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What do we know about Environmental Testing?

As the US prepares to receive workers back to various types of work sites, the usefulness of adding environmental testing to the cleaning and disinfection protocols is being questioned. Some cleaning vendors are advocating the use of PCR or ATP for cleaning verification for production floors, offices and other non-regulated areas. Monitoring of cleaning and disinfection efficiency is already in place in various industries such as healthcare, food preparation, and pharmaceutical manufacturing. Here are the industry standards or guidelines available:

Healthcare: CDC Guideline for Disinfection and Sterilization in Healthcare Facilities , 2008 – Updated May 2019
https://www.cdc.gov/infectioncontrol/pdf/guidelines/disinfection-guidelines-H.pdf

Food Industry: Cleaning and Disinfection Procedures in the Food Industry - General Aspects and Practical Applications [Chapter 13]. January 2007 DOI: 10.1007/978-0-387-33957-3_13 In book: Food Safety (pp.253-280)

Pharmacy: United States Pharmacopeia <1072> Disinfectants and Antiseptics [Disinfectants in a Cleaning and Sanitization Program]
http://www.uspbpep.com/usp31/v31261/usp31nf26s1_c1072.asp

The following are selected references where there has been comparison between the ATP bioluminescence system and microbial colony forming systems, the correlation between the two systems is indicated if available in the publication.

Testing method	Benchmark (RLU)	Location	Correlation Luminometer (RLU)/ Swab (CFU)	Reference
Luminocontrol II (PBI internarnational, Milano) [1]	100	Healthcare	Poor (R2=0.29)	Amodio E, Analytical performance issues: comparison of ATP bioluminescence and aerobic bacterial count for evaluating surface

				cleanliness in an Italian hospital. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7196686/
Pd-10 kikkoman Co, Japan[1]	Not reported	Healthcare	Significant (κ = 0.249)	Aycicek H, Oguz U, Karci K. Comparison of results of ATP bioluminescence and traditional hygiene swabbing methods for the determination of surface cleanliness at a hospital kitchen. Int J Hyg Environ Health. 2006;209:203–206. [PubMed] [Google Scholar]
3M Clean-Trace ATP System[1]	250	Healthcare	From poor to moderate (r from 0.356 to 0.649)	Boyce JM, Havill NL, Dumigan DG, Golebiewski M, Balogun O, Rizvani R. Monitoring the effectiveness of hospital cleaning practices by use of an adenosine triphosphate bioluminescence assay. Infect Control Hosp Epidemiol. 2009;30:678–684. [PubMed] [Google Scholar]
Biotrace International, Ltd, Brigend, UK [1]	250	Healthcare	Significant	Lewis T, Griffith C, Gallo M, Weinbren M. A modified ATP benchmark for evaluating the cleaning of some hospital environmental surfaces. J Hosp Infect. 2008;69:156–163. [PubMed] [Google Scholar]
Biotrace Cleantrace system [1]	500	Healthcare	Significant	Malik RE, Cooper RA, Griffith CJ. Use of audit tools to evaluate the efficacy of cleaning systems in hospitals. Am J Infect Control. 2003;31:181–187. [PubMed] [Google Scholar]
Hygiena system[1]	250	Healthcare	Significant	Mulvey D, Redding P, Robertson C, Woodall C, Kingsmore P, Bedwell D, Dancer SJ. Finding a benchmark for monitoring hospital cleanliness. J Hosp Infect.
3M Clean-Trace ATP System[1]	250	Healthcare	Significant only precleaning	Smith PW, Gibbs S, Sayles H, Hewlett A, Rupp ME, Iwen PC. Observations on hospital room contamination testing. Healthcare Infection. 2013;18:10–13.
3M Clean-Trace ATP System[1]	250	Healthcare	Significant	Smith PW, Sayles H, Hewlett A, Cavalieri J, Gibbs SG, Rupp ME. A study of three methods for assessment of hospital environmental cleaning. Healthcare Infection. 2013;18:80–85.
3M Clean-Trace ATP System[1]	127	Healthcare	Poor (r = 0.287)	Watanabe R, Shimoda T, Yano R, Hayashi Y, Nakamura S, Matsuo J, Yamaguchi H. Visualization of hospital cleanliness in three Japanese hospitals with a tendency toward long-term care. BMC Res Notes. 2014;7

Hygiena system[1]	100(surfaces), 300 (floor)	Healthcare	Poor (r = 0.15)	Willis C, Morley R, Westbury J, Greenwood M, Pallett A. Evaluation of ATP bioluminescence swabbing as a monitoring and training tool for effective hospital cleaning. Br J Infect Contr. 2007;8:17–21
MäATPbioluminescence Uni-LiteâNG luminometer[1]	500	Healthcare	No significance	Sherlock O. Is it really clean? An evaluation of the efficacy of four methods for determining hospital cleanliness. J Hosp Infect. 2009 Jun;72(2):140-6.
3M Clean-Trace ATP System	100 canteen table 150 raw meat preparation table 400 chopping board	University canteen	Significant (r = 0.99)	Osimani, A. Bioluminescence ATP Monitoring for the Routine Assessment of Food Contact Surface Cleanliness in a University Canteen Int. J. Environ. Res. Public Health 2014, 11, 10824-10837 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4211008/
SystemSURE™ ATP - Hygiena	No data	Office space	Significant but no specific value provided RLU/PFU (MS-2 phage)	Sifuentes, L. et al. Use of ATP Readings to Predict a Successful Hygiene Intervention in the Workplace to Reduce the Spread of Viruses on Fomites. Food and Environmental Virology volume 9, pages14–19. 2017 https://link.springer.com/content/pdf/10.1007/s12560-016-9256-2.pdf

What do these methods detect?

	Bioluminescence	**Microbial colony count**	**PCR**
Principle	Adenosine Triphosphate (ATP) is present in all living material and is the universal unit of energy used in all living cells. Viruses do not exhibit the characteristics of life while outside cells, and are generally NOT considered to have ATP in the virion unless it is a small amount of contaminating material from the cell incorporated during	Microbial growth in specific media, may or may not pick up organisms being used/grown in the area, based on the media, incubation temperature, etc. Generally, it is not considered efficacious for free virions outside of cells. This technique does not detect viruses.	Small segments of target microbial DNA are amplified and detected by specific probes that release a signal. In the case of SARS-CoV-2, RNA is amplified by reverse transcriptase PCR (RT-PCR).

	viral assembly or egress from the cell.[2]		
Units	Relative light units	Colony forming units	NA
Common application of this technology	Hospital infection control to evaluate cleaning efficacy	Clean room manufacturing to evaluate cleaning efficacy	Diagnostic testing for a specific virus
What does it measure	Residual ATP from living organic matter, including microbes or cells present in blood, urine, feces	Specific microbe (i.e. aerobic bacteria)	Presence of organism-specific **segment** of DNA or RNA from a sample. This does not detect the presence of other organisms.
What does it mean?	Presence of organic matter live or residual, does not detect viruses.	Bioburden, will not detect virus, only some bacteria and some fungi	The presence of a specific RNA/DNA is detected, may be from a viable or non-viable organism
Turn around result	Minutes	Days	Hours
When should it be used?	After cleaning a surface and before sanitizing	Usually used to monitor environmental contamination during manufacturing process	Presence of a specific infectious organism (as a diagnostic test) for which the genetic sequence is known because it required design of target specific primers
Factors that affect the result and limitations	• Collection of the sample with swab • Time between collection of the swab and reading • Cannot distinguish microbial **ATP** from other live-source **ATP** left behind after cleaning (e.g. shed cells from the cleaner) • May be affected adversely by residual disinfectants[3] • Type of microbe: may not detect viruses[4]	• Contamination of swab with another surface • Type of media, incubation temperatures • Use of swabs vs. touch plates	• Poor collection • Poor handling • Will detect nucleic acids from live and dead organisms • Contamination during testing • Use of antibiotics • Use of specialized equipment such as a thermocycler

Application to SARS-CoV-2 cleaning regimens (non-health-care situations)	Neither of these testing methods will detect SARS-CoV-2 virus directly. They are only useful as an indicator of relative bioburden from the testing site.	If a SARS-CoV-2 PCR test is run, it may be able to detect virus, but it cannot distinguish between viable and non-viable virus. Testing reagents, swabs and supplies are not readily available and successful testing is very technique dependent.

Considerations for monitoring efficiency of disinfection practices:

1. Training and SOPs for cleaning and disinfecting
2. Visual audit and record keeping of areas cleaned
3. Provide feedback to environmental services (personnel doing the cleaning and disinfection) as soon as possible[5]
4. If a monitoring system will be implemented, consider the following points when developing the plan:
    - What is the goal of the monitoring system (Detection of any live microorganism? Detection of a specific microorganism? Use of a micro-organism as a surrogate for overall cleaning efficacy?)
    - Does the monitoring system detect non-viable as well as viable microorganisms? Is there a particular microbe to be tested for (i.e. SARS-CoV-2)
    - What is the baseline for the area to be cleaned? What are you expecting to see as far as reduction in numbers after cleaning? What will your results mean?
    - Who conducts the monitoring?
    - Validation of the system and reagents should be conducted before implementation
    - Train personnel
    - Ensure that there is a written standardized method for cleaning and disinfection
    - Determine how often the monitoring will be conducted
    - Use the PDCA method (Plan, Do, Check, Act) to evaluate the efficiency (how well surfaces are cleaned) and efficacy (cleaners and disinfectants used) of cleaning and disinfection
5. Maintain and enforce other intervention measures to decrease transmission such as hand hygiene, cough etiquette, frequent wiping of high-touch surfaces

Key to Abbreviations:

ATP – adenosine triphosphate

CFU – colony forming units

RNA -- ribonucleic acid

SOP – standard operating procedure

PCR – polymerase chain reaction

PFU – plaque forming units

RT PCR – reverse transcriptase polymerase chain reaction

PDCA – plan, do, check, act method

RLU – relative light units

DNA – deoxyribonucleic acid

References:

1. Nante N, et al. Effectiveness of ATP bioluminescence to assess hospital cleaning: a review. *J Prev Med Hyg*. 2017;58(2):E177-E183. [Modified Table 2] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5584088/

2. Vancouver Coastal Health. Infection Prevention & Control. ATP BIOLUMINESCENCE TESTING: FREQUENTLY ASKED QUESTIONS. 15 August 2018. http://ipac.vch.ca/Documents/Cleaning%20and%20Disinfection/What%20is%20ATP.pdf

3. Turner D E, et al. Efficacy and Limitations of an ATP-Based Monitoring System. *J Am Assoc Lab Anim Sci*. 2010 Mar; 49(2): 190–195.

" https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2846007/

4. Omidbakhsh N, Ahmadpour F, Kenny N (2014) How Reliable Are ATP Bioluminescence Meters in Assessing Decontamination of Environmental Surfaces in Healthcare Settings?. PLOS ONE 9(6): 99951. https://doi.org/10.1371/journal.pone.0099951 https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0099951&type=printable

5. Doll, M. et al. Environmental cleaning and disinfection of patient areas, International Journal of Infectious Diseases, Volume 67, 2018, Pages 52-57,https://www.sciencedirect.com/science/article/pii/S1201971217302709

Additional resources:

Millipore Sigma, **ATP Testing & Sanitation:** https://www.sigmaaldrich.com/technical-documents/articles/microbiology/mvp-icon/atp-testing-and-sanitation.html

Food Quality & Safety. **5 Things *Not* to Do With ATP Monitoring**. 25 July 2019 https://www.foodqualityandsafety.com/article/atp-monitoring-what-not-to-do/