisms, this may lead to the acquisition of these microorganisms onto the hand and facilitate subsequent transfer to other objects, patients or other healthcare workers (Boyce *et al.*,1997). This was illustrated in the nosocomial transmission of vancomycin-resistant enterococci from surfaces (Ray *et al.,* 2002).

More recently a framework for determining cleanliness of surfaces in the NHS has been developed and is primarily based on visual assessment (NHS National Patient Safety Agency, 2001). This follows from the Infection Control Nurses Association collaborative work with the Association of Domestic Managers who developed a set of National Cleaning Standards (ICNA and Association of Domestic Management, 1999). There have been many other initiatives which have attempted to improve environmental cleanliness. For example, in July 2000, as part of the NHS plan, the Department of Health proposed plans for investment and reform, and the Health Minister at this time, Lord Hunt, launched a new NHS hospital clean-up initiative (Department of Health 2000). This was designed to improve hospital cleanliness and improve the patient experience in our hospitals. More recently the Deep Clean Programme was announced in September 2007. The Government invested £57m to ensure hospitals assessed their current environments. Hospitals had to implement robust cleaning schedules. The Deep Clean Programmes are available to the public and monitored annually by The Care Quality Commission (CQC).

The Care Quality Commission (CQC) is the independent regulator of health and social care in England and began operating on 1st April 2009. The CQC aim to make sure improved care is provided for every patient, whether it is hospital or the community. The CQC have a range of legal powers and duties to ensure care providers meet the essential standards of quality and safety. If hospitals drop below essential standards and patients safety are at risk they can enforce fines and public warnings and if necessary close down of services. Included in these inspections are assessment of the environmental contamination and cleanliness. Unfortunately, the measure of cleanliness has been shown to be a relatively unreliable indicator of cleaning efficacy (Malik *et al.,* 2003).

It is also recognised that some microorganisms including bacteria, viruses and fungi, can persist in the environment for extended durations, even following extensive cleaning (Blythe *et al.,* 1998). This is of particular concern as it clearly demonstrates that, even with active cleaning programmes using defined cleaning schedules, environmental contamination with microorganism may still occur which is unacceptable.

There are no standards currently for acceptable environmental microbial loads in hospitals. However, Dancer *et al.* (2004) suggested actual values for the numbers of microorganisms on hand touch sites in the healthcare setting. This follows what has been applied for several years in food preparation areas. For example, the US Department of Agriculture, Guidelines for reviewing microbiological control and monitoring programmes, (part 8.55, attachment 2, Meat and poultry inspection manual, Washington DC: US Department of Agriculture 1994) has proposed that an acceptable number for aerobic bacteria should be less than five colony forming units per square centimetre surface. Dancer (2004) has also suggested that the absence of certain indicator pathogens including *Staphylococcus aureus*, *Clostridium difficile* and Gram-negative bacilli should be considered.

Not only should the cleaning and decontamination of the environment be considered, but the design and use of materials for the healthcare facility should be taken into account. More recently, these factors have been considered in Infection Control in the Built Environment, Design and Planning by NHS Estates, 2002. In this report on the design and planning of healthcare facilities, finishes, fixtures and fittings, walls and ceilings were all reviewed in terms of materials to select and the type of finish which would be desirable.

For example, in this review it was recommended that materials and finishes should be selected to minimise maintenance and should be chosen with cleaning in mind especially where contamination with blood or body fluids is as possibility. It was recommended that surfaces should be smooth, non-porous and water resistant. Design should also ensure that the surfaces are easily accessible, would not be physically affected by detergents nor disinfectant and will allow rapid drying to occur. Walls similarly should be free from open joints and crevices that may permit retention of microorganisms and that they should be sealed to stop entry of contamination from ducts and other associated areas. Interestingly, the authors recommend that fixtures and fittings should be accessible for cleaning and that if they are not cleaned on a regular basis, they may be a potential reservoir of infection.

It should also be taken into account that equipment that is in direct contact with patients has been implicated in the outbreaks of infections (Irwin *et al.,* 1980). An outbreak of *Acinetobacter* infection for example was associated with the use of a ventilator spirometer, (Irwin *et al.,* 1980).

1.7 Antimicrobial Environmental Surfaces

The quality of finishes in all health care environments should ideally be of a high standard in that they should be smooth, easily cleaned and appropriately water resistant. Advice on the use of antimicrobial surfaces was however not considered by the NHS Estates report (2002). If cleaning schedules are unable to achieve a level of cleanliness which need to be applied in the healthcare setting, other approaches besides cleaning deserve consideration. Use of chemical decontamination has been attempted and has been shown to be successful in different studies. For example hydrogen peroxide vapour has been used for decontamination. French (2004) demonstrated that hydrogen peroxide vapour was more efficacious than conventional terminal cleaning and suggested that this should be considered for the decontamination of the hospital environment when outbreaks involving MRSA occur.

Other approaches have included the use of antimicrobial materials for surfaces which are frequently touched by health care workers. This has included the use of silver antimicrobial technology (Taylor *et al.*, 2009). In this study they demonstrated that when surfaces in the ward area are coated with silver, there was an associated reduction in the numbers of microorganisms on the surfaces.

More recently copper metal has been shown to inhibit and kill a wide range of microorganisms in *in-vitro* experiments (Noyce *et al.*, 2006). In these studies, it was demonstrated that when *Escherichia coli*, MRSA, *Listeria monocytogenes,* Influenza A virus and *Clostridium difficile* were applied to the surface of a range of copper alloys, there was a significant reduction in the numbers of microorganisms which could be recovered. This antimicrobial activity was demonstrated to occur within hours of applying these microorganisms to the copper alloy surfaces.

It is therefore possible that copper surfaces if applied to the clinical environment, may result in a decrease in the numbers of microorganisms contaminating the environment. A preliminary study suggested this was indeed a possibility (Sasaharat *et al.*, 2007). In this study, copper was used for various fomites in the clinical setting and a reduction in the numbers of microorganisms on surfaces over a period of time was demonstrated. The study was, however uncontrolled, it was not undertaken in a hospital setting and therefore comparison to standard hospital equipment could not be made.

In this current study, the application of various alloys of copper as antimicrobial touch surfaces to reduce microbial environmental contamination was determined in a clinical setting. Preliminary investigations in terms of *in-vitro* activity of the various alloys containing copper were carried out. Hospital environmental equipment was subsequently fabricated with these alloys containing copper which were then put in place on a busy medical ward. The study was designed as a cross-over to allow comparison to standard NHS hospital equipment and to determine the numbers of microorganisms on each of these surfaces per unit surface area. The presence or absence of indicator microorganisms including MRSA, *C. difficile* and VRE were also investigated. The hypothesis which was tested was that, based on previous *in-vitro* investigations, the application of copper to the clinical environment results in reduced microbial contamination compared to standard surfaces, even when strict cleaning schedules were put in place.

CHAPTER 2 CLINICAL TRIAL

2.1 Introduction and Methods

In this chapter the protocol used to determine the antimicrobial activity of various fomites made of copper in the clinical environment is described. Such a clinical study has not been previously undertaken and it was therefore important to consider carefully an appropriate control. To achieve this a cross-over study was designed in which items on one medical ward were changed to copper and compared to standard equipment. After a period of time the items were then switched over. This overcame potential bias from factors including, utilisation related to appearance. In this chapter the clinical protocol which was used for evaluating three items, a toilet seat, door push plate and sink taps is described in detail. The sampling protocol and microbiological methods used are also subsequently presented.

2.2 Clinical protocol

Three copper containing items were selected for evaluation. These were selected based on what was considered to be potentially the highest risk of microbial contamination on a busy medical ward at Selly Oak Hospital, Birmingham. The items included a toilet seat which was coated with a pure copper / resin composite containing a final concentration of 70% copper; a set of brass taps which contained 60% copper, and a brass door push plate containing 70% copper.

The supply of the copper fittings was facilitated by the Copper Development Association (CDA) and all fitting of appliances was undertaken by the Trust's Estates Department. All the copper items were installed on the ward at least 6 months prior to commencement of the study.

The surfaces of the copper items were sampled for microbial contamination and compared against equivalent standard NHS items fabricated from plastic (toilet seat), chrome plated brass (taps) and aluminium (push plates). In an attempt to overcome bias from the different appearances of the items they were all installed at least 6 months prior to commencing the study. This permitted health care workers, domestic staff and also clinical staff to become accustomed to the appearance of the copper containing fixtures and to treat them in a similar manner to the standard materials. This aspect of the study was evaluated in a summary described later. Each copper containing item was compared with a standard non copper containing item which was considered at that time to have an equal opportunity for frequency of use. A detailed plan of the ward is shown in Figure 2.1 and shows the location of the test copper items and control items.

Other copper fittings which were examined in a follow up study included door handles, grab rails, light switches, light pull cords, plug sockets, sink waste fittings, toilet system levers, commode seats and arm rest, over bed tables and dressing trolleys (see Appendix 1).

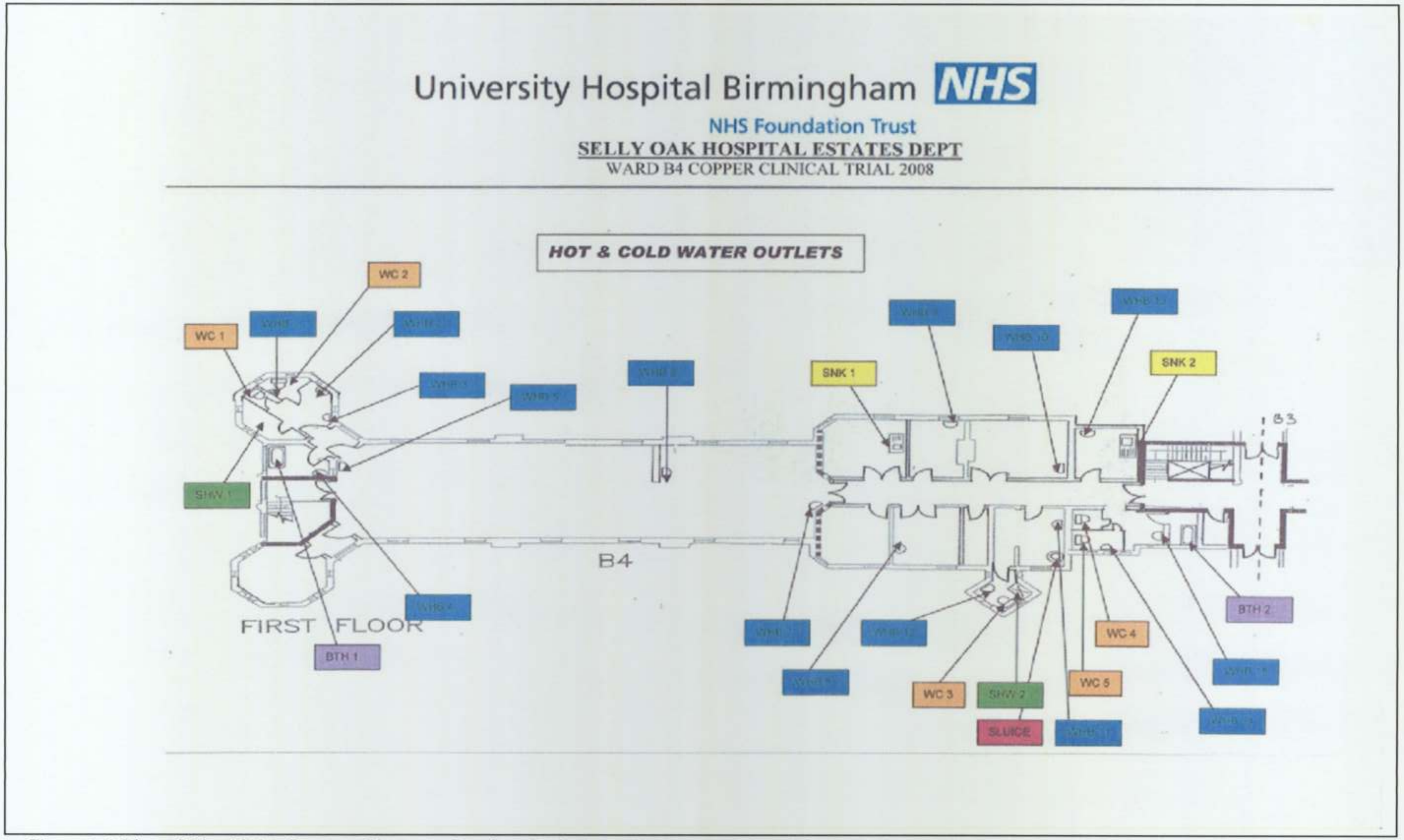


Figure 2.1 Plan of Ward B4 Green = Showers, Purple = Bathrooms, Orange = Toilets, Blue = Patient Bed Areas, Red = Sluice, Yellow Sink

From this detailed plan (Figure 2.1) the location of the toilets is shown on WC1 to WC5. The location of the wash basins are WHB1 to WHB15. The copper toilet seat was initially located as position WC4 and the control WC5. The copper taps were initially located at position WHB7 and the control taps at WHB8. The copper push plate was on the door located at the main entrance to the ward. The control push plate was on the entrance to an adjacent medical ward which was used at a similar rate to the test ward. The copper control items were switched over after 5 weeks of the study. This completed the first part of the study.

2.3 Cleaning

Prior to commencement of the study domestic staff were instructed on the standard cleaning procedures to ensure that they were fully conversant with what their job expectation was, similarly nursing staff were reminded of their shared responsibility. The outline of cleaning schedule used on Ward B4 (test ward) at Selly Oak Hospital is outlined in Figure 2.2.

The equipment areas and associated responsibilities of different staff groups are shown. The frequency of cleaning and type of cleaning is outlined.

Figure 2.2 **National Cleaning Standards Frequencies and Responsibilities**

SOH – Ward Protocol B4

Equipment / Areas	Nursing Responsibilities		Domestic Responsibilities		Ward Caterer Responsibilities		Others	Sign off as complete
	After every patient use	Between patients	Routine	Deep Clean		Routine	Deep Clean	Nursing Staff
WARD / GENERAL AREAS								
Bed – upper frame		√	2 x daily					
Bed lower frame		√	3 x weekly					
Mattress		√						
Lockers		√	2 x daily	Weekly				
Interior bed side lockers		√	On vacation					
Tables		√	6 x daily	Weekly				
TV monitors, including bracket			Daily					
Patient chairs			Daily	Weekly				
Visitor / staff chairs			Daily	Weekly				
Curtain rails			2 x weekly	On curtain change				
Bed side oxygen and suction		√	2 x daily					
Over bed lights		√	2 x daily					
Patient call hand sets		√	2 x daily					
Nursing station			Daily				Ward Admin – clean and tidy	
Weighing scales	√		Daily	Weekly				
Manual handling equipment	√		Daily	Weekly				
Macerator	√		Daily					
Drip stands	√		Daily	Weekly				
Infusion pumps	√		Daily					
Hand readers			2 x daily					

Equipment / Areas	Nursing Responsibilities		Domestic Responsibilities		Ward Caterer Responsibilities		Others	Sign off as complete
	After every patient use	Between patients	Routine	Deep Clean		Routine	Deep Clean	Nursing Staff
Pulse oximeters	√							
Medical gas cylinders	√		Daily	Weekly				
Clipboards		√						
Bed side hand gels		√	2 x daily					
Patient fans external	√	√	2 x daily					
Patient fans inside grid							Ests – on request	
Notice boards			2 x daily					
Wheel chairs	√		Daily	Weekly				
Floors			3 x daily					
Floors – polish			Weekly					
Radiators			Daily	Weekly			Ests – 6 monthly	
Notes trolley			Daily	Weekly				
Drug trolley / fridge		Internal weekly	External daily	Weekly				
Resuscitation trolley	√		Daily	Weekly				
Linen trolleys			Daily	Weekly				
High dust walls			Weekly					
Racking and shelving			Weekly					
Doors			Daily					
Door handles / touch points			6 x daily					
All bins			3 x daily	Weekly				
Cubicle curtains			Between patients	Weekly				
Window curtains				6 monthly				
Replenish supplies / gel/soap/towels	As necessary out of hours		As necessary					
Domestic equipment			2 x daily	Weekly				
Terminal clean of bed space			Between patients					

Equipment / Areas	Nursing Responsibilities		Domestic Responsibilities		Ward Caterer Responsibilities		Others	Sign off as complete
	After every patient use	Between patients	Routine	Deep Clean		Routine	Deep Clean	Nursing Staff
SANITARY AREAS								
Toilets	1 x between 2:00 – 07:00	Check hourly	6 x daily hourly check	Weekly				
Bathrooms	√		3 x daily	Weekly				
Baths	√		3 x daily	Weekly				
Sinks / WHB			6 x daily	Weekly				
Sanitary area floors			6 x daily	Weekly				
Touch points			6 x daily	Weekly				
Commodes	√		2 x daily	Weekly				
CATERING								
All kitchen equipment						2 x daily	Weekly	
Surfaces						2 x daily		
Cupboards						1 x daily	Weekly	
Water jugs						3 x daily		
Make/serve patient drinks						5 x daily as req'd		
Wipe/lay patient table (pre food)						3 x daily		
Collect crockery						5 x daily		
Wash up patient crockery – SOH						3 x daily as req'd		
Collection of waste & dirty linen							4 x daily Porters	

- Every one will be responsible for cleaning any spillages they make whether it is on floors / equipment or furniture
- Patient fans will be used for individual patients and will be removed from the ward for deep cleaning following use

Domestic Cover - 07:30 - 15:30 Monday to Sunday
17:00 – 20:00 Monday to Sunday

Ward Caterer Cover - 10:30 - 13-30 Monday to Sunday
16:30 to 19:30 Monday to Sunday

The domestic staff followed the standard ward cleaning time table as shown in Figure 2.2. During the study period the disinfectant Chlor-clean, which contains sodium dichloroisocyanurate with 1000ppm available chlorine and detergent Johnson Diversey General Detergents Pre-measured were used for both copper and non-copper containing items using defined protocols. This timetable was followed between the hours of 07.00 – 17.00hrs. It included disinfection by applying Chlor-clean on both sides of the toilet seat at approximately two hour intervals during this period. The taps and push plates were cleaned four times during this period. Subsequent disinfection and cleaning between the hours of 17:00 to 07:00 was on a request basis only following any obvious visual soiling. Microfibre cloths are used to clean the ward. These cloths are colour coded for each area; red for toilets, blue for main ward area, green for kitchen and yellow for any isolated infected patients. The microfibre cloths are cleaned at 60 degrees after each cycle of cleaning.

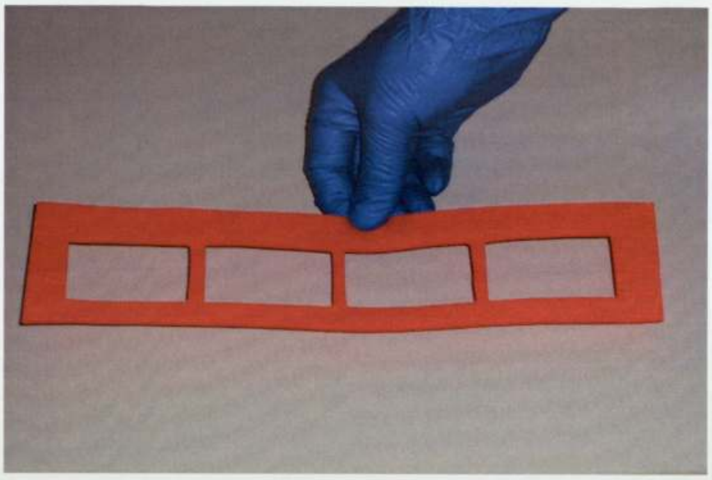
The disinfectant and detergent was made up fresh daily and applied with new microfibre cloths. The same protocol for cleaning was applied to both copper and non copper containing items by the same domestic allocated to the Ward. The same domestic worked Monday to Friday but a different domestic worked on a Saturday and Sunday.

The cleaning of the push plates on the entrance doors to both control and test ward were monitored. The investigator carried out an audit using direct observation to ensure consistency was maintained on both doors. The domestic staff were unaware of these checks. The checks confirmed that the cleaning schedule outlined above was being adhered to. The ward had its own domestic who worked Monday to Friday 07:30 to 15:30 and a regular evening cleaner would attend to ward B4. In addition, the domestic supervisor performed weekly checks to ensure standards were being maintained. This was a Trust wide initiative and scored on a % basis. The ward consistently scored between 95 – 98%. The records of these checks further confirmed that the cleaning was being applied consistently and the cleaning schedules followed.

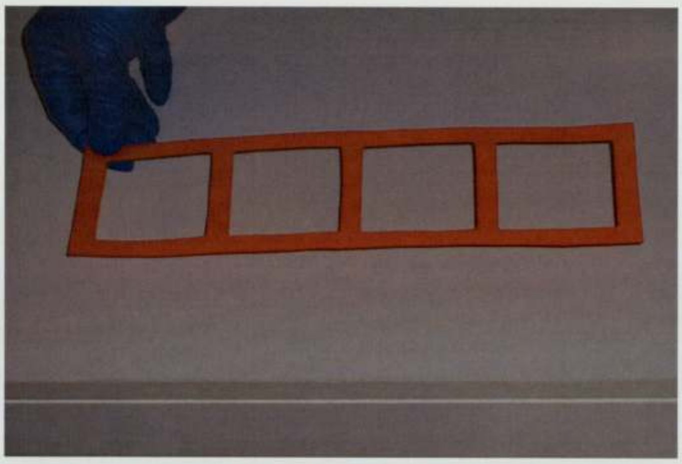
2.4 Sampling Protocol - Time of Sampling

The surfaces of the test and control items were sampled for the presence of any viable microorganisms. They were sampled once weekly on a Tuesday for ten weeks at both 07.00 hours and 17.00 hours. This allowed the numbers of microorganisms present following a relatively quiet period over night on the ward and also following a busy period during the day to be determined. Each item was sampled in duplicate at every time point. Adjacent areas were selected so that no area was sampled twice in any one day. This was to prevent bias in the sampling. To facilitate this approach a template was designed for each item. This template involved the use of a grid and records were kept to ensure that sampling was randomly selected and that no area was sampled more than once on any particular day.

a)



b)



c)

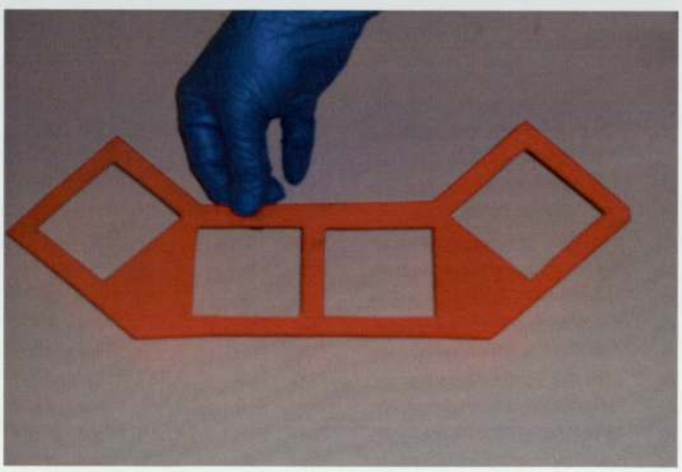


Figure 2.3
Templates used in swabbing surface.
Various shaped designs were employed (a,b,c) to allow access and swabbing of a variety of surfaces (e.g. push plates, toilet seats). See text for details.

2.5 Methods of Sampling

For the toilet seats and door push plates, a 5cm by 5cm sterile template was applied firmly to the surface of each toilet seat and door push plate. A sterile nasopharyngeal swab moistened in sterile 0.9% (w/v) saline was then firmly applied 15 times horizontally and a further 15 times vertically in a zig zag pattern so that the entire area was sampled. The swab was rotated whilst sampling. Both the upper and underside of the toilet seats were sampled.

For tap handles the sterile nasopharyngeal swab moistened in sterile 0.9% (w/v) saline was firmly applied 6 times horizontally and 15 times vertically over a 5cm by 2cm area as described above. Both the hot and cold water taps were sampled.

Each swab was immediately transferred to 3ml of sterile neutralising broth (D/E neutralising broth, Difco, Beckton Dickenson, Franlin Lakes, New Jersey, USA) to neutralise any further antimicrobial activity of copper.

2.6 Neutraliser

The efficacy of the neutraliser selected for this study has been previously evaluated both against Gram-positive and Gram-negative bacterial species (Wheeldon *et al.*, 2008). The antimicrobial activity of copper was shown in this study to be effectively neutralised and the neutraliser was also shown to have no adverse effects on growth of the microorganisms. The use of a neutraliser was important to remove any residual antimicrobial activity of copper which may have also been collected when the swabbing of the surfaces was performed.

2.7 Cross-over

After 5 weeks of sampling as described above, the Hospitals Facilities Department arranged for the copper containing and non copper containing control items on the ward to be interchanged. The reason for this as outlined above was to further exclude any possible bias according to either appearance or preferential use of any item based at that location. Prior to re starting the study following crossover all items were cleaned as per ward protocol. As outlined in section 2.2

2.8 Microbiological Methods

All samples were examined in the laboratory within 4 hours of taking them, by the following methods. The neutralising broth containing the single swabs which had been used to sample the surfaces were vortexed for one minute. This extracted any microorganisms present on each of the swabs which facilitated subsequent determination of the numbers present. For the toilet seat and push plate samples, 200 microlitres of undiluted solution and a 1 in 10 dilution were inoculated onto a range of microbiological culture media plates giving a theoretical lower detection limit of 6 bacteria per 10 square centimetres of sampled surface. For the tap handle samples 300 microlitres was inoculated onto each agar plate giving a lower detection limit of 1.0 colony-forming units per square centimetre of sampled surface. A total aerobic microbial colony count was determined by inoculating blood agar plates (bioMerieux, Basinstoke, UK). In addition a number of indicator microorganisms present on the various samples were determined. These indicator microorganisms included meticillin sensitive and meticillin resistant *S.aureus* (MRSA), vancomycin resistant enterococci (VRE), *Clostridium difficile* and coliform bacteria.

For the detection of *S. aureus* each solution was inoculated onto *S. aureus* chromogenic agar (chromID S. aureus and chrom ID MRSA) bio Merieux, France). For identifying the coliform bacteria cysteine lactose electrolyte deficient agar (CLED agar bio Merieux, France) was used and for the enterococci, bile aesculin agar (D-coccosel agar, bio Merieux France) was used.

Each agar plate was incubated in air at 37 degrees C and examined after 24 and 48 hours. The identity of the microorganisms was subsequently determined using standard microbiological tests involving Gram staining and automated biochemical profiling using the Vitek 2 instrument. The Vitek 2 was also used to determine the antibiotic susceptibility of the staphylococcal isolates. The antibiotic sensitivity of enterococcal isolates was determined using the British Society for Antimicrobial Chemotherapy disc diffusion method (Taylor, L *et al.*, 2009).

C. difficile was detected using selective isolation agar *(C. difficile* agar; bio Merieux, France). These plates were incubated at 37°C anaerobically and were examined after 24 and 48 hours. The identity of any presumptive *C. difficile* isolates was confirmed using standard microbiological tests. Total numbers of aerobic microorganisms and *C. difficile* were determined and calculated per square centimetre of surface area of the sampled fomites.

2.9 Statistical Methods

The median total aerobic count per square centimetre for each duplicate set was subjected to non parametric statistical analysis.

CHAPTER 3 - CLINICAL TRIAL ON COPPER WARD

RESULTS

3.1 Introduction

The numbers of microorganisms detected on either the copper or standard items on the medical ward are presented in this chapter. In addition the types of patients treated in the busy medical ward during this time is presented. Finally the numbers of patients with infections during the study period are also presented.

3.2 Utilisation of Medical Ward

The medical ward selected (B4) at Selly Oak Hospital for the study was a general medical ward which has 19 beds. The ward as seen in Figure 2.1 included a side room with two single beds, a side room with one single bed and an open ward nightingale style with 16 beds. The patients were acute medical patients who had been either admitted from their G.P. or directly from Accident and Emergency at Selly Oak Hospital. The patients' conditions were reflective of an acute medical ward and included patients with chest infections, non surgical abdominal pain, alcoholism, cellulitis, cardiovascular disease and diabetes. The majority of patients were aged between 50 to 80 years and the male to female ratio was 1:2.

3.3 Cleaning on Ward

An audit of the cleaning process during this trial was carried out weekly by the domestic supervisors. This was purely an observation audit and the domestic staff were unaware of its process. It was confirmed during this audit by direct observation that the domestics were closely adhering to the cleaning schedule (as discussed in Chapter 2).

3.4 Infected Patients

There were no outbreaks of infection during the study period. This included evaluating for MRSA, norovirus and *C. difficile*. During the 10 week period of study, 1 patient had pneumonia caused by *Klebsiella pneumoniae*, a further patient had a urinary tract infection caused by *Klebsiella oxytoca* and another had *Enterobacter cloacae* in their abdominal drain fluid. Three patients had *C. difficile* infections and these occurred at weeks 1, 5 and 7 of the study. In addition two patients had *S. aureus* wound infections and both were meticillin sensitive and occurred during week 4 of the study.

3.5 Microbiological Results

The median total aerobic CFU counts per square cm on both the copper containing toilet seat, set of tap handles and push plates and their control equivalents over a 10 week period are summarised in Table 3.1.

Table 3.1 - Median total aerobic colony-forming units (cfu) on copper containing items compared with controls in the clinical setting

Median total aerobic colony-forming units (cfu) on copper-containing items compared with controls in the clinical setting						
Item	Time sampled	Median cfu count per cm2 (range)		Median copper cfu cont as % of control cfu count (range)	Wilcoxon signed rank test *P*-value	Mann-Whitney *P*-value
		Control items	Copper items			
Upper side of toilet seat	07:00	87.6 (9-266.4)	2.1 (0-38.4)	6 (0-33)	0.002a	< 0.0001
	17:00	64.5 (28.2-254.4)	1.2 (0-23.4)	2 (0-15)	0.002	< 0.0001
Under side of toilet seat	07:00	10.8 (0-101.4)	0 (0-4.2)	2 ((0-129)	0.023	0.007
	17:00	1.5 (0-121.8)	0 (0-4.2)	0 (0-220)	0.027	0.019
Push Plate	07:00	1.8 (0-7.8)	0 (0-0.6)	0 (0-100)	0.004a	0.0002
	17:00	0.6 (0-3.6)	0 (0-1.2)	0 (0-100)	0.016	0.009
Hot tap handle	07:00	6.6 (0-504)	0 (0-3)	10 (0 – b)	0.016	0.023
	17:00	3 (0-36)	0 (0-39)	0 (0 -2700)	0.195	0.019
Cold tap handle	07:00	7.5 (0-87)	0 (0-3)	0 (0-100)	0.016a	0.005
	17:00	4.5 (0-51)	0 (0-3)	0 (0-100)	0.016a	0.005

a) A positive cfu count as present on copper surfaces compared with a zero count on standard surfaces

b) Paired variables were negatively correlated. For this reason, the Mann-Whitney test was also performed on all items for completeness

The median total aerobic CFU count on each copper containing item as a percentage of the median total aerobic count on each control item was further calculated.

All the items which contained copper had between 90 and 100% lower numbers of microorganisms present than their controlled equivalents at both 07.00 and 17.00 hours sampling time points. This reached statistical significance in 9 of the 10 paired analysis and in all 10 unpaired analysis. The exception was the hot tap handle sampled at 17:00. However even with this sample there was a trend for a reduction in microbial counts on the copper item.

During the study period no MRSA or *C. difficile* were isolated from any of the surfaces sampled. Meticillin sensitive *S. aureus* was isolated from the control door push plate during weeks 2 and 3 of the study and on the upper and lower surfaces of the control toilet seat during week 6. The vancomycin resistant *Enterococcus faecium* was isolated from the upper and lower surfaces of the control toilet seat during week 1. *E.coli* was isolated from the upper side of the control toilet seat during weeks 3 and 6. It was also isolated on the lower side of the control toilet seat during week 4. No meticillin sensitive *S. aureus*, vancomycin resistant enterococci or *E.coli* were isolated from any of the copper containing surfaces during the study period.

Overall there was no significant difference in the total aerobic colony counts on control items at 07.00 hours as compared to 17.00 hours (median 3.6 versus 2.1 CFUs per square centimetre retrospectively $p = 0.97$).

Interestingly, based on median, total aerobic CFU counts over the 10 weeks, 5 out of 10 controls toilet seats and tap handles and 0 out of 10 copper sample points failed proposed bench mark values.

3.6 Copper Susceptibility Testing

The susceptibility to copper of microorganisms isolated from the copper items was also checked by the following methods. Survival of representative isolates of VRE, MSSA, MRSA and coliforms on surfaces was determined by a carrier test using 1 cm^2 coupons of copper or stainless steel. These were first cleaned with acetone and sterilised by autoclaving. Suspensions of isolates were prepared in sterile distilled water from colonies grown on horse blood agar plates for 24 hours. Twenty microlitres of suspension containing approximately $1x10^7$ cfu / ml was applied to the surface of metal coupons, spread and allowed to dry for 1h in air at 37˚C. The coupons were then allowed to stand for a further 2h at room temperature to simulate exposure on surfaces and drying in the hospital ward. The coupons were then placed in 1 mL of BBL D/E neutralising broth containing glass beads, vortex mixed to release microorganisms and viable counts performed (Wheeldon *et al.*, 2008; Casey *et al.*, 2010). 200 µL of the undiluted solutions (and serial dilutions where appropriate) were inoculated onto 5% (v/v) horse blood agar plates (BA; bioMerieux, Basingstoke, UK). The inoculated agar plates were incubated in air at 37˚C for 48 h and the total aerobic cfu determined. All the samples were processed within 3h of sampling.

Copper susceptibility

None of the VRE, MSSA, MRSA and coliforms isolates tested showed evidence of resistance on metallic copper surfaces. The number of viable microorganisms on the copper surface reduced by >3 log_{10} cfu (i.e. reduction in viable numbers from $1x10^7$ to below $1x10^4$) within the 3h test period, compared to <1 log_{10} cfu on stainless steel. The reduction in viable numbers of bacteria observed on the copper surfaces was similar to that reported previously in laboratory studies using similar methods (Royce *et al.* 2006, Wheeldon *et al.* 2008) Therefore, although reduced copper sensitivity has been demonstrated in a laboratory scenario (Santo *et al.,* 2008, 2010) there was no evidence in this study for selection of microorganisms with reduced sensitivity on the copper surfaces.

3.7 Summary of results

A novel cross over study to evaluate the antimicrobial activity of copper containing items was investigated on a busy acute medical ward. A toilet seat, set of tap handles, wash hand basin and a ward entrance door push plate each containing copper were sampled for the presence of microorganisms and were compared to standard non copper containing items located on the same ward, or adjacent ward for the door push plates. Items were sampled for the presence of microorganisms once weekly for ten weeks at both 07.00 and 17.00 hours. After five weeks the copper containing and non copper containing items were interchanged.

Copper containing items had between 90 and 100% fewer microorganisms present on their surfaces than their control equivalents at both time points of sampling. This reached statistical significance for every item sampled with one exception. Based on median total aerobic colony forming unit counts from the study period five out of ten control sample points but none out of the 10 copper points failed proposed bench mark values of total aerobic counts. There was no evidence of copper resistance in any of the microorganisms isolated from the copper containing items. These results together with the bench mark values will be discussed in chapter 5.

CHAPTER 4

VIEW POINT OF PATIENTS VISITORS AND NURSES

4.1 Introduction

It was important to assess the view points of both patients and health care workers regarding the appearance of the new copper containing items placed on the test ward. This was to determine the usability of the copper containing items to evaluate whether they caused any clinical issues and also to determine whether or not staff or patients treated these items in a different way as compared to standard items. As presented earlier the copper containing items were placed on the test medical ward at least six months prior to commencement of the study. Medical care workers and patients were asked for their viewpoint of the copper containing items during this period. This part of the study was carried out when 14 different copper containing ward items were being assessed.

4.2 Methodology

A questionnaire was designed for patients and health care workers to complete. The answers were all recorded anonymously and all individuals were informed of this prior to completion of the questionnaire. An example of the questionnaire which was designed is shown in (Figure 4.1).

Ethical committee approval for this part of the study was obtained from the Black Country Ethics Committee. All patients selected were those who were deemed by the Nursing staff caring for these individuals, able to understand the questions and to answer them accurately. Permission from the patients was obtained prior to requesting completion of the forms. Any patient who refused to complete the forms was acknowledged and as per ethical application it was made clear this made no difference to their subsequent care. Questionnaires for the staff were left in the staff room with completed forms requested to be placed in the return envelope.

4.3 Appearance of Copper Containing Items

The 14 copper and copper alloy fittings which were studied appeared different to the standard fittings on the Ward (table 4.1). In order to gauge the acceptability of the copper furnishings a questionnaire was developed in order to evaluate this. Full Ethical Committee approval was obtained from the Black Country Research Ethics committee (07/H1202/100) and research and Development at the UHB NHSFT (Appendix 2).

4.4 Staff and Visitors Questionnaire

The copper containing items had variable appearances (see Appendix 1). In particular the toilet seat, which was made of a composite of resin polymer and copper, was green / brown in colour. The colour was not even which gave the toilet seat an appearance of being unclean. Comparison of all the copper items with the control items is shown in Appendix 1.

Two questionnaires were developed one for patients and visitors and the other for members of the clinical ward team on the ward as shown in figure 4.1 and 4.2.

A total of 59 questionnaires were completed and returned; 8 nurses, 23 patients and 28 visitors responded to the questionnaires. All the patients had stayed on the study ward for more than one day [2-4 days (39.1%); 5-7 days (21.7%); more than 7 days (39.1%)]. The majority of visitors (46.4%) who took part in the survey had visited the study ward in the past month more than seven times. The remainder had visited 1 time (7.1%); 2-4 times (35.7%) and 5-7 times (10.7%).

4.5 Results of Questionnaire

Patients most frequently noticed the copper taps (21) in the ward, and visitors the door push plates (19), taps (18) and door pull handles (18). Three visitors (10.7%) had not noticed any of the copper fittings on the ward before responding to the questionnaires.

The perception of the nurses, patients and visitors towards the appearance of the copper items on the ward and their attitude towards using them are summarised in table 4. Overall most of the respondents (68%) considered the copper items the same (46%), better (12%) or much better (10%) then control items. Two of the visitors who rated the majority of the copper fittings acceptable rated the toilet seat worst in their overall perception of the copper items. However, the majority of the respondents treated the copper items the same as standard items (nurses 100%, patients 73.9% and visitors 71.4%).

Many patients and relatives commented on the appearance of the copper items, especially toilet seats. Many thought that it was difficult to distinguish if the copper surface such as a toilet seat was unclean or had just undergone normal oxidisitation. However, the acceptability of this appearance was more positive when the antimicrobial properties of copper and the potential benefit of copper in the environment in reducing microbial contamination / infections were discussed. The nurses on the ward were very supportive of the study. Although they received very few complaints or queries regarding the copper items, if they did, they were able to speak confidently about the study and show enthusiasm about their participation.

The Domestic staff in the embronic stage of the study voiced concerns regarding the copper items as they wanted to use products that would ensure the copper was always shiny and free from marks such as finger prints. They also commented on how much extra time this would take and could affect the wards agreed cleaning schedule. All these issues were talked through with their Supervisors and their support toward the study was crucial. These issues resolved during the installation phase prior to sampling. At this stage the Domestic staff clearly understood that the same cleaning protocols were to be applied to the copper as well as the control items.

Table 4.1

The perception of staff, patients and visitors to the appearance of the copper items of the ward and their attitudes of using these items (percentage of all responses)

Response	Staff (n=8)	Patients (n=23)	Visitors (n=28)
	Question: appearance		
Much better	0	13.4% (3)	10.72% (3)
Better	25% (2)	13.4% (3)	7.14% (2)
Same	37.5% (3)	43.48% (10)	50% (14)
Worse	37.5% (3)	21.74% (5)	17.86% (5)
Much worse	0	8.7% (2)	7.14% (2)
No response	0	0	7.14% (2)
	Question: use of copper items		
Made point of touching them	0	8.7% (2)	14.29% (4)
Treated the same	100% (8)	73.91% (17)	71.43% (20)
Avoided touching them	0	17.39% (4)	7.14% (2)
No response	0	0	7.14% (2)

Figure 4.1 – Patient & Visitor Questionnaire

University Hospitals Birmingham NHS
NHS Foundation Trust

Dear Patient/ Visitor,

We would like your help in evaluating the new surface materials in the hospital environment. We would value your comments on the copper items currently installed on the ward areas by taking few minutes to answer questions below.

This survey is anonymous and your personal details will not be recorded.

Thank you for your help!

Q1 If you are a **patient**, how many days have you stayed on this ward (during this visit)? (Please tick one box.)

1 ☐ 2-4 ☐ 5-7 ☐ More than 7 ☐

Please go to Q3

Q2 If you are a **visitor**, how many times have you visited this ward in the last month? Please tick the appropriate box

1 ☐ 2-4 ☐ 5-7 ☐ More than 7 ☐

Q3 Have you seen any of the copper items pictured below, during your stay/ visit? (Please tick all that apply)





Taps?	Toilet seat?	Door handle?	Grab rails?	Door push plates?
☐	☐	☐	☐	☐

Please go to Q4

I have not seen any of the copper items ☐

Please go to Q6

Q4 Compared to other similar items in the hospital, how did the copper items look? (Please tick one box.)

Much better ☐ Better ☐ Same ☐ Worse ☐ Much worse ☐

Q5 Which phrase best describes your use of the copper items? (Please tick one box.)

I made a point of touching them

I treated them the same as standard items ☐

I avoided touching them ☐

Q6 Are there any other comments you wish to make about the copper items on this ward?

Thank you for taking the time to complete this survey.
Your help is very much appreciated!

Figure 4.2 – Staff Questionnaire

University Hospitals Birmingham NHS
NHS Foundation Trust

Dear staff,

We would like your help in evaluating new surface materials in the hospital environment. We would value your comments on the copper items currently installed on the ward by taking a few minutes to answer the questions below.

This survey is anonymous and your personal details will not be recorded.

Thank you for your help!

Question 1. Compared to other similar items in the hospital, how do the copper items fitted on to this ward (including door handles and push plates, taps, toilet seats and table tops), look? (Please tick one box.)

Much better ☐ better ☐ same ☐ worse ☐ much worse ☐

Question 2. Which phrase best describes your use of the copper items? (Please tick one box.)

I made a point of touching them ☐
I treated them the same as standard items ☐
I avoided touching them ☐

Question 3. Is there any other comment you wish to make about the copper items on this ward?

Question 4. Have you received any positive or negative feedback from patients and visitors regarding the copper items? If yes, please outline?

Thank you for taking the time to complete this survey.
Your help is very much appreciated!

4.6 Discussion

The majority of the patients did not notice the copper containing items, in particular the taps or push plates and therefore did not use them in a different way to standard items. However 10% noted the unusual appearance of the toilet seat being brown in colour and were concerned about its cosmetic appearance and cleanliness. After explanation by staff all the patients were reassured and the patients continued to use the copper toilet seat as per normal. This potential concern was overcome for all future patients were appropriately educated about the appearance of copper items.

All the respondents considered that they would prefer to use the copper containing items rather than standard items despite the appearance of the copper. Positive feedback on the research on copper and on reducing the risk of infections in hospitals was given. A patient and visitor commented that they preferred the copper as it was "old fashioned" and how it was "a shame taps and door handles have been replaced with stainless steel over the years".

The important finding for this study was confirmation that the majority of staff, patient and relatives treated the copper items the same as the standard control items.

CHAPTER 5 DISCUSSION AND CONCLUSIONS

5.1 Healthcare Associated Infections - Acquisition and Prevention

Each year in the UK hospital acquired infections cost the National Health Service nearly 1 billion pounds sterling and up to 5000 patients per year die as a result of acquiring such infections. Factors associated with the acquisition of hospital acquired infections include the level of environmental contamination. It must be recognised that not all hospital acquired infections are preventable but it has been claimed that up to 15% of these infections can be prevented if strict infection prevention measures are taken. This has included the application of strict cleaning schedules into hospitals to reduce the environmental microbial contamination.

The microorganisms which cause hospital acquired infections include meticillin resistant *Staphylococcus aureus*, coagulase negative *staphylococci* and also *C. difficile*. These microorganisms result in a range of infections. The commonest hospital acquired infections include urinary tract infections associated with urethral catheterisation, pneumonia particularly associated with ventilated patients and bacteraemia associated with intra vascular catheters. Wound infections particularly post operative infections can also contribute significantly to the overall numbers and in some serious have accounted for 5% of all patients undergoing operative procedures.

Infection control is therefore an important component of the battle against infections which patients may develop in the hospital environment.

As indicated above microorganisms may be derived from the environment. These could represent contamination from patients themselves or even health care workers. The commonest route of spread of infection is thought to occur via hand carriage and it is logical therefore to assume that contamination of inanimate surfaces such as door push plates and taps occurs following the use of these items by patients, their relatives and friends or health care workers. Several approaches have been previously taken to improve environmental cleaning to reduce the numbers of microorganisms which are present on surfaces. This has included the application of disinfectants such as hypochlorite solutions commonly used at 10000 parts per million (free chlorine) in the outbreak situation. Detergents are also recommended for routine cleaning which again should keep the numbers of microorganisms down.

There is however no evidence to show what level of microbial contamination should be deemed as acceptable. In this current study the use of copper to enhance the approaches already taken to reduce environmental contamination further was evaluated in the clinical situation.

5.2 Use of Copper

Copper has been known since approximately 2000BC to be of value in preventing spread of diseases now known to be infections. Indeed the first recorded medical use of copper was described in the Smith Papyrus one of the oldest books known. In this Egyptian text written between 2600 and 2200BC the use of copper to sterilise chest wounds and drinking water were described. In the hippocratic collection partly written by the Greek physician Hippocrates in the year 460 – 380BC copper was recommended for the treatment of leg ulcers associated with varicose veins. The Greeks sprinkled a dry powder of copper oxide and copper sulphate onto wounds to try to prevent infection in recently acquired trauma patients. More recently copper has been reported as being of value in the treatment of arthritic patients (Dollwet & Sorenson, 1985). It had also been shown in the 1930's that individuals suffering from diseases such as scarlet fever, diphtheria, and tuberculosis have elevated copper levels in their blood. It has been subsequently claimed that the re-distribution of copper in the body has a role in responding to disease and that this may have antibacterial and antifungal activity. Indeed it was reported that copper is selected by the body as part of a metabolic response to overcome the challenge of infection. The first modern research on the use of copper in medicinal substances was reported by (Sorenson *et al.*, 1985) who demonstrated in 1966 that copper complexes have therapeutic efficacy in the treatment of inflammatory diseases.

Since this time copper complexes have been used to treat patients with arthritic and other chronic degenerative diseases. More recently the antimicrobial activity of copper against microorganisms have been described (Keevil *et al.,* 2009). Prof Keevil in Southampton has been leading in this area of research. In their laboratory studies they have clearly demonstrated that copper, including copper alloys have antimicrobial actively against a range of microorganisms. Killing activity against a whole range of microorganisms was described and included MRSA, VRE, *C. difficile* and influenza A. These studies have been described in various publications (Noycejo et al.,2006)., (Rever et al., 2008). It is interesting to note in these studies that the microbial killing induced by the copper occurred within hours. With regards to MRSA significant killing occurred within 4 hours of exposure to the copper, in comparison to other metal surfaces such as stainless steel, where no killing was observed. These laboratory studies have therefore suggested that the use of copper may be of value in the clinical environment by reducing the numbers of microorganisms on surfaces which in time may prevent some of the hospital acquired infections.

5.3 Current Study

The current study which evaluated the use of copper in the clinical environment has clearly demonstrated two key factors. The numbers or microorganisms present on normal hospital fixtures and fittings which include push plates, toilet seats and wash basin taps were still significant in terms of total numbers even following appropriate and regular cleaning schedules. In comparison, for the copper items the number of microorganisms present at the start of a busy clinical day at 07.00 in the morning and at the end of this day at 5.00 to 6.00pm was significantly reduced.

Two questions need to be asked based on these results, firstly how has copper achieved this remarkable activity in terms of reducing the number of microorganisms and secondly whether of not this would have clinical applications for the prevention of spread of infection?

The antimicrobial activity of copper and its mode of action is currently unclear. Several mechanisms have been proposed (Weaver et al., 2010) which are listed below (Warnes *et al.,* 2010). These include:

1. Copper may disrupt cell function through several mechanisms simultaneously.
2. Copper may inactivate proteins including enzymes
3. Copper may complex with a component of nucleic acid.
4. Copper may destabilise lipids which are found in the membrane surrounding all microorganisms resulting in holes appearing in this structure with loss of function.

Further evaluation of how copper works is obviously required. It was interesting to note in the current study that even when microorganisms were surrounded by contamination from protein and other organic material found in the environment such as on toilet seats the copper present in each item studied still retained antimicrobial activity. This observation has important implications for the use of copper in the clinical environment.

The explanation for why some microorganisms were isolated from the surface of copper items further test needs to be considered. The results of the copper susceptibility tests clearly demonstrated that no reduced copper sensitivity had occurred and that all the microorganisms isolated were not resistant to this metal. A more likely explanation is the time required to kill the contaminating microorganisms. Bill Kevil and colleagues (2009) have clearly demonstrated that copper can take several hours to kill microorganisms. It is probable that the presence of bacteria albeit in low numbers of the control item reflected the long period from contamination to time to kill. Despite this, the low number of microorganisms in the copper items reflected that this required a time period to kill did not negate the potential value of copper in maintaining decreased environmental contamination.

If copper is able to reduce the environmental microbial contamination as the above study suggest this may augment the disinfection cleaning schedules which trained domestic staff utilised. It is highly probable that in the clinical environment that contamination particularly of surfaces such as toilet seats can occur at any time during a 24 hour cycle and that despite regular cleaning schedule this will continue to occur. The potential then for spread to other patients is a continuing risk in the clinical environment and that intermittent cleaning schedules do not overcome this.

It is therefore clearly evident from the results of this first clinical study on the use of copper that it potentially can augment cleaning procedures in terms of maintaining fewer microorganisms on surfaces and in doing so may therefore be a valuable addition in the fight against hospital acquired infections.

It was also of interest that the copper was able to exhibit activity in 3 different settings. The copper not only exhibited antimicrobial activity on the toilet seat, where there would be a fair degree of organic material present, but also was effective on taps and push plates which are frequently used by staff as well as patients and visitors. Microorganisms can be spread via the hands and from surfaces to hand and in doing so can result in infection being spread. The efficacy of copper on the taps was therefore a potentially highly significant finding.

Use of copper surfaces may therefore be a powerful tool in reducing the numbers of microorganisms which are both in the environment and potentially may be spread from patient to patient. Further evaluations need to be carried out in the future to determine whether of not this antimicrobial effect of copper has an actual influence on the numbers of hospital acquired infections by patients in a clinical environment. From this current study which was carried out over a number of months there were not sufficient numbers of hospital acquired infections to evaluate this. Such studies would need to be carried out where all items on a ward were made of copper and compared to a controlled ward with standard fittings. In doing so it would then be feasible to evaluate further the clinical efficacy of the use of copper in the ward environment.

5.4 Conclusions

This study has for the first time evaluated in the clinical environment the use of items made of copper and has determined whether or not this has resulted in a reduction in the numbers or microorganisms in the busy clinical environment. The results clearly demonstrated that by applying copper to various items including hot and cold water taps on a hand wash basin, a copper impregnated plastic toilet seat and a copper push plate at an entry to the ward have all resulted in a significant reduction in the numbers of microorganism associated with that surface. This was shown both at 07:00 in the morning and 17:00 in the afternoon. This observation was made with a concomitant background of appropriate cleaning schedules on a busy medical ward which still resulted in some microorganisms being present in the clinical environment.

The value of copper has therefore been shown to augment cleaning schedules and may be a useful weapon in the prevention of hospital acquired infections. This needs to be further evaluated in the clinical environment to include the end point of the numbers of infections that patients may acquire whilst in hospital in a copper environment verses a control environment.

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APPENDICES

Appendix 1

Non Copper Door Push Plates

Copper Door Push Plates

Non Copper Taps

Copper Taps

Copper grab rails

Non copper grab rails

Non copper dressing trolley

Copper dressing trolley

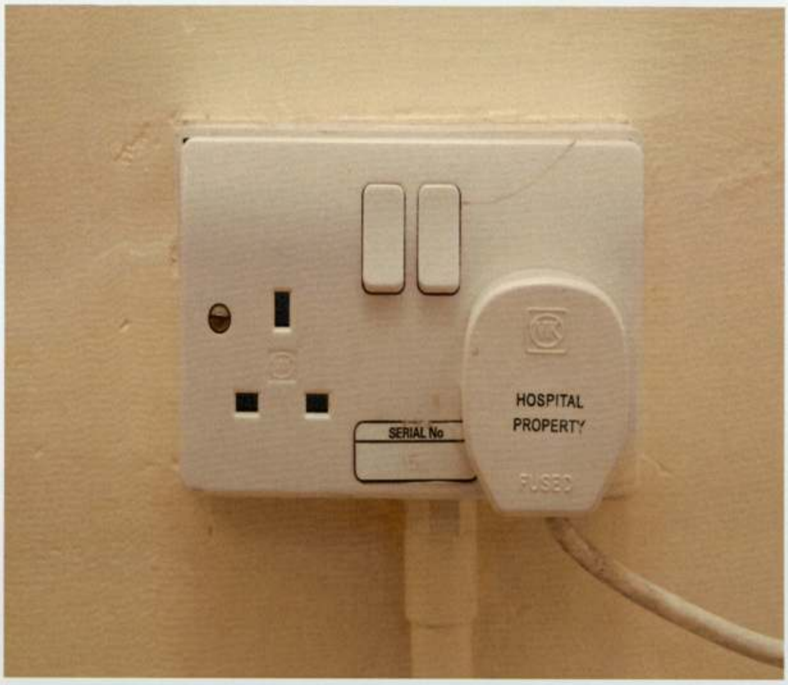
Copper patients over bed table

Non copper patients over bed table

Non copper light switch

Copper light switch

Non copper plug socket



Copper plug socket

Copper commode seat

Non copper commode seat

Non copper arm rest

Copper arm rest

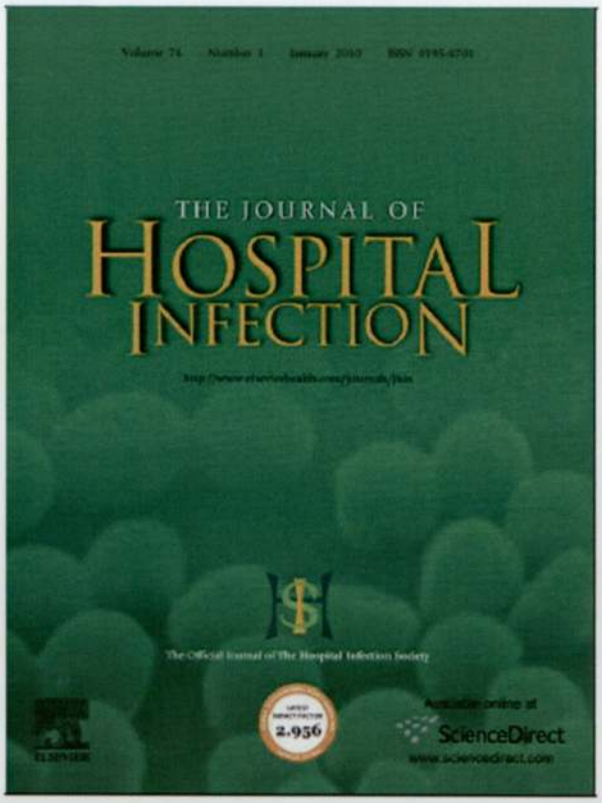
Copper door handles

Non copper door handles

Copper sink waste fittings

Copper sink waste fittings

Non copper sink waste fitting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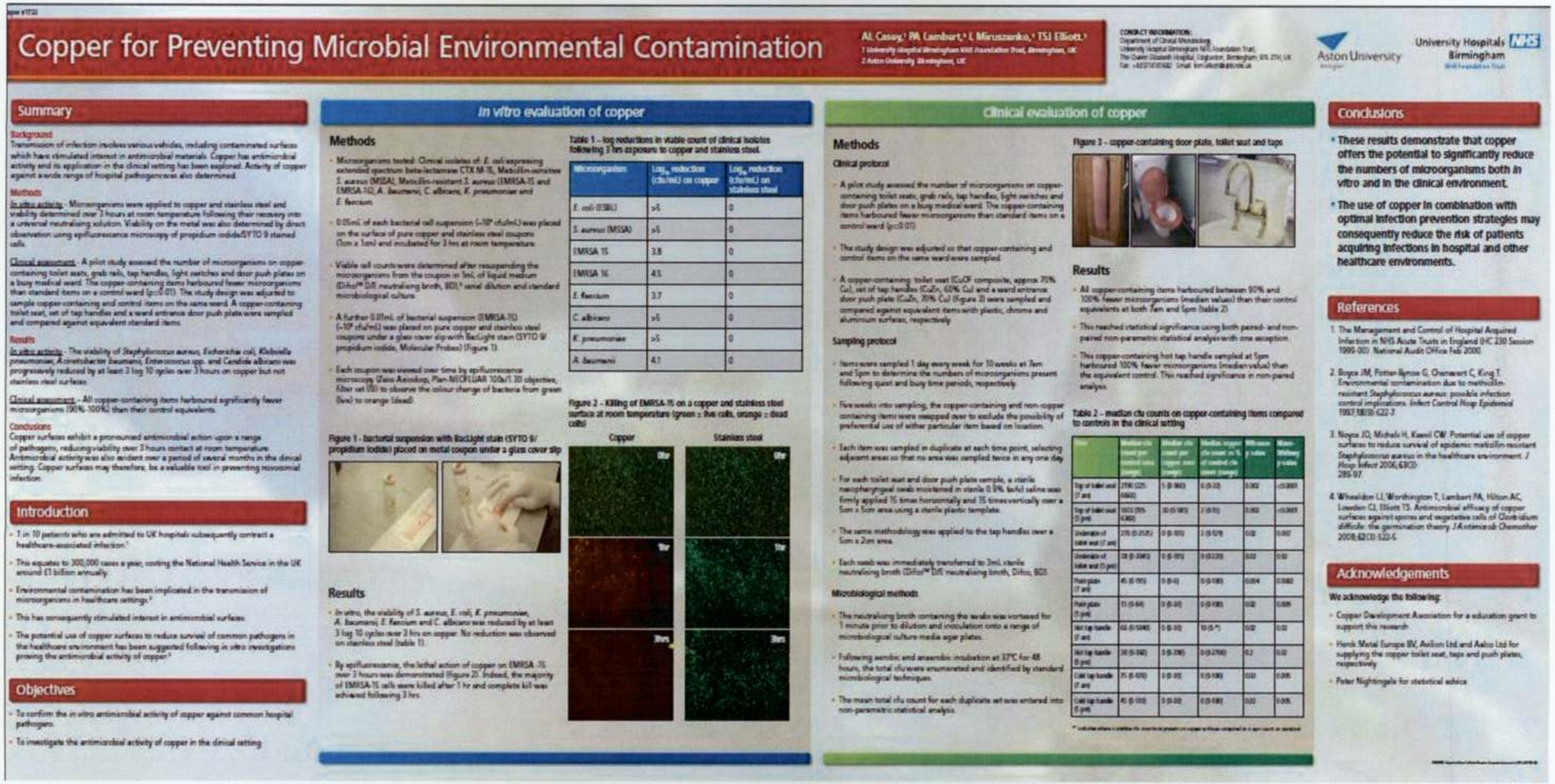

Copper for Preventing Microbial Environmental Contamination
AL Casey, PA Lambert, L Miruszenko, TSJ Elliott
Aston University
University Hospitals Birmingham NHS
Summary
Introduction
Objectives
In vitro evaluation of copper
Methods
Results
Table 1 – log reductions in viable count of clinical isolates following 3 hrs exposure to copper and stainless steel
E. coli (ESBL) >5 0
S. aureus (MSSA) >5 0
EMRSA 15 3.8 0
EMRSA 16 4.5 0
E. faecium 3.7 0
C. albicans >5 0
K. pneumoniae >5 0
A. baumanii 4.1 0
Figure 2 – Killing of EMRSA-15 on a copper and stainless steel surface at room temperature (green = live cells, orange = dead cells)
Copper
Stainless steel
Clinical evaluation of copper
Figure 3 – copper-containing door plate, toilet seat and taps
Sampling protocol
Microbiological methods
Conclusions
These results demonstrate that copper offers the potential to significantly reduce the numbers of microorganisms both in vitro and in the clinical environment.
The use of copper in combination with optimal infection prevention strategies may consequently reduce the risk of patients acquiring infections in hospital and other healthcare environments.
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Acknowledgements

An evaluation of the antimicrobial properties of healthcare fomites (furnishings and equipment) made of copper alloys

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1. Introduction

- Pathogens, such as meticillin-resistant *Staphylococcus aureus*, colonise the healthcare environment and survive on surfaces for extended periods.[1]
- Following cleaning, the surfaces become rapidly re-contaminated due to lack of residual antimicrobial activity of many cleaning agents.[2-4]
- Furthermore, the hands of healthcare workers become readily contaminated with pathogens when touching surfaces or patients.[4,5]
- Environmental contamination has been implicated in the transmission of microorganisms in healthcare settings.[6] This has consequently stimulated interest in antimicrobial surfaces.
- It has been demonstrated in both laboratory and clinical studies that copper surfaces reduce the survival of common pathogens.[7-11]
- The use of copper may therefore play a part in reducing healthcare-associated infections.

2. Objective

- The aim of this study was to evaluate the ability of copper to reduce environmental microbial contamination in the clinical setting.

3. Methods

- A 19-bedded acute medical ward at a University Hospital was fitted with copper- containing furnishings and equipment (Table 1 and Figure 1).
- The surfaces of the items were sampled once weekly for 24 weeks by swabbing.[8] In brief, the surfaces were sampled with a sterile template and a cotton swab moistened in 0.9% (w/v) sodium chloride. After sampling, the tip of the swab was placed into 2 mL of BBL Dey/ Engley neutralising broth (BD, UK). The samples were vortexed and 200 µL inoculated onto blood and selective agar. The plates were incubated as previously described.[8] Samples were taken in duplicate, except for toilet flush handles, light and socket switches and light pull cords. In these instances the whole surface area was sampled.
- The surfaces were sampled (in rotation) each Monday afternoon (between 14.00- 17.00) during visiting hours.
- Routine ward cleaning took place in the morning before 12.30 and in the evening after 17.00.
- Following 12 weeks of sampling, the copper and non-copper items were interchanged to exclude the possibility of preferential use of items from either group based on location.
- The total aerobic colony count was determined and the number of microorganisms on the copper surfaces was compared against the number on equivalent standard items on the same ward.
- The presence of vancomycin-resistant enterococci (VRE), meticillin-sensitive and-resistant *Staphylococcus aureus* (MSSA and MRSA respectively), coliform bacteria and *Clostridium difficile* on the areas sampled was also determined.

Table 1. The composition of study items.

Item	Standard item composition	Copper item composition (% Cu)
Door push plates	Aluminium	CuZn37 (63%) CuZn30 (70%) CuOF (99.95%)
Door pull handles	Aluminium	CuSn8 (92%) CuZn39Pb3 (58%)
Door lever handles	Aluminium	CuSn8 (92%)
Grab rails	Painted steel	CuZn30 (70%)
Toilet seats	Plastic	CuOF composite/ sprayed coating (approx. 70%)
Toilet flush lever handles	Chrome	Copper plated (99.95%)
Commodes	Plastic	CuOF composite/ sprayed coating (approx. 70%)
Patient over-bed tables	Plastic laminated	CuDHP (99.9%) CuOF composite/sprayed coating (approx. 70%)
Dressing trolleys	Stainless steel	CuZn30 (70%)
Sockets (switches)	Plastic	CuZn15 (85%)
Light switches	Plastic	CuZn15 (85%)
Light pull cords (toggle)	Plastic	CuDHP (99.9%)
Sink waste fittings	Chrome	CuZn40Pb2 (58%)
Tap handles	Chrome	CuZn39Pb1 (60%)

Figure 1. Examples of copper items (door push plate, toilet seat, tap handles, grab rails, door pull handle, light switch, socket)

4. Results

- Eight out of 14 types of copper items had significantly fewer microorganisms on their surfaces as compared to standard surfaces. These included door push plates, door pull handles, tap handles, toilet flush lever handles, patient over-bed tables, dressing trolleys, socket switches and light pull cords (toggles). All other items demonstrated a trend towards a reduction in microbial numbers on the copper surfaces compared to standard surfaces, but did not reach significance (Figure 2).
- Indicator microorganisms were recovered from both the copper and non-copper surfaces, however significantly fewer surfaces were colonised with VRE, MSSA and coliform bacteria in the copper group (Table 2).

Figure 2. The median total aerobic counts on copper and standard items (Mann-Whitney p values).

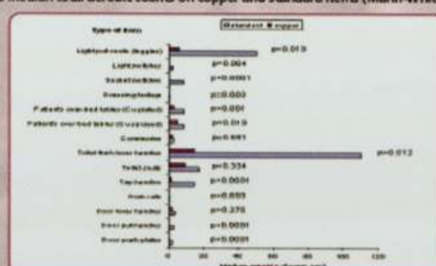

Table 2. The number of copper and standard surfaces contaminated with indicator micro-organisms (excludes results from sink waste fittings)

Indicator microorganism	Copper surfaces (n=559)	Standard surfaces (n=542)	Fisher's Exact Test (p value)
VRE	1	10	0.005
MSSA	7	25	0.001
MRSA	13	20	0.217
Coliforms	19	44	0.001
C.difficile	8	2	0.108

5. Discussion & conclusion

- On a busy medical ward, during continuous challenges from staff, patients and visitors, copper frequent-touch surfaces and other hospital furnishings, were associated with a lower microbial load than standard equivalent items.
- VRE, MSSA and coliform bacteria were also recovered less frequently on the copper containing surfaces compared to standard surfaces.
- These results demonstrate that copper offers the potential to significantly reduce the numbers of microorganisms in the clinical environment.
- The use of copper in combination with optimal infection prevention strategies may therefore reduce further the risk of patients acquiring infections in hospital and other healthcare environments.

References

[illegible]

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