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A modified ATP benchmark for evaluating the cleaning of some hospital environmental surfaces

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Summary Hospital cleaning continues to attract patient, media and political attention. In the UK it is still primarily assessed via visual inspection, which can be misleading. Calls have therefore been made for a more objective approach to assessing surface cleanliness. To improve the management of hospital cleaning the use of adenosine triphosphate (ATP) in combination with microbiological analysis has been proposed, with a general ATP benchmark value of 500 relative light units (RLU) for one combination of test and equipment. In this study, the same test combination was used to assess cleaning effectiveness in a 1300-bed teaching hospital after routine and modified cleaning protocols. Based upon the ATP results a revised stricter pass/fail benchmark of 250 RLU is proposed for the range of surfaces used in this study. This was routinely achieved using modified best practice cleaning procedures which also gave reduced surface counts with, for example, aerobic colony counts reduced from >100 to <2.5 cfu/cm^2, and counts of *Staphylococcus aureus* reduced from up to 2.5 to <1 cfu/cm^2 (95% of the time). Benchmarking is linked to incremental quality improvements and both the original suggestion of 500 RLU and the revised figure of 250 RLU can be used by hospitals as part of this process. They can also be used in the assessment of novel cleaning methods, such as steam cleaning and microfibre cloths, which have potential use in the National Health Service.

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Introduction

Although the role of the healthcare environment in the spread of some infections is far from universally agreed, circumstantial evidence suggests that contaminated hospital environmental surfaces can be a risk factor for infection caused by some pathogens.[1–8] Those advocating an important role for the environment as a reservoir of nosocomial pathogens have argued that effective environmental cleaning is important in helping to break the cycle of transmission. Infection control aside, cleaning costs money and UK trusts should try to achieve maximum value, especially when patients, relatives and other organisations have expressed concerns over hospital cleanliness.[9]

The government, in an attempt to improve standards, has launched a number of initiatives.[10,11] One of these places a 'duty on hospitals to provide and maintain a clean and appropriate environment for healthcare'.[12] Similarly the latest evidence-based guidelines for preventing healthcare-associated infections recommend 'a clean environment free from dust and soilage and acceptable to patients'.[13] Such recommendations and patient assessments are based on visual determination of surface cleanliness. Unfortunately, visual assessment is not an accurate measure of surface cleanliness nor of microbial contamination and can be a misleading measure of cleaning efficacy.[14–16] When non-visual methods to assess cleanliness have been used, concerns over cleanliness levels have been expressed even when National Health Service (NHS) cleaning guidelines have been followed.[14,17] There have been calls for a more evidence-based approach to assessment of surface cleanliness and various standards have been proposed.[18]

Benchmarking is a tool used in quality management where performance is compared to that achieved by following best practice with the results being used to set standards and as the basis for quality improvement.[19]

The aim of this study was to assess the surface cleanliness and microbial contamination levels of environmental surfaces following routine and best practice cleaning and to compare the results with previously proposed benchmark values.

Methods

Sites selected

The routine weekday cleaning of six sites on three wards over a four-week period was assessed in a 1300-bed English teaching hospital.

A sample consisting of a general medical, general surgical and a medical admission ward was used. Each ward had 30 beds, with predominantly four-bedded bays. Occupancy levels exceeded 95% throughout the duration of the study. The six sites were selected based on frequency of hand contact, people movement, problem cleaning areas with previously high failure rates and proximity to patients. They consisted of the patient toilet flush handle, toilet sink tap handle, bedside table and locker, commode and drugs trolley, as well as the water used during cleaning. The sites were fixed throughout the study period. When handles were sampled, all sampling was performed on the one handle. For larger surfaces, adjacent areas of 100 cm^2 were sampled, using a previously published method.[14]

Sampling

Cleaning efficacy was assessed within 10 min of completion of the morning cleaning session, using two different cleaning regimens, every weekday for two weeks.

Cleaning regimens

Existing hospital cleaning protocols, although based on NHS guidelines, lacked detail and related more to frequency of cleaning rather than how the process was undertaken and managed. Cleaning of bathrooms was undertaken by domestic staff employed by the trust, cleaning of bedside areas by 'hostess' staff with commodes and drug trolleys cleaned by nursing staff. The existing protocols involved spraying surfaces with a non-ionic detergent (Johnson Diversey, Northants, UK) and wiping with a reusable cloth. It was specified that cloths were to be changed when visibly soiled or worn. Modified best practice protocols were designed to increase physical removal of soil with a reduction in the potential for recontamination, coupled with drying — factors that can affect cleaning efficacy and microbial transfer.[20] Surfaces were initially cleaned using potable water and a disposable paper towel, then sprayed with the detergent (same as normal protocol) and wiping with a disposable cloth. This was followed by a potable water rinse and drying with disposable paper towels. The best practice cleaning was undertaken by the same cleaning staff after brief training including a 10 min demonstration. Practices used during normal cleaning as well as implementation of the modified cleaning protocol were audited by infection control staff using a standardised checklist.

Tests used

All testing was undertaken by medical or infection control staff and included a standardised visual assessment (visual soiling, staining, foreign objects, surface condition and the presence of moisture).[16] Additionally surfaces were tested for adenosine triphosphate (ATP), a sensitive indicator of organic soiling, including residual microbial contamination.[16]

ATP levels were determined using 'Cleantrace' swabs and a Uni-Lite NG luminometer (Biotrace International Ltd, Bridgend, UK) over an area of 100 cm^2 in a close zig-zag pattern using the manufacturer's guidelines and expressed as relative light units (RLU).

Contact-based bacterial counting methods (dip slides) were used as they have been found to have superior sensitivity and reproducibility, especially for dry surfaces, compared with routine swabbing without broth enrichment.[21,22] The dipslides (Biotrace) were pressed onto the surface for 10 s at a pressure of $\sim$25 g/cm^2 (tested by pressing a control slide onto the surface of a top pan balance) without lateral movement. For microbiological assessment of the cleaners' water, dipslides were immersed for 5 s (manufacturer's guidelines) in the cleaning bowls.

Samples were incubated aerobically at 37 °C for 48 h. Colony densities were determined by visual comparison with the manufacturer's standard charts supplied with the dipslides. Aerobic colony counts were determined using a plate count agar. Baird—Parker medium was used to isolate *Staphylococcus aureus*, with potential isolates confirmed by DNase expression and detection of bound coagulase/protein A (Remel). Meticillin resistance was determined by standard oxacillin disc testing methodology (British Society for Antimicrobial Chemotherapy) on Columbia salt agar at 30 °C. Gram-negative organisms were isolated using a Violet Red—bile—glucose agar. Presumptive isolates of Enterobacteriaceae were further identified using an API 20E kit (bioMérieux), with antibiotic sensitivity testing carried out according to standard methods.[23] Other Gram-negative organisms were subcultured onto cysteine lactose electrolyte-deficient agar. *Pseudomonas aeruginosa* was identified by characteristic smell, colony morphology and positive oxidase test. Other organisms were identified using an API 20NE kit (bioMérieux).

Data analysis

All results were entered into a Microsoft Excel database. Determination of median and 95th percentiles was performed by ranking of data by value. Values for ranges of ATP values used in the histogram analysis were chosen in conjunction with previously suggested cut-offs and to reflect the spread of data.

Results

The results of the two trial periods (routine cleaning and best practice cleaning, carried out on 10 consecutive weekdays) using visual, ATP and microbiological testing were as follows.

Visual inspection

The majority of surfaces, following both cleaning protocols, were dry and visually free from dirt, dust, stains and smears. Exceptions included the toilet flush handle on the surgical ward, which was badly scratched and coated in limescale. The drugs trolley failed on a daily basis, due to the presence of stickers which, although not new, did not trap gross organic soil. Two surfaces, the medical ward bedside table and the surgical ward bedside table, failed due to sticky deposits. Auditing of the cleaning process itself confirmed that the staff implemented the revised cleaning protocol correctly. It was, however, noted that during routine cleaning, cloths were not always changed as frequently as they should have been and were sometimes left damp for extended periods when in use.

ATP analysis

ATP bioluminescence results for individual ward sites are shown in Table I and summarised in Figure 1. The results using the modified cleaning protocol were lower and there were decreases in median ATP levels at all sites (Figure 1), including sites in close proximity to the patient. ATP bioluminescence values could be reduced to $<$250 RLU in $>$95% of tests with the best practice protocol for all sites in all wards.

Microbiological analysis

With the existing cleaning protocol, aerobic colony counts (ACCs) $<$ 100 cfu/cm^2 were achieved 95% of the time (Figure 2), with *Staphylococcus aureus* and Enterobacteriaceae present at $<$2.5 cfu/cm^2, 95% of the time. With the best practice cleaning protocol these were reduced (95% of the time) to: ACC $<$ 2.5 cfu/cm^2, *S. aureus* $<$ 1 cfu/cm^2, Enterobacteriaceae $<$ 1 cfu/cm^2.

Table I Median ATP results for individual ward sites (with ranges), sampled 10 min after cleaning, on 10 consecutive weekdays

	ATP bioluminescence (RLU)	
	Standard cleaning protocol	Modified cleaning protocol
Medical ward		
Commode	590 (320–2100)	14 (6–29)
Drugs trolley	460 (260–1100)	12 (5–60)
Bedside locker	140 (31–300)	34 (12–76)
Bedside table	340 (130–550)	180 (27–280)
Tap handle	450 (95–750)	130 (17–490)
Toilet handle	340 (27–3100)	19 (11–80)
Surgical ward		
Commode	260 (100–1400)	29 (3–78)
Drugs trolley	270 (88–2700)	19 (3–56)
Bedside locker	350 (35–1400)	32 (18–120)
Bedside table	140 (30–560)	32 (12–160)
Tap handle	7000 (1700–220 000)	60 (43–3700)
Toilet handle	110 (23–1800)	29 (16–1300)
Admissions ward		
Commode	310 (100–2100)	24 (10–54)
Drugs trolley	460 (360–6200)	20 (7–90)
Bedside locker	340 (110–9900)	15 (6–50)
Bedside table	1500 (400–43 000)	48 (10–240)
Tap handle	58 (9–190)	21 (9–56)
Toilet handle	71 (19–5000)	17 (19–36)

RLU, relative light units.

After routine cleaning, *S. aureus* was most frequently isolated from commodes and bedside tables (both seven times), bedside lockers (five times), toilet handles (four times) and a drugs trolley and tap handle once. Although only a low number of samples were available at each site, there were no apparent differences in isolation frequencies between the wards and none were identified as meticillin resistant.

The one tap handle that was visually badly scratched supported the growth of *P. aeruginosa* on most days. Other non-fermenting organisms isolated and identified included *Acinetobacter baumannii*. This was found on bedside tables and lockers, as well as toilet tap handles. Some organisms isolated from tap handles were also isolated from the cleaning water. On one occasion an extended-spectrum beta-lactamase (ESBL)-producing *Klebsiella pneumoniae* was isolated from the cleaning water.

Applying standards to visual, ATP and microbiological analysis

Pass and fail levels were set as the standard achieved 95% of the time with the best practice cleaning protocol. The performance at each site on each day by each method of assessment is shown in Figure 3. It can be seen that ATP fails and microbiological fails tend to cluster, while there is little relationship between microbiological fails and visual fails.

ATP analysis measures both microbiological and non-microbiological sources of ATP, both of which should be removed by an effective cleaning protocol. Nevertheless, the validity of a cleaning assessment tool is enhanced if there is correlation between its performance and the degree of microbiological contamination on a surface. It can be

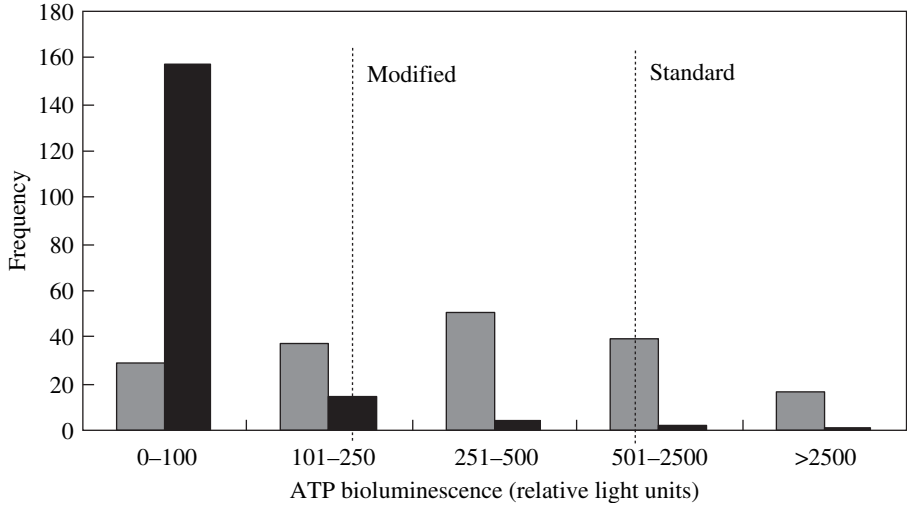

Figure 1 Distribution of ATP bioluminescence values from all sites after standard (grey bars) or modified protocol (black bars) cleaning. Six sites on three wards were analysed 10 min after cleaning on 10 consecutive weekdays. Dotted lines show standards that could be achieved 95% of the time with either modified or standard protocols.

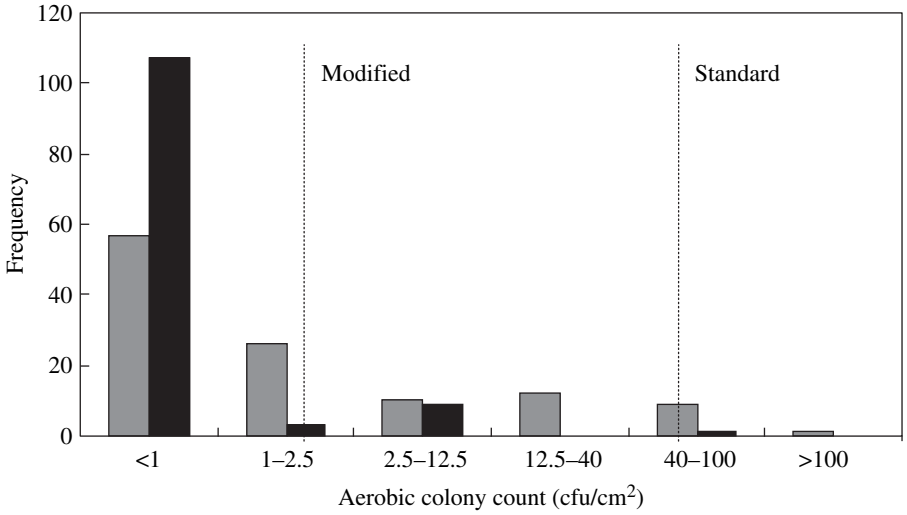

Figure 2 Histogram showing frequency distribution of aerobic colony count after standard (grey bars) or modifed (black) protocol cleaning. Six sites on three wards were analysed 10 min after cleaning on 10 consecutive weekdays. Lines show standards that could be achieved 95% of the time with either modified or standard protocols.

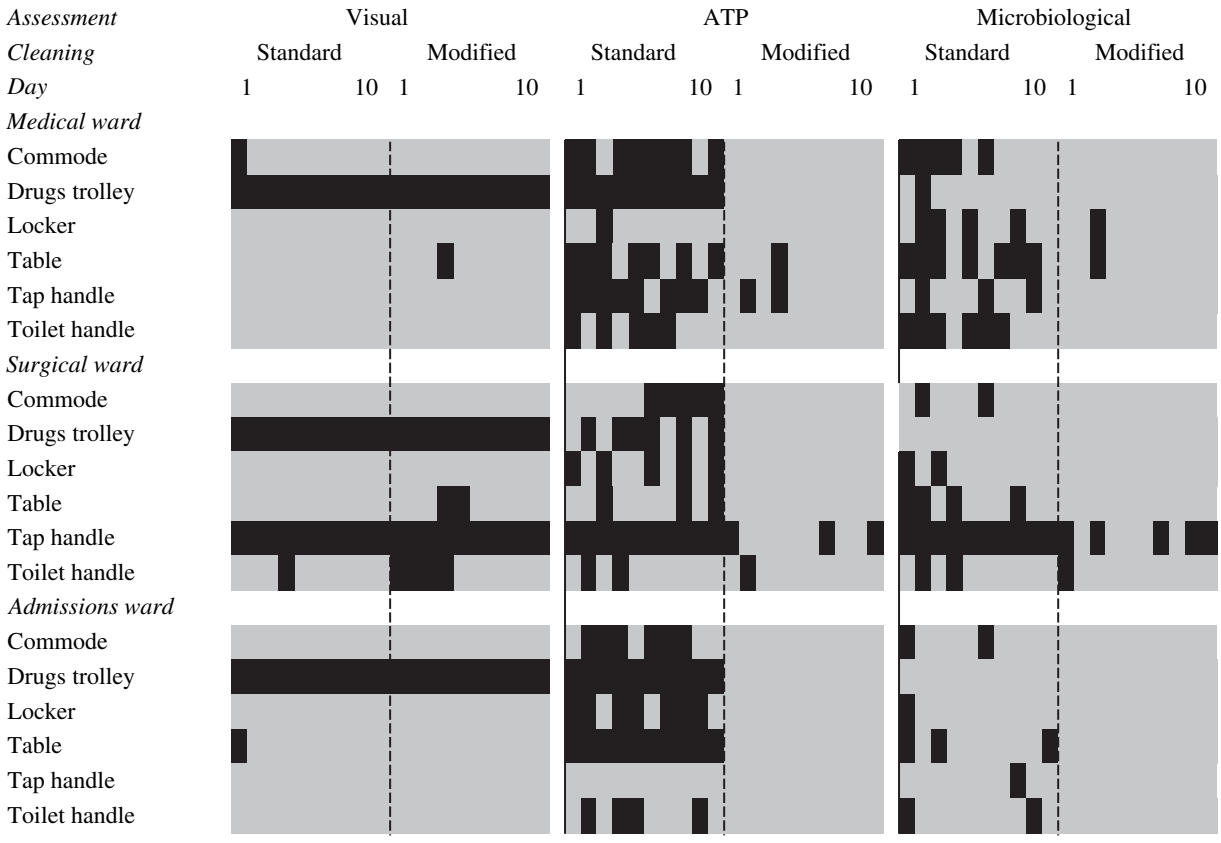

Figure 3 Pass/fail rates for different wards and sites using different assessment methods. Cleaning assessment at each site on each day by the following criteria: visual (see Methods); ATP $>$ 250 relative light units; microbiological, either aerobic colony count $>$ 2.5 cfu/cm^2 or detectable *Staphylococcus aureus* or detectable Enterobacteriaceae. Each square represents one site on one day with grey indicating a pass and black a fail. The dotted line indicates the change in cleaning protocol.

seen from Figure 4 that as the ACC on a surface rises, so does the probability of failing by ATP testing. Conversely, there is little relationship between visual assessment and microbiological counts, except at very high levels of contamination. Most of this occurred on the limescale-coated tap handle in the surgical ward. This demonstrates that visual assessment is important in the determination of whether some surfaces can ever be considered cleanable, but that it will lead to false reassurance as to the microbiological burden left behind after standard cleaning practices.

Discussion

A considerable amount of money is spent on cleaning within the NHS and currently there are few accurate data to indicate or judge cleaning efficacy and value for money. The results confirm previous findings that visual assessment on its own is not a good indication of cleaning efficacy.[14,15] The development of new cleaning audit tools must be based on a more scientific method. By relying primarily on visual assessment, such audits[24] may provide false reassurance on cleaning efficacy and the microbiological status of the environment.

The current results support previous findings that cleaning efficacy (in terms of soil, ATP removal, and reduction in surface counts) can be improved by incorporating relatively simple additional steps into routine cleaning.[14] Results obtained with the revised cleaning protocol were also more consistent than those after standard routine cleaning. Greater consistency can be a measure of how well the cleaning process is managed.[25] This may in part relate to the use of disposable rather than reuseable materials, which were not always changed appropriately during the existing routine protocol and are known to spread contamination.[26]

A benchmark value of 500 RLU for ATP testing has been proposed.[14,16] This was based on a wide variety of surfaces from the home, catering environment and hospitals and used a different cleaning protocol. Based on the present results a more stringent benchmark value of 250 RLU for some hospital sites was routinely achieved. This applies to this ATP instrument/test combination only and is not transferable to other makes of equipment which may be less sensitive.

The objective monitoring of cleaning performance with feedback to the staff involved has been recommended in infection control.[28–31] The ATP and microbiological benchmark values in this study provide a precise measure of surface cleanliness following a properly implemented cleaning protocol. ATP testing can be used to provide instant feedback on surface cleanliness, and was found to be a powerful way of demonstrating deficiencies in cleaning protocols and techniques to staff.

The benchmarks, by providing objective and attainable measures, could also be used for the evaluation of novel cleaning methods (such as steam cleaning and microfibre cloths). Such benchmark values apply only immediately after cleaning, as recontamination will occur, and may not be applicable to all surfaces. However, surfaces unable to achieve this sort of value may not be capable of being cleaned effectively (e.g. due to wear) and may need to be changed. These

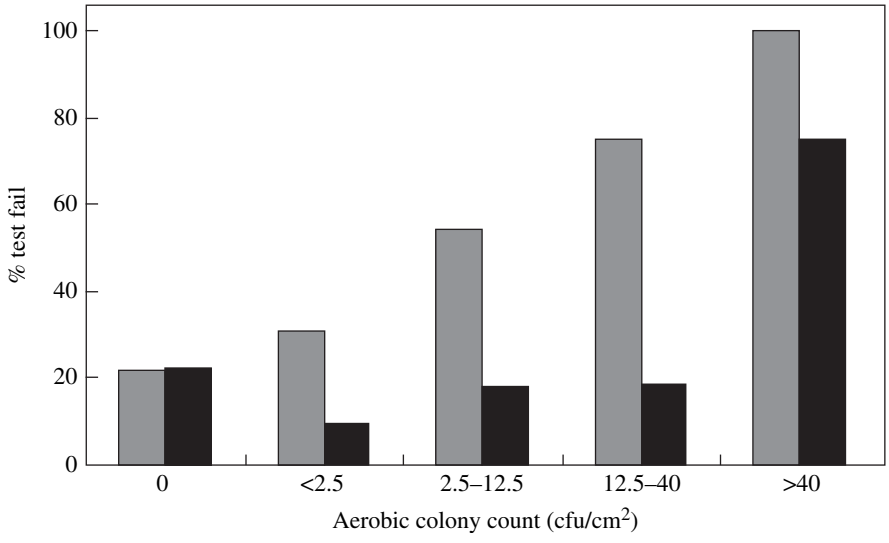

Figure 4 Relationship between the aerobic colony count (ACC) from a surface and its pass or fail using either ATP assessment (grey bars; fail if >250 relative light units) or visual assessment (black bars; see Methods). Graph shows percentage of fails by either form of assessment for each range of ACC isolated.

benchmark values could also be used to determine optimum cleaning frequencies for specific surfaces based upon the speed of recontamination.

It is more difficult to relate these benchmark values to infection risk. ATP is a measure of general cleanliness. The proposed ACC benchmark of 2.5 cfu/cm^2 is similar to that proposed elsewhere but lower than others.[32,33] It was routinely achieved (95% of the time) in this study but the count does not relate to pathogens. Risk is more likely to be related to the frequency and level of surface contamination with specific pathogens in combination with frequency of touch and hand hygiene practices. Pathogens are usually more difficult to isolate from the environment, and surface sampling for these is more relevant when circumstances indicate their presence, e.g. during outbreak investigations or after a colonised patient has inhabited a room.

ATP measures residual surface organic soil, which may include micro-organisms, whereas microbiological assessments measure numbers of residual viable organisms. There is little value in trying to directly correlate one with the other and this approach, although sometimes attempted, is questionable.[27] For a strong correlation the ratio between organic debris and micro-organisms would need to be constant and there are many reasons why this may not occur.[28] Typically, ~33% of the ATP from hand contact surfaces is likely to be of microbial origin with the remainder non-microbial.[16] However, minute traces of blood, urine or some foods (e.g. milk) could significantly increase ATP readings yet have little effect on viable surface counts.

If cleaning is intended to remove pathogens from a surface, it is a requirement of the process that it should be able to reduce residual organic material to a low level. Thus, a cleaning protocol that fails to achieve benchmark values for removal of organic soil, as determined by a sensitive ATP test, is unlikely to be fit for purpose. In a hospital environment, this would necessitate either reassessment of adherence to the protocol, or adoption of new cleaning methods or frequencies. Microbiological assessment in specific instances, and more general use of sensitive ATP testing in training and process management, may be one way of formulating an integrated and cost-effective cleaning assessment strategy.[16]

Conflict of interest statement
None declared.

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