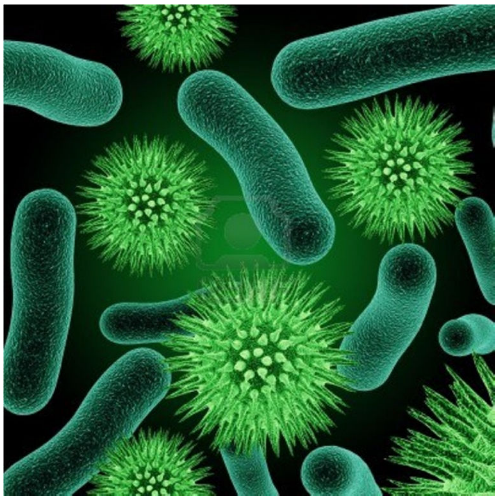

10 Reasons Why Pulsed Light Is Selected as an Antimicrobial Process

#1- Powerful Sterilization Agent

Due to high peak power pulses, > 1 kW/cm^2, and broad spectrum, 100 – 1100 nm, pulsed ultraviolet (UV) light technology is effective in the treatment of all known virus, bacteria and fungi. Pulsed light is a rapid physical process, that causes a molecular rearrangement of the genetic material, known as the DNA, of the microorganism. The effects of pulsed UV light on microbial cells can be classified as photochemical (e.g. thymine-thymine dimer formation in microbial DNA), photothermal (localized heating of bacteria), and photophysical (constant disturbance caused by the high energy pulses) effects. Because it kills DNA and inactivates microorganisms, including fungal yeasts and molds, rickettsiae, and mycoplasma, it is classified as a sterilization agent.[1]

#2- Environmentally Friendly

Pulsed light surface disinfection process is nonthermal, dry and without chemicals. It is a viable alternative to thermal or harsh chemical processing. It does not produce by-products, toxins, or volatile organic compound emissions. Flashlamps are mercury-free and do not pose a hazard to workers in the event of breakage.

#3- Approved for Use with Food Processing

In 1996, the U.S. Food and Drug Administration (FDA)[2] concluded there are no human safety concerns associated with the sale of food treated by pulsed light during the production, processing and handling of foods.

#4- Fits Perfectly into Process Requirements

Pulsed light can be used as a simple, fast and reliable method in continuous operation in filling plants. Applications include the food production industry as well as pharmaceutical and cosmetics industry to disinfect packaging materials prior to filling. This method of surface disinfection can be integrated into equipment wherever bacteria and viruses need to be inactivated rapidly, safely and economically.

#5- Low Temperature Process

Lower temperatures are achieved with pulsed light, helping to improve the integrity of the product being treated. Minimum temperature buildup occurs because the short, microsecond duration pulses reduce the time for heat buildup. Pulsed lamps do not operate at the extreme high temperature required to vaporize mercury in lamps used in continuous UV-C systems. Pulsed light lamps are turned completely ON/OFF in microseconds, reducing any thermal component completely during non-treatment times.

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[1] Different pathogens have unique resistance to pulsed light. Each requires a correct dose to completely deactivate. Dose, or fluence, is determined by pulse light intensity (J/cm^2) over exposure time (microseconds).

[2] Food and Drug Administration; 1999. Code 21CFR179.41 "Pulsed Light for the treatment of food".

#6- Reliable Technology

Commercial Pulsed Light systems are operating today in applications such as controlling hospital acquired infections, barrier isolation and disinfection of bottle caps and food packaging. These systems normally are validated to achieve a 3-6 log kill to meet most application regulatory requirements.[3]

#7- Highest Germicidal Power

Pulsed light xenon lamps provide a rich UV spectrum in addition to wavelengths greater than the traditional monochromatic 254 nm supplied by low pressure mercury lamps. Studies have shown emissions that fall outside the traditional 250 to 280 nm germicidal regain also contribute to disinfection efficiency as well as a reduced treatment time when compared to low pressure mercury vapor lamps.[4]

#8- Minimum Use of Energy

Pulsed light technology offers easily controlled process parameters that minimize energy consumption and ease of maintenance. Lamps are applied with almost instant ON/OFF control in contrast to the continuous ON operation of mercury vapor lamps. Mercury lamps require a warm up and cool down cycle, resulting in the use of energy and time.

#9- Extensive Testing Undertaken by Researchers

The use of xenon-gas flashlamps generating intense, short pulses of ultraviolet light for microbial inactivation, started during the late 1970s in Japan. Since that time, global University and Research Institutions have undertaken numerous studies demonstrating high intensity pulsed light as a means for treating air, wastewater, food, food contact surfaces, non-opaque liquids and packaging material. The use of XENON's research system has resulted in the availability of extensive data (refer to appendix) supporting the efficacy of pulsed light for microbial decontamination.[5]

#10- Individualized Solutions

Commercial and industrial pulsed light equipment is available in compact, modular designs for installation and operation in both existing and new manufacturing lines. Responding to specialized equipment requirements is a hallmark of XENON Corporation, with a history of working closely with industry partners in creating custom-engineered solutions. Pulse light sterilization in the Healthcare, Medical Device, Dairy, Pharmaceutical, Food Processing and Bottle/Beverage Industries is expected to increase as health and safety concerns grow due to microbial contamination.

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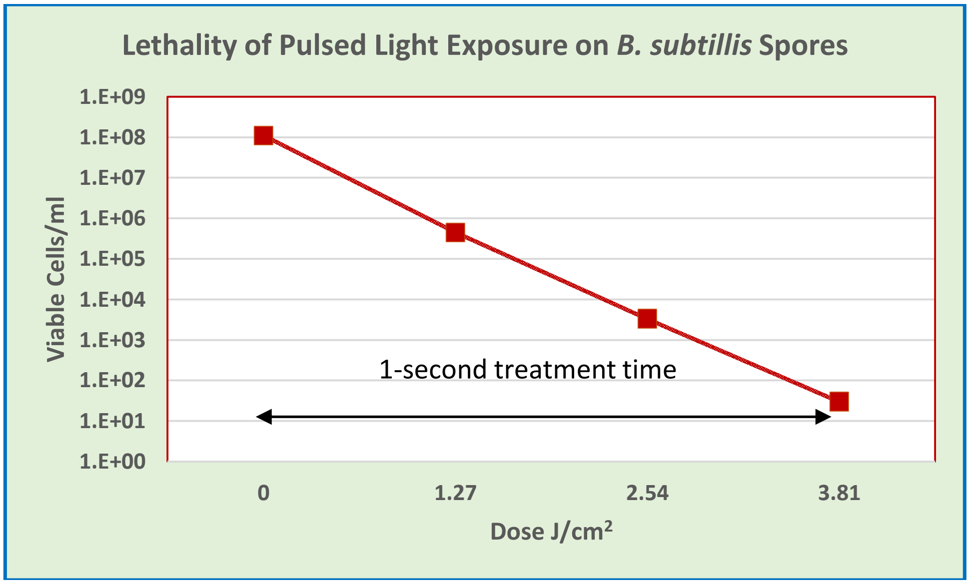
[3] Pulsed light is a surface treatment and the decontaminated areas are those which receive the light pulses. The effects of shadows due to the shapes of the surfaces treated limit the technology. In addition, factors such the dose response of the particular microorganism will determine log reduction.

[4] **Bohrevora, Z., Shemer, H., Lantis, R., Impellitteri, C.A., and Linden, K.G**., "Comparative Disinfection Efficiency of Pulsed and Continuous-Wave UV Irradiation Technologies". Water Research 42, 2975-2982

[5] **Gema, O.O, and Belloso, O.M.,** "Pulsed Light Treatments for Food Preservation, A Review", Food Biopress Technol, DOI 10.1007/s11947-008-0147x.

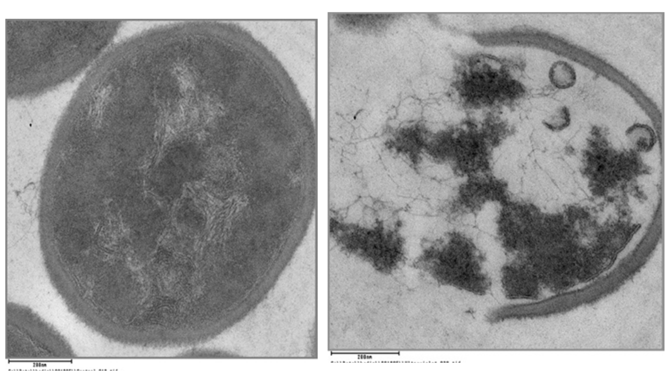
Appendix

I - Achieving > 6 log_{10} cfu/ml reduction of *B. subtilis* spores[6]



Example of exposing exposing *B. subtilis* spores to consecutive light pulses achieving a > 6 $\log_{10}$ cfu/ml reduction (99.9999%) after a 1,080 µs, 3.8 J/cm^2 dose exposure. A suspension of 1.1 x 10^8 spores/ml was exposed to three, 360 µs duration pulses, each with a radiant energy of 1.27 J/cm^2, spaced 333 ms apart – a 1-second treatment time. XENON's Z-1000 system was used in this study of microbial deactivation.

II - *Staphyloccus aureus* cells treated with Pulsed Light Exposure[7]



Intact Cell - Before Cell Wall Damage – After

Photophysical Inactivation: Krishnamurthy et al., 2009

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[6] **Sonenshein, A.L**., "Killing of Bacillus Spores by High Intensity Ultraviolet Light", Dept. of Molecular Biology and Microbiology, Tufts University School of Medicine, 2006, study commission by XENON Corporation.

[7] **Krishnamurthy, K**., "Shedding Light on Food Safety, Applications of Light-based Technologies". IFT15 Conference, 2015, Institute of Food Technologies

III- Selected Publications and Proceedings Using XENON's Pulsed Light Systems at various Universities.

a. ***Krishnamurthy, K., Demirci, A., and Irudayaraj, J. M.***, "*Staphylococcus aureus* Inactivation Using Pulsed UV light for Continuous Milk Treatment", ASAE International Meeting Presentation, paper 056151, 2005, Tampa, FL.

b. ***Woodling, S.E., and Moraru, C.I***., "Effect of Spectral Range in Surface Inactivation of *Listeria innocua* Using Broad-Spectrum Pulsed Light", Journal of Food Protection, Vol. 70, No. 4, 2007, 909-916

c. ***Bialka, K.L., Demirci, A., and Puri, V.M.,*** "Modeling the inactivation of *Escherichia coli* O157:H7 and *Salmonella enterica* on raspberries and strawberries resulting from exposure to ozone or pulsed UV-light", Journal Food Eng. 85 (2008), 444-449

d. ***Demirci, A. and Panico, L***., "Pulsed Ultraviolet Light", Food Sci. Technol Int., 14(5), 443-446.

e. ***Chung, S. –Y., Yang, W., and Krishnamurthy, K***., "Effects of Pulsed UV-Light on Peanut Allergens in Extracts and Liquid Peanut Butter", Journal of Food Science, Vol. 73, Nr. 5, 2008

f. ***Keklik, N. M., Demirci, A., and Puri, V. M***., "Decontamination of Chicken Frankfurters with Pulsed UV-Light" ASABE International Meeting, paper No. 095973, 2009, Reno, NV.

g. ***Keklik, N.M., Demirci, A., Patterson, P.H. and Puri, V.M.,*** "Pulsed UV Light Inactivation of *Salmonella Enteritidis* on Eggshells and Its Effects on Egg Quality", Journal of Food Protection, Vol. 73, No. 8, 2010,1408-1415

h. ***Proulx, J., Hsu, L.C., Miller, B.M., Sullivan, G., Paradis K. and Moraru C.I***., "Pulsed-light Inactivation of Pathogenic and Spoilage Bacteria on Cheese Surface", Journal of Dairy Sci. Vol. 98, No. 9, 2015.

i. ***Manzocco, L., Maifreni, Anese, M., Munari, M., Bartolomeoli, I., Zanardi, S., Suman, M. and Nicoli, M.C.***, "Effect of Pulsed Light on Safety and Quality of Fresh Egg Pasta", Food Biopress Technol (2014) 7:1973-1980

j. ***Uslu, G., Demirci, A. and Regan, J.M.***, "Efficacy of Pulsed UV-Light Treatment on Wastewater Effluent Disinfection and Suspended Solid Reduction". Journal Environ. Eng., Nov. 2014

k. ***Montgomery, N.L. and Banerjee, P***., "Inactivation of *Escherichia coli* O157:H7 and *Listeria monocytogenes* in biofilms by pulsed ultraviolet light, BMC Res. Notes 8:235, 2015

l. ***Woodling, S.E., and Moraru, C.I***., "Influence of Surface Topography on the Effectiveness of Pulsed Light Treatment for the Inactivation of *Listeria innocura* on Stainless-steel Surfaces", Journal of Food Science, Vol. 70, No. 7: M345-M351, 2005

m. ***Bialka, K.L., Demirci, A., Walker, P.N. and Puri, V.M.,*** "Pulsed UV-Light Penetration of Characterization and the Inactivation of *Escherichia Coli* K121 in Solid Model Systems", ASABE, Vol. 51(1):195-204, 2008

n. ***Pataro, G., Donsi, G. and Ferrari, G.,*** "Post-harvest UV-C and PL Irradiation of Fruits and Vegetables", Chem. Eng. Trans., vol. 44, 2015

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