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Methods to evaluate environmental cleanliness in healthcare facilities

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Abstract. ***Background*:** The role of environment in infection prevention and control is being increasingly acknowledged. However, gaps remain between what is promoted as best practice in the literature and what is occurring in healthcare settings. In part, this is due to a lack of generally accepted scientific standards, further confounding the ability to demonstrate an undisputed role for the healthcare environment in healthcare-acquired infections (HAIs). Evaluating environmental cleanliness in a standardised format is required, in order to enable a framework for performance management and provide a method by which interventions can be evaluated. Standardised assessment would provide reliable data to support quality-improvement activities and to ensure that healthcare staff have relevant and useful information to inform and adapt practice.

***Methods*:** This integrative literature review describes approaches to assessing environmental cleanliness. A search of the published literature was undertaken, in combination with a targeted review of the grey literature.

***Results*:** Four methods for assessing environmental cleanliness were identified: visual inspection, fluorescent gel marker, adenosine triphosphate (ATP) and microbial cultures. Advantages and disadvantages for each are explored.

***Conclusion*:** Methods that evaluate cleaning performance are useful in assessing adherence to cleaning protocols, whereas methods that sample bio-burden provide a more relevant indication of infection risk. Fast, reproducible, cost-effective and reliable methods are needed for routine environmental cleaning evaluation in order to predict timely clinical risk.

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Background

There is currently no single solution for controlling healthcare-associated infections (HAIs). Key elements for preventing infection in healthcare environments include hand hygiene, environmental cleanliness, isolation and barrier precautions, surveillance and antimicrobial stewardship. To understand how the environment may play a part in the acquisition of infections, it is important to consider the role of the patient. For example, individuals colonised with microorganisms can contaminate their environment, whereupon these microorganisms can be transferred to other sites, most commonly by peoples' hands. Microorganisms acquired from these sites may then be transferred to other patients. In the past, the role of the inanimate hospital environment in the spread of HAIs has been controversial but there is increasing evidence to support the environment as a reservoir for hospital pathogens and transmission risk.[1]

The potential for contaminated environmental surfaces to facilitate HAIs depends on several factors, including:

- ability of pathogens to remain viable on environmental surfaces
- frequency by which organisms contaminate surfaces
- location of reservoirs

Implications

- Environmental contamination plays a role in the transmission of HAIs
- Four methods are commonly used to evaluate standards of cleanliness
- Fast, reproducible, cost-effective and reliable methods are needed for routine environmental cleaning evaluation
- A definition for 'clean' which relates to clinical risk for patients is required

- hand-touch frequency of surfaces
- adequate contamination levels to present a transmission risk[2]
- pathogen infectivity index

Survival time for pathogens in the environment varies considerably and depends upon the particular characteristics of the organism. *Staphylococcus aureus* remains capable of causing infection for at least 10 days after inoculation onto a dry surface.[3] Evidence for longevity of microorganisms in the environment is supported by numerous studies.[4–7] Unless adequate cleaning is undertaken, microorganisms in the healthcare environment may contaminate hands or be deposited onto a patient or surfaces near a patient by air currents.[8–12] Frequently handled sites are of particular importance. Microorganisms do not discriminate between environmental sites and when they persist on sites that are likely to be touched, there is increased risk of onward transmission to patients via healthcare workers' hands.

Several studies have shown that persistence of microorganisms in the environment leads to an increased risk of infection in patients subsequently admitted to a room previously occupied by a patient colonised or infected with that particular organism.[13] Environmental contamination in conjunction with colonisation pressure (i.e. proportion of patients colonised or infected with an organism in a ward or unit) is thought to encourage transmission of microorganisms. This explains the transmission of organisms such as methicillin-resistant *Staphylococcus aureus* (MRSA), *Clostridium difficile* and vancomycin-resistant enterococcus (VRE) in the healthcare environment, and represents the best evidence for an environmental role in HAI.[14–17]

Microorganisms are found on a large number of surfaces in the healthcare environment. Items in close proximity to the patient tend to be more heavily contaminated than more remote sites.[18] It has been suggested that the greatest risk of acquiring pathogens arise from near-patient items such as bedrails and bedside tables, as contamination of these sites provides frequent opportunity for hands to touch and transfer organisms. Paradoxically, the thoroughness of cleaning sometimes appears to be oriented towards sites that are traditionally or aesthetically important, or physically easier to clean, such as walls and floors, rather than these high-risk sites.[19]

Published studies demonstrating the importance of cleaning in outbreaks underscore the role that environmental contamination plays in the transmission of HAIs.[20,21] Multiple studies have shown that enhanced cleaning significantly decreases environmental contamination by a range of pathogens associated with HAIs.[18,22–25] Despite this, considerable international debate exists regarding the role of the environment and HAIs, including methods to evaluate environmental cleanliness. The public has linked the visual appearance of a hospital with the risk of HAI but more evidence is required to support this view.[26,27]

The role of environmental cleaning has been acknowledged and promoted in national guidelines, with many government-sponsored documents prescribing some form of quality-assurance audit or assessment. However, gaps remain between what is outlined as best practice and what actually takes place in hospitals. In part, this is due to a lack of generally-accepted scientific standards,[28] which further confounds the ability to demonstrate an undisputed role for the healthcare environment in HAIs.[29–32]

Methods

Aim

The aim of this review is to describe the approaches used to assess environmental cleanliness.

Study design

An integrative review design was used.

Search methods

Identifying information on methods to evaluate environmental cleanliness involved two strategies. First, searches of online databases Medline, Cinahl and PubMed, examining articles published in English, using keywords were performed. The keywords used in the search strategy were 'healthcare associated infection', 'healthcare-acquired infection', 'hospital-acquired infection', 'infection control', 'cleaning', 'environmental cleanliness' and 'environment'. The second strategy was to identify information located in the grey literature. This involved searching infection-control professional organisations' websites and Australian state government and territory infection control unit websites. In the case of Australian state-based infection-control units, we also conducted interviews by phone. To identify further information in the grey literature a specific search of national guidelines in Australia (National Health and Medical Research Council) the United Kingdom (Department of Health) and the Centers for Disease Control and Prevention (CDC) was conducted.

Data abstraction and synthesis

The abstracts of all published articles identified in the literature search were analysed chronologically. In articles that obtained information in evaluating environmental cleanliness, a review of the article was conducted and notes made on the key findings and themes. Information obtained

through this process was reviewed by two researchers. Information obtained via the grey literature search and from phone interviews was summarised. Where information was obtained via a phone interview, the researchers provided the interviewee with a summary of the extracted key points to ensure their views were accurately reported.

Results

A total of 124 published articles were reviewed. These described methods for assessing both the efficacy of cleaning and the extent of environmental contamination in the hospital environment. Methods for assessing environmental cleanliness were assessed as one of two main types: process evaluation, where the cleaning process is monitored by visual inspection or by using a fluorescent gel marker; and outcome evaluation, where cleanliness is evaluated with the use of adenosine triphosphate (ATP) or microbial cultures.[13] We present the findings within these two categories in conjunction with a summary of current Australian and international practices.

Process evaluation

Visual inspection

The primary method for assessing the cleanliness of healthcare environments is visual inspection.[33] Visual inspection detects visible dirt, dust, rubbish, stains, soiling and moisture. Environmental cleanliness audits reliant upon visual inspection are generally undertaken by environmental cleaning staff, and the effectiveness of these is intermittently assessed by healthcare professionals such as infection control staff or trained monitoring consultants.[30,31]

We identified quantitative studies that compared the performance of visual assessments with results from microbial swabbing or ATP assays in the healthcare environment.[23,33–37] In these six studies, visual assessment was reported to perform poorly at identifying microbial load, typically passing between 17–93% more surfaces as 'clean' than other assessment methods.

Fluorescent gel marker

This method employs an invisible transparent gel that dries on surfaces and resists dry abrasion, but is easily removed with light abrasion after wetting. The gel is visible only under ultraviolet (UV) light so thoroughness of cleaning can be determined by using UV illumination for sites where the gel was applied before cleaning (Fig. 1). We identified studies that used this method to assess the thoroughness of routine hospital cleaning and the subsequent effect of cleaning interventions.[19,29,38–42]

The fluorescent gel method demonstrates frequent lack of attention to high-risk surfaces in the near-patient zone. Targeting objects and their subsequent evaluation following cleaning has been shown to take less than two minutes per room for each activity, permitting cleaning evaluation to be undertaken on a large scale.[38]

Outcome evaluation

Adenosine triphosphate bioluminescence

The measurement of ATP is the first of two methods commonly employed for sampling bio-burden in the hospital environment. Sampling a surface for ATP measures the amount of organic soil present. This method uses a specialised swab to sample a standardised area. The swabs are placed in a detection device that uses the firefly enzyme and substrate luciferase and luciferan, respectively, to catalyse a reaction with ATP. Light output from the reaction is proportional to the amount of ATP present, and can be measured with a luminometer (measured in relative light units or RLUs) (Fig. 2). While considerable variation can occur among readouts[34,43] and in the sensitivity of commercially available systems,[44] very low readings are typically associated with low aerobic colony counts (ACC) on surfaces.[45]

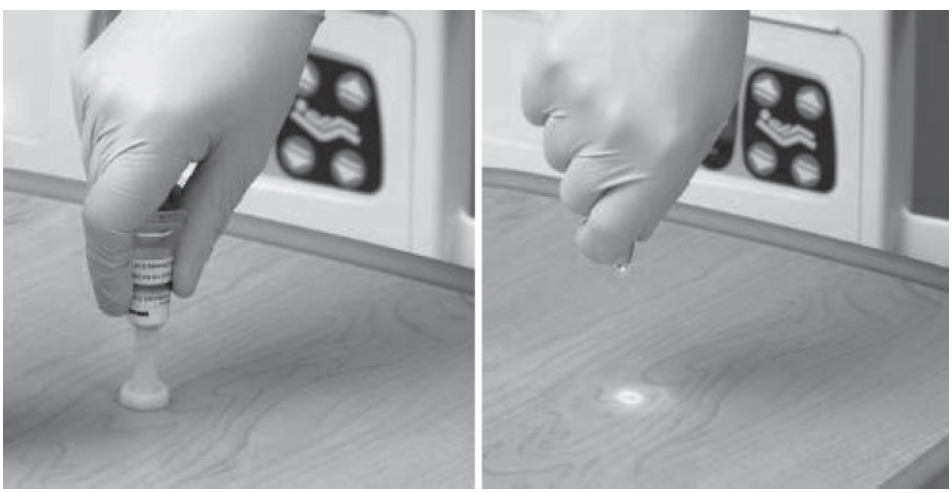

Fig. 1. Examples of a fluorescent marker. Note: Pictures of the DAZO Fluorescent Marking Gel and UV Light pen are used with permission from Ecolab.

Fig. 2. Example of an ATP bioluminescence system. Note: Pictures of the 3M Clean-Trace system are used with permission from FOSS.

Adenosine triphosphate measurement has been used to evaluate cleanliness of food preparation surfaces for over 30 years.[13,33] It is increasingly used in studies of hospital surface contamination where ATP data is gathered in addition to microbial swabbing, either to evaluate cleaning performance or to test the success of a cleaning intervention.[23–25,33–36,43,45,46]

Adenosine triphosphate measurements provide quantification of organic material collected from a swab, including viable bacteria, but also including non-viable bacteria and organic debris such as food and liquids such as milk, blood or urine.[34] Thus, an ATP result represents a quantitative indicator of all of these. However, it is possible to distinguish the ratio of microbial to non-microbial components of an ATP measurement by enzymatic removal of non-bacterial ATP before the assay. Studies that have done this calculated that 33% of the ATP load was attributable to microbial organisms.[33,47]

For this reason, ATP measurements illustrate low sensitivity and specificity in detecting bacteria, with one study finding that one ATP measurement system had a sensitivity and specificity of just 57%.[43] ATP measurements can also be compromised by factors such as residual detergents or disinfectants including sodium hypochlorite,[48,49] eroded surfaces,[33] plasticisers found in microfibre cloths or ammonium compounds found in laundry products.[50] These factors may all impact on ATP readings.[34]

Microbial methods

Microbial methods for evaluating environmental cleaning have long been used to evaluate surface contamination and have been employed in hospitals to assess surface cleanliness.[51] Through the late 1950s and 1960s, microbiological sampling was common practice as part of on-going hospital monitoring programs and accordingly, colony counts, Rodac plate counts, and quantitative air sampling were all routinely used in the hospital environment, including screening of inanimate objects[13,51] Swabs, dipslides, sampling sponges and settle plates may all be used to sample surfaces, and the choice of sampling method will affect microbial colony counts. Dipslides have been evaluated as having superior sensitivity and consistency, particularly for dry surfaces, while swabs will not always accurately detect surface bio-burden and may retain bacteria within the swab bud itself[52–54] Finally, there is an airborne component of infection risk in a ward and this can often be overlooked in environmental sampling studies. Settle plates and air samplers have been used to measure airborne contamination caused by floor mopping and bed making, as well as routine cleaning.[55–57]

In today's hospitals, environmental sampling typically targets a range of surfaces within wards or work stations as well as equipment. It involves the use of swabs or dipslides to culture organisms in order to gain a quantitative colony count and/or to detect the presence of specific bacteria. This type of investigation is generally only recommended as part of an ongoing outbreak investigation, as a research study, or as part of policy or process evaluation because the time taken to enumerate microbial counts or identify pathogens may be at least two days, and requires specific expertise as well as access to a microbiology laboratory.[31,58]

Costs

We estimated costs of three of the assessment methods – fluorescent gel marker, ATP and microbiological sampling. The costs were based on a 350 bed hospital with an assumption that 10% of hospital beds would be sampled per quarter, with 6 high-touch areas screened around individual beds. This equates to 140 bed areas assessed per annum with 840 high-touch areas sampled. Costs were sought from the manufacturers of the fluorescent gel marker and ATP as well as via an Australian microbiology laboratory which is National Association of Testing Authorities (NATA) accredited to assess environmental surface swabs.

The complete fluorescent gel marker system included initial set-up costs, direct data-entry devices, reporting software with the gel markers and UV lights. The kit cost approximately A$9500 for the first year, with costs decreasing

by approximately A$1300 to $A8200 per annum for subsequent years. This cost could be reduced to approximately A$900 per annum if gel markers and UV lights only are purchased and the training and development of a reporting matrix was done in-house with costs absorbed by the organisation. The initial set-up costs of the ATP system were calculated to be approximately A$10 000 with a per annum running cost of around $A5000. Again these costs do not include any software and are only calculated using the costs of ATP swabs and luminometer. Microbiological methods had a range of costs depending on whether non-selective or selective plates were used, and/or settle plates and/or diluent methods were used. Estimated costs of A$6300–A$11 620 per annum also includes the reporting fee.

Australian practices

The most commonly used method for assessing environmental cleaning within Australian healthcare facilities is visual assessment with a variety of methods and programs in use. No jurisdictions routinely use any alternative methodologies such as fluorescent markers, ATP bioluminescence or microbial counts for assessing environmental cleanliness.

Local and international guidelines

Routine environmental sampling is not recommended as part of the Australia National Health and Medical Research Council guidelines owing to the limitations of the methods available. Thus, cleaning audits are mainly carried out via visual assessment. A role for environmental sampling may be considered in the management of a specific situation.[31]

In the United Kingdom, a self-assessment framework known as the Patient Environment Action Team (PEAT) was used in all hospitals with more than 10 beds. One component of this benchmarking tool enabled hospitals to perform an annual assessment of environmental cleanliness. The cleanliness of both the hospital environment and clinical and non-clinical equipment was visually assessed. The results of the annual audit could then be benchmarked with the aim of improving non-clinical services. Each year, a proportion of PEAT assessments were validated by an independent member.[59] In January 2012, a replacement for the PEAT program was proposed. The development of a patient- lead inspection program is currently underway to replace the PEAT program. The National Institute for Health and Clinical Excellence also has a quality-improvement statement for environmental cleanliness.[60]

In the United States of America, the Healthcare Infection Control Practices Advisory Committee (HICPAC) Guidelines for Environmental Infection Control in Health-Care Facilities do not outline any specific methodology for assessing environmental cleanliness, but they do recommend limiting microbiological sampling for use in quality assurance purposes, epidemiological investigations or for research purposes.[58]

A review of the literature demonstrates that benefits and limitations exist for all methods of environmental cleaning evaluation. These are summarised in Table 1.

Discussion

Increasing focus on methods for quantitative assessment of cleanliness in hospital environments has highlighted many of the shortcomings of visual assessment. These studies reiterate that a visual appraisal of cleanliness is not a proxy for adequate decontamination. While visual assessment of the cleanliness of a hospital ward, surface or item may satisfy aesthetic obligations, it cannot reliably assess the infection risk posed to patients.[28] It is the cheapest and quickest of all methods described in this report however, requiring less training and fewer personnel than other methods. As a means of measuring the efficacy of hospital cleaning and personnel performance, visual inspection has its merits as it is the only method that can quickly assess a large number of surfaces for gross deficiencies in a hospital ward that may harbour pathogens.

As with visual assessment, the fluorescent gel method evaluates cleaning performance rather than environmental contamination *per se* and relies upon the assumption that improved cleaning procedures can reduce environmental sources of pathogens and thus risk of microbial transmission.[22,61] Furthermore the fluorescent gel method can provide a more standardised approach to process evaluation compared with visual inspection. Addressing cleaning performance remains a vital step in the evaluation of environmental cleaning and the use of a fluorescent marking system to monitor cleaning can provide an effective method to accomplish this.

The benefits of using ATP measurements to evaluate hospital cleanliness are speed of data collection,[35] ease of use[36] and the facility to benchmark.

Limitations of ATP measurement systems are found in both the propensity of systems to produce false positives, and in the ability of the system to produce consistent results for all sampling assessments and surfaces. In addition, the low sensitivity and specificity along with the wide range of factors that can compromise ATP measurements could be considered to be too unreliable to justify stringent monitoring using this method alone.

Microbiological evaluation of hospital surfaces provides the most accurate indication of infection risk of all the methods discussed because it can detect and quantify viable bacteria and fungi. Reasons for not advocating microbiological evaluations in all situations centre on the time and resources required to process conventional microbiological cultures. While microbiological methods can produce results with high specificity, sampling techniques have varied sensitivity and often underestimate bio-burden on a surface, thereby hindering accurate assessments of surface contamination and study comparability.[34]

A limiting factor for all of the assessment methods studied is the cost. None of the methods are particularly cheap but savings could be made if the testing protocol and reporting

Table 1. Summary of methodologies

	Advantages	Disadvantages[A]
	Assessing performance	
Visual inspection	Ease of use for large areas (wards, rooms)	Subjective
	Can be done with minimal training	Does not assess bio-burden
	Benchmarking possible	Does not correlate with bio-burden
	Simple and inexpensive	Can be confounded by clutter, fabric deficits and odours
Fluorescent gel	Quick	Does not assess bio-burden
	Provides immediate feedback on performance	Could be labour intensive as surfaces must be marked before cleaning and checked post cleaning
	Minimal training required	Potentially costly
	Objective	Emphasis on easily visible non-high-touch surfaces (walls, floors)
	Benchmarking possible	
	Assessing outcome	
Adenosine triphosphate bioluminescence	Quick	Expensive
	Provides immediate feedback	Low sensitivity and specificity
	Minimal training required	No current standardisation of tests
	Objective	Variable benchmarks
		Technology constantly changing
Microbial cultures	High sensitivity and specificity	Expensive
	Objective	Prolonged time for results
	Can identify screened pathogen	Requires accessible laboratory resources and trained personnel for interpreting results
	Provides quantitative data	Not supported for routine use by local and international guidelines
	May suggest or confirm environmental reservoir(s) and/or source of outbreak	Few laboratories NATA accredited to perform these tests
		Relies on standardised benchmark to assess infection risk

[A]Disadvantages of all of these methods include requiring feedback to cleaners, the fact that they may lose impact over time and that they need to be linked with formal performance indicators.

matrix are done in-house. This was particularly noticeable in the fluorescent gel system where a substantial sum of money could be saved by using in-house devised reporting systems.

Evaluating environmental cleanliness in a standardised format is required, in order to enable a framework for performance management and provide a method by which interventions can be evaluated. Standardised assessment would provide reliable data to support quality improvement activities and to ensure that healthcare staff have relevant and useful information to inform and adapt practice. We need a definition for 'clean' which relates to clinical risk for patients in healthcare facilities.

Conclusion

There are four main methods used to evaluate environmental cleanliness in healthcare facilities – ATP bioluminescence, microbiological methods, visual inspection and gel markers. Each of these methods has advantages and limitations. Methods that evaluate cleaning performance are useful in assessing adherence to cleaning protocols, whereas methods that sample bio-burden provide a more relevant indication of infection risk. Fast, reproducible, cost-effective and reliable methods are needed for routine environmental cleaning evaluation in order to predict timely clinical risk. Further, a standardised format is required, to enable a framework for performance management and provide a method by which interventions can be evaluated.

Conflict of interest

One of the authors has an editorial affiliation with the journal. This author play no part whatsoever in the review process.

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