

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

In re Patent of: S. Edward Neister  
U.S. Patent No.: 11,246,951 Attorney Docket No. 00012-0216IP1  
Issue Date: February 15, 2022  
Appl. Serial No.: 15/645,480  
Filing Date: July 10, 2017  
Title: METHOD AND APPARATUS FOR STERILIZING AND  
DISINFECTING AIR AND SURFACES AND PROTECTING A  
ZONE FROM EXTERNAL MICROBIAL CONTAMINATION

**DECLARATION OF JUNE ANN MUNFORD**

1. My name is June Ann Munford. I am over the age of 18, have personal knowledge of the facts set forth herein, and am competent to testify to the same.

2. I earned a Master of Library and Information Science (MLIS) from the University of Wisconsin-Milwaukee in 2009. I have over ten years of experience in the library/information science field. Beginning in 2004, I have served in various positions in the public library sector including Assistant Librarian, Youth Services Librarian and Library Director. I have attached my Curriculum Vitae as Appendix CV.

3. During my career in the library profession, I have been responsible for materials acquisition for multiple libraries. In that position, I have cataloged, purchased and processed incoming library works. That includes purchasing materials directly from vendors, recording publishing data from the material in question, creating detailed material records for library catalogs and physically preparing that material for circulation. In addition to my experience in acquisitions, I was also responsible for analyzing large collections of library materials, tailoring library records for optimal catalog search performance and creating lending agreements between libraries during my time as a Library Director.

4. I am fully familiar with the catalog record creation process in the library sector. In preparing a material for public availability, a library catalog

record describing that material would be created. These records are typically written in Machine Readable Catalog (herein referred to as “MARC”) code and contain information such as a physical description of the material, metadata from the material’s publisher, and date of library acquisition. In particular, the 008 field of the MARC record is reserved for denoting the date of creation of the library record itself. As this typically occurs during the process of preparing materials for public access, it is my experience that an item’s MARC record indicates the date of an item’s public availability.

5. Typically, in creating a MARC record, a librarian would gather various bits of metadata such as book title, publisher and subject headings among others and assign each value to a relevant numerical field. For example, a book’s physical description is tracked in field 300 while title/attribution is tracked in field 245. The 008 field of the MARC record is reserved for denoting the creation of the library record itself. As this is the only date reflecting the inclusion of said materials within the library’s collection, it is my experience that an item’s 008 field accurately indicates the date of an item’s public availability.

6. I have reviewed Exhibit 1022, “Standardization of Methods for Fluence (UV Dose) Determination in Bench-Scale UV Experiments” by James R. Bolton and Karl G. Linden as published in *Journal of Environmental Engineering*, March 2003.

7. Attached hereto as Appendix BOLTON01 is a true and correct copy of the MARC record for *Journal of Environmental Engineering* as held by the Linda Hall Library. I secured this record myself from the library's public catalog. The MARC record contained within Appendix BOLTON01 accurately describes the title, author, publisher, and ISSN number of *Journal of Environmental Engineering*. The 'Locations' field of this record visible on page 2 indicates this collection includes the March 2003 edition of *Journal of Environmental Engineering* containing "Standardization of Methods for Fluence (UV Dose) Determination in Bench-Scale UV Experiments". In comparing Exhibit 1022 to Appendix BOLTON01, it is my determination that Exhibit 1022 is a true and correct copy of "Standardization of Methods for Fluence (UV Dose) Determination in Bench-Scale UV Experiments" by James R. Bolton and Karl G. Linden as published in *Journal of Environmental Engineering* March 2003.

8. The 008 field of the MARC record in Appendix BOLTON01 indicates the date of record creation. The 008 field of Appendix BOLTON01 indicates the Linda Hall Library first acquired this journal as of October 10, 1982 and held the journal in perpetuity until 2013. Considering this information, it is my determination that *Journal of Environmental Engineering* March 2003 and therefore "Standardization of Methods for Fluence (UV Dose) Determination in

Bench-Scale UV Experiments” was made available to the public shortly after its initial release in March 2003.

9. I have reviewed Exhibit 1020, “High-Intensity Sources of Incoherent UV and VUV Excimer Radiation for Low-Temperature Materials Processing” by U. Kogelschatz, H. Esrom, J.-Y. Zhang and I.W. Boyd as published in *Applied Surface Science*, December 2000.

10. Attached hereto as Appendix KOGELSCHATZ01 is a true and correct copy of the MARC record for *Applied Surface Science* as held by the Linda Hall Library. I secured this record myself from the library’s public catalog. The MARC record contained within Appendix KOGELSCHATZ01 accurately describes the title, author, publisher, and ISSN number of *Applied Surface Science*. The ‘Locations’ field of this record visible on page 2 indicates this collection includes the December 2000 edition of *Applied Surface Science* containing “High-Intensity Sources of Incoherent UV and VUV Excimer Radiation for Low-Temperature Materials Processing”. In comparing Exhibit 1022 to Appendix KOGELSCHATZ01, it is my determination that Exhibit 1022 is a true and correct copy of “High-Intensity Sources of Incoherent UV and VUV Excimer Radiation for Low-Temperature Materials Processing” by U. Kogelschatz, H. Esrom, J.-Y. Zhang and I.W. Boyd as published in *Applied Surface Science* December 2000.

11. The 008 field of the MARC record in Appendix KOGELSCHATZ01 indicates the date of record creation. The 008 field of Appendix KOGELSCHATZ01 indicates the Linda Hall Library first acquired this journal as of September 26, 1985 and held the journal in perpetuity until 2016. Considering this information, it is my determination that *Applied Surface Science* December 2000 and therefore “High-Intensity Sources of Incoherent UV and VUV Excimer Radiation for Low-Temperature Materials Processing” was made available to the public shortly after its initial release in December 2000.

12. I have reviewed Exhibit 1021, *Molecular Cell Biology* by Harvey Lodish, Arnold Berk, S. Lawrence Zipursky, Paul Matsudaira and James Darnell, 4<sup>th</sup> edition.

13. Attached hereto as Appendix LODISH01 is a true and correct copy of the MARC record for *Molecular Cell Biology* as held by the University of Pennsylvania - Franklin library. I secured this record myself from the library’s public catalog. The MARC record contained within Appendix LODISH01 accurately describes the title, author, publisher, and ISBN number of *Molecular Cell Biology*. In comparing Exhibit 1021 to Appendix LODISH01, it is my determination that Exhibit 1021 is a true and correct copy of *Molecular Cell Biology* by Harvey Lodish, Arnold Berk, S. Lawrence Zipursky, Paul Matsudaira and James Darnell.

14. The 008 field of the MARC record in Appendix LODISH01 indicates the date of record creation. The 008 field of Appendix LODISH01 indicates University of Pennsylvania - Franklin library first acquired this book as of April 20, 1999. Considering this information, it is my determination that *Molecular Cell Biology* was made available to the public shortly after its initial acquisition in April 1999.

15. I have reviewed Exhibit 1017, “Ultraviolet Light C in Treatment of Chronic Wounds with MRSA: A Case Study” by Thao P. Thai, Pamela E. Houghton, David H. Keast, Karen E. Campbell and M. Gail Woodbury as published in *Ostomy/Wound Management*, November 2002.

16. Attached hereto as Appendix THAI01 is a true and correct copy of the MARC record for *Ostomy/Wound Management* as held by the University of Michigan library. I secured this record myself from the library’s public catalog. The MARC record contained within Appendix THAI01 accurately describes the title, author, publisher, and ISSN number of *Ostomy/Wound Management*. The ‘Available at’ field of this record visible on page 2 indicates this collection includes the November 2002 edition of *Ostomy/Wound Management* containing “Ultraviolet Light C in Treatment of Chronic Wounds with MRSA: A Case Study”. In comparing Exhibit 1017 to Appendix THAI01, it is my determination that Exhibit 1017 is a true and correct copy of “Ultraviolet Light C in Treatment of

Chronic Wounds with MRSA: A Case Study” by Thao P Thai, Pamela E. Houghton, David H. Keast, Karen E. Campbell and M. Gail Woodbury as published in *Ostomy/Wound Management* November 2002.

17. The 008 field of the MARC record in Appendix THAI01 indicates the date of record creation. The 008 field of Appendix THAI01 indicates the University of Michigan library first acquired this journal as of January 29, 2001 - and held the journal in perpetuity until 2008. Considering this information, it is my determination that *Ostomy/Wound Management* November 2002 and therefore “Ultraviolet Light C in Treatment of Chronic Wounds with MRSA: A Case Study” was made available to the public shortly after its initial release in November 2002.

18. I have reviewed Exhibit 1037, “The Effects of UV Irradiation and Gas Plasma Treatment on Living Mammalian Cells and Bacteria” by Edward A. Sosnin, Eva Stoffels, Michael V. Erofeev, Ingrid E. Kift and Sergey E. Kunts as published in *IEEE Transactions on Plasma Science*, August 2004.

19. Attached hereto as Appendix SOSNIN01 is a true and correct copy of the MARC record for *IEEE Transactions on Plasma Science* as held by the Carnegie Library of Pittsburgh. I secured this record myself from the library’s public catalog. The MARC record contained within Appendix SOSNIN01 accurately describes the title, author, publisher, and ISSN number of *IEEE Transactions on Plasma Science*. The ‘Lib Has’ field of this record visible on page

2 indicates this collection includes the August 2004 edition of *IEEE Transactions on Plasma Science* containing “The Effects of UV Irradiation and Gas Plasma Treatment on Living Mammalian Cells and Bacteria”.

20. Attached hereto as Appendix SOSNIN02 is a true and correct copy of “The Effects of UV Irradiation and Gas Plasma Treatment on Living Mammalian Cells and Bacteria” as published in *IEEE Transactions on Plasma Science* as held by the Carnegie Library of Pittsburgh. I secured these scans myself from the library’s collection. In comparing Exhibit 1037 to Appendix SOSNIN02, it is my determination that Exhibit 1037 is a true and correct copy of “The Effects of UV Irradiation and Gas Plasma Treatment on Living Mammalian Cells and Bacteria” by Edward A. Sosnin, Eva Stoffels, Michael V. Erofeev, Ingrid E. Kift and Sergey E. Kunts as published in *IEEE Transactions on Plasma Science* August 2004.

21. The 008 field of the MARC record in Appendix SOSNIN01 indicates the date of record creation. The 008 field of Appendix SOSNIN01 indicates the Carnegie Library of Pittsburgh first acquired this journal as of May 14, 1974 and held the journal in perpetuity until 2009. Considering this information, it is my determination that *IEEE Transactions on Plasma Science* August 2004 and therefore “The Effects of UV Irradiation and Gas Plasma Treatment on Living Mammalian Cells and Bacteria” was made available to the public shortly after its initial release in August 2004.

22. I have reviewed Exhibit 1039, “Disinfection by Free Radicals and UV-Radiation” by C. von Sonntag as published in *Water Supply*, vol. 4 (1986).

23. Attached hereto as Appendix VONSONNTAG01 is a true and correct copy of the MARC record for *Water Supply* as held by the Cornell University library. I secured this record myself from the library’s public catalog. The MARC record contained within Appendix VONSONNTAG01 accurately describes the title, author, publisher, and ISSN number of *Water Supply*. The ‘Availability’ field of this record visible on page 3 indicates this collection includes the vol. 4 (1986) edition of *Water Supply* containing “Disinfection by Free Radicals and UV-Radiation”. In comparing Exhibit 1039 to Appendix VONSONNTAG01, it is my determination that Exhibit 1039 is a true and correct copy of “Disinfection by Free Radicals and UV-Radiation” by C. von Sonntag as published in *Water Supply* vol. 4 (1986).

24. The 008 field of the MARC record in Appendix VONSONNTAG01 indicates the date of record creation. The 008 field of Appendix VONSONNTAG01 indicates the Cornell University library first acquired this journal as of October 13, 1983 and held the journal in perpetuity until 2000. Considering this information, it is my determination that *Water Supply* vol. 4 (1986) and therefore “Disinfection by Free Radicals and UV-Radiation” was made available to the public shortly after its initial release in 1986.

25. I have reviewed Exhibit 1040, “A Study of the Bactericidal Action of Ultra Violet Light” by F.L. Gates as published in *The Journal of General Physiology*, November 1929.

26. Attached hereto as Appendix GATES01 is a true and correct copy of the MARC record for *The Journal of General Physiology* as held by the University of Akron library. I secured this record myself from the library’s public catalog. The MARC record contained within Appendix GATES01 accurately describes the title, author, publisher, and ISSN number of *The Journal of General Physiology*. The ‘Lib Has’ field of this record visible on page 3 indicates this collection includes the November 1929 edition of *The Journal of General Physiology* containing “A Study of the Bactericidal Action of Ultra Violet Light”. In comparing Exhibit 1040 to Appendix GATES01, it is my determination that Exhibit 1040 is a true and correct copy of “A Study of the Bactericidal Action of Ultra Violet Light” by F.L. Gates as published in *The Journal of General Physiology* November 1929.

27. The 008 field of the MARC record in Appendix GATES01 indicates the date of record creation. The 008 field of Appendix GATES01 indicates the University of Akron library first acquired this journal as of June 13, 1975. Considering this information, it is my determination that *The Journal of General Physiology* November 1929 and therefore “A Study of the Bactericidal Action of Ultra Violet Light” was made available to the public shortly after its initial

acquisition in June 1975 and likely earlier due to the work's original publication date.

28. I have reviewed Exhibit 1005, "A New Bacterial UV Light Sources - Excilamps" by Edward A. Sosnin, Larisa V. Lavrent'eva, Mikhail V. Erofeev, Yana V. Masterova, Eugenia N. Kuznetzova and Victor F. Tarasenko as published in *Proceedings of SPIE Vol. 5483 – Atomic and Molecular Pulsed Lasers V*.

29. Attached hereto as Appendix SOSNIN03 is a true and correct copy of the MARC record for *Proceedings of SPIE Vol. 5483 – Atomic and Molecular Pulsed Lasers V* as held by the Penn State University library. I secured this record myself from the library's public catalog. The MARC record contained within Appendix SOSNIN03 accurately describes the title, author, publisher, and ISBN number of *Proceedings of SPIE Vol. 5483 – Atomic and Molecular Pulsed Lasers V*.

30. Attached hereto as Appendix SOSNIN04 is a true and correct copy of "A New Bacterial UV Light Sources - Excilamps" as published in *Proceedings of SPIE Vol. 5483 – Atomic and Molecular Pulsed Lasers V* as held by the Penn State University library. I secured this file myself from the library's collection. In comparing Exhibit 1005 to Appendix SOSNIN04, it is my determination that Exhibit 1005 is a true and correct copy of "A New Bacterial UV Light Sources - Excilamps" as published in *Proceedings of SPIE Vol. 5483 – Atomic and*

*Molecular Pulsed Lasers V* by Edward A. Sosnin, Larisa V. Lavrent'eva, Mikhail V. Erofeev, Yana V. Masterova, Eugenia N. Kuznetzova and Victor F. Tarasenko.

31. The 008 field of the MARC record in Appendix SOSNIN03 indicates the date of record creation. The 008 field of Appendix SOSNIN03 indicates the Penn State University library first acquired these proceedings as of July 24, 2004. Considering this information, it is my determination that *Proceedings of SPIE Vol. 5483 – Atomic and Molecular Pulsed Lasers V* and therefore “A New Bacterial UV Light Sources - Excilamps” was made available to the public shortly after its initial acquisition in July 24, 2004.

32. I have reviewed Exhibit 1006, *A Recommended Standard for Occupational Exposure to Ultraviolet Radiation* by the National Institute for Occupational Safety & Health.

33. Attached hereto as Appendix NIOSH01 is a true and correct copy of the MARC record for *A Recommended Standard for Occupational Exposure to Ultraviolet Radiation* as held by the Penn State University library. I secured this record myself from the library's public catalog. The MARC record contained within Appendix NIOSH01 accurately describes the title, author, publisher, and ISBN number of *A Recommended Standard for Occupational Exposure to Ultraviolet Radiation*.

34. Attached hereto as Appendix NIOSH02 is a true and correct copy of *A Recommended Standard for Occupational Exposure to Ultraviolet Radiation* as held by the Penn State University library. I secured these scans myself from the library's collection. In comparing Exhibit 1006 to Appendix NIOSH02, it is my determination that Exhibit 1006 is a true and correct copy of *A Recommended Standard for Occupational Exposure to Ultraviolet Radiation* by The National Institute for Occupational Safety & Health.

35. The 008 field of the MARC record in Appendix NIOSH01 indicates the date of record creation. The 008 field of Appendix NIOSH01 indicates Penn State University library first acquired this book as of February 11, 1993. Considering this information, it is my determination that *A Recommended Standard for Occupational Exposure to Ultraviolet Radiation* was made available to the public shortly after its initial acquisition in February 1993.

36. I have reviewed Exhibit 1007, *Health and the Environmental Effects of Ultraviolet Radiation: A Summary of Environmental Health Criteria 160 Ultraviolet Radiation* by the World Health Organization.

37. Attached hereto as Appendix WHO01 is a true and correct copy of the MARC record for *Health and the Environmental Effects of Ultraviolet Radiation: A Summary of Environmental Health Criteria 160 Ultraviolet Radiation* as held by the National Library of Medicine. I secured this record myself from the library's

public catalog. The MARC record contained within Appendix WHO01 accurately describes the title, author, publisher, and ISBN number of *Health and the Environmental Effects of Ultraviolet Radiation: A Summary of Environmental Health Criteria 160 Ultraviolet Radiation*. In comparing Exhibit 1007 to Appendix WHO01, it is my determination that Exhibit 1007 is a true and correct copy of *Health and the Environmental Effects of Ultraviolet Radiation: A Summary of Environmental Health Criteria 160 Ultraviolet Radiation* by the World Health Organization.

38. The 008 field of the MARC record in Appendix WHO01 indicates the date of record creation. The 008 field of Appendix WHO01 indicates the National Library of Medicine first acquired this document as of June 20, 1996. Considering this information, it is my determination that *Health and the Environmental Effects of Ultraviolet Radiation: A Summary of Environmental Health Criteria 160 Ultraviolet Radiation* was made available to the public shortly after its initial acquisition in June 1996.

39. I have been retained on behalf of the Petitioners to provide assistance in the above-illustrated matter in establishing the authenticity and public availability of the documents discussed in this declaration. I am being compensated for my services in this matter at the rate of \$100.00 per hour plus reasonable

expenses. My statements are objective, and my compensation does not depend on the outcome of this matter.

40. I declare under penalty of perjury that the foregoing is true and correct. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Dated: 3/8/2023

A handwritten signature in black ink, appearing to read "June Ann Munford", written in a cursive style.

June Ann Munford

## **APPENDIX CV**

J. Munford  
Curriculum Vitae

## **Education**

University of Wisconsin-Milwaukee - MS, Library & Information Science, 2009  
Milwaukee, WI

- Coursework included cataloging, metadata, data analysis, library systems, management strategies and collection development.
- Specialized in library advocacy, cataloging and public administration.

Grand Valley State University - BA, English Language & Literature, 2008  
Allendale, MI

- Coursework included linguistics, documentation and literary analysis.
- Minor in political science with a focus in local-level economics and government.

## **Professional Experience**

Researcher / Expert Witness, October 2017 – present  
Freelance ● Pittsburgh, Pennsylvania & Grand Rapids, Michigan

- Material authentication and public accessibility determination. Declarations of authenticity and/or public accessibility provided upon research completion. Experienced with appeals and deposition process.
- Research provided on topics of public library operations, material publication history, digital database services and legacy web resources.
- Past clients include Alston & Bird, Arnold & Porter, Baker Botts, Fish & Richardson, Erise IP, Irell & Manella, O'Melveny & Myers, Perkins-Coie, Pillsbury Winthrop Shaw Pittman and Slayden Grubert Beard.

Library Director, February 2013 - March 2015  
Dowagiac District Library ● Dowagiac, Michigan

- Executive administrator of the Dowagiac District Library. Located in

Southwest Michigan, this library has a service area of 13,000, an annual operating budget of over \$400,000 and total assets of approximately \$1,300,000.

- Developed careful budgeting guidelines to produce a 15% surplus during the 2013-2014 & 2014-2015 fiscal years while being audited.
- Using this budget surplus, oversaw significant library investments including the purchase of property for a future building site, demolition of existing buildings and building renovation projects on the current facility.
- Led the organization and digitization of the library's archival records.
- Served as the public representative for the library, developing business relationships with local school, museum and tribal government entities.
- Developed an objective-based analysis system for measuring library services - including a full collection analysis of the library's 50,000+ circulating items and their records.

November 2010 - January 2013

Librarian & Branch Manager, Anchorage Public Library ● Anchorage, Alaska

- Headed the 2013 Anchorage Reads community reading campaign including event planning, staging public performances and creating marketing materials for mass distribution.
- Co-led the social media department of the library's marketing team, drafting social media guidelines, creating original content and instituting long-term planning via content calendars.
- Developed business relationships with The Boys & Girls Club, Anchorage School District and the US Army to establish summer reading programs for children.

June 2004 - September 2005, September 2006 - October 2013

Library Assistant, Hart Area Public Library  
Hart, MI

- Responsible for verifying imported MARC records and original MARC

cataloging for the local-level collection as well as the Michigan Electronic Library.

- Handled OCLC Worldcat interlibrary loan requests & fulfillment via ongoing communication with lending libraries.

## **Professional Involvement**

Alaska Library Association - Anchorage Chapter

- Treasurer, 2012

Library Of Michigan

- Level VII Certification, 2008
- Level II Certification, 2013

Michigan Library Association Annual Conference 2014

- New Directors Conference Panel Member

Southwest Michigan Library Cooperative

- Represented the Dowagiac District Library, 2013-2015

## **Professional Development**

Library Of Michigan Beginning Workshop, May 2008

Petoskey, MI

- Received training in cataloging, local history, collection management, children's literacy and reference service.

Public Library Association Intensive Library Management Training, October 2011

Nashville, TN

- Attended a five-day workshop focused on strategic planning, staff management, statistical analysis, collections and cataloging theory.

Alaska Library Association Annual Conference 2012 - Fairbanks, February 2012

Fairbanks, AK

- Attended seminars on EBSCO advanced search methods, budgeting, cataloging, database usage and marketing.

## **Depositions**

2019 • Fish & Richardson

IPR Petitions of 865 Patent, Apple v. Qualcomm (IPR2018-001281 / 39521-00421IP & IPR2018-01282 / 39521-00421IP2)

2019 • Erise IP

Implicit, LLC v. Netscout Systems, Inc (Civil Action No. 2:18-cv-53-JRG)

2019 • Perkins-Coie

Adobe Inc. v. RAH Color Technologies LLC (Cases IPR2019-00627, IPR2019-00628, IPR2019-00629 and IPR2019-00646)

2020 • O'Melveny & Myers

Maxell, Ltd. v. Apple Inc. (Case 5:19-cv-00036-RWS)

2021 • Pillsbury Winthrop Shaw Pittman LLP

Intel v. SRC (Case IPR2020-1449)

## **Limited Case History & Potential Conflicts**

Alston & Bird

- Nokia (v. Neptune Subsea, Xtera)

Arnold & Porter

- Ivantis (v. Glaukos)

Erise I.P.

- Apple

v. Future Link Systems (IPRs 6317804, 6622108, 6807505, and 7917680)

v. INVT

v. Navblazer LLC (Case No. IPR2020-01253)

v. Qualcomm (IPR2018-001281, 39521-00421IP, IPR2018-01282, 39521-00421IP2)

v. Quest Nettech Corp, Wynn Technologies (Case No. IPR2019-00XXX, RE. Patent Re38137)

- Fanduel (v CGT)
- Garmin (v. Phillips North America LLC, Case No. 2:19-cv-6301-AB-KS Central District of California)
- Netscout
  - v. Longhorn HD LLC)
  - v. Implicit, LLC (Civil Action No. 2:18-cv-53-JRG)
- Sony Interactive Entertainment LLC
  - v. Bot M8 LLC
  - v. Infernal Technology LLC
- Unified Patents (v GE Video Compression, Civil Action No. 2:19-cv-248)

#### Fish & Richardson

- Apple
  - v. LBS Innovations
  - v. Masimo (IPR 50095-0012IP1, 50095-0012IP2, 50095-0013IP1, 50095-0013IP2, 50095-0006IP1)
  - v. Neonode
  - v. Qualcomm (IPR2018-001281, 39521-00421IP, IPR2018-01282, 39521-00421IP2)
- Dish Network
  - v. Realtime Adaptive Streaming, Case No 1:17-CV-02097-RBJ)

v. TQ Delta LLC

- Huawei (IPR 76933211)
- Kianxis
- LG Electronics (v. Bell Northern Research LLC, Case No. 3:18-cv-2864-CAB-BLM)
- Metaswitch
- MLC Intellectual Property (v. MicronTech, Case No. 3:14-cv-03657-SI)
- Realtek Semiconductor
- Quectel
- Samsung (v. Bell Northern Research, Civil Action No. 2:19-cv-00286-JRG)
- Texas Instruments

Irell & Manella

- Curium

O'Melveny & Myers

- Apple (v. Maxell, Case 5:19-cv-00036-RWS)

Perkins-Coie

- TCL Industries (v. Koninklijke Philips NV, PTAB Case Nos. IPR2021-00495, IPR2021-00496, and IPR2021-00497)

Pillsbury Winthrop Shaw Pittman

- Intel (v. FG SRC LLC, Case No. 6:20-cv-00315 W.D. Tex)

## **APPENDIX BOLTON01**

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leader 03459cas a2200709 a 4500
001 992756363405961
005 20201123165946.0
008 820810c19839999nyubr1p 0 a0eng d
010 ##$a 84641507 $zsn 82005938
012 ##$a3 $b3 $i8405 $k1 $l1 $m1
022 0#$a0733-9372
030 ##$aJOEEDU
032 ##$a285140 $bUSPS
035 ##$a(OCOLC)8675387
035 ##$a(Horizon)381740
035 ##$a(MoKL)275636-lhalldb
035 ##$a(lhalldb)275636-lhalldb
037 ##$bAmerican Society of Civil Engineers, 345 E. 47th St., New York, NY 10017
040 ##$aNSD $cNSD $dNST $dNSD $dOCL $dNST $dIXA $dSER $dDLC $dNST $dAIP $dNST $dAIP $dDLC $dAIP $dNST $dAIP $dNST $dAIP $dOCL $dIUL $dNST $dAIP
042 ##$ansdp $alc
049 ##$aLHLA
050 00$aTD1 $b.A32
069 1#$aJ20062000
082 0#$a628/.05 $219
130 0#$aJournal of environmental engineering (New York, N.Y.)
210 0#$aJ. environ. eng. $b(New York, N.Y.)
222 #0$aJournal of environmental engineering $b(New York, N.Y.)
245 10$aJournal of environmental engineering.
246 10$aA.S.C.E. environmental engineering
246 18$aASCE environmental engineering
260 ##$aNew York, N.Y. : $bAmerican Society of Civil Engineers, Environmental Engineering Division, $cc1983-
310 ##$aBimonthly
362 0#$aVol. 109, no. 1 (Feb. 1983)-
510 0#$aBibliography of agriculture $x0006-1530 $bVol. 112, no. 1, 1986.
510 1#$aApplied science & technology index $x0003-6986
510 1#$aASCE annual combined index $x0742-1753 $b1983-
510 1#$aASCE publications information $x0734-1962 $b1983-
510 1#$aTransactions of the American Society of Civil Engineers $x0066-0604 $b1983-
510 2#$aAbstract bulletin of the Institute of Paper Chemistry $x0020-3033
510 2#$aCanadian Environment
510 2#$aChemical abstracts $x0009-2258 $b1983-
510 2#$aCoal abstracts $x0309-4979
510 2#$aEnergy research abstracts $bFeb. 1983- $x0160-3604
510 2#$aExcerpta medica
510 2#$aFLUIDEX $b1983-
510 2#$aGeoRef $x0197-7482
510 2#$aLife sciences collection
510 2#$aSelected water resources abstracts $x0037-136X
562 ##$aTitle received on deposit; do not claim as of 9.10.2010.
599 11$aSelected volumes/issues transferred from the Engineering Societies Library, January 1995.
650 #0$aEnvironmental engineering $vPeriodicals
650 #0$aSanitary engineering $vPeriodicals
710 2#$aAmerican Society of Civil Engineers. $bEnvironmental Engineering Division
780 00$aAmerican Society of Civil Engineers. Environmental Engineering Division. $tJournal of the Environmental Engineering Division $x0090-3914
850 ##$aAAP $aAU $aArU $aAzU $aCLSU $aCSt $aCU $aCU-A $aCU-I $aCU-RivA $aCU-S $aCU-SB $aCaAEU $aCaMWU $aCaOLU $aCaOPAL $aCaOTU $aCaOWA $aCaSSU $
890 ##$aJournal of environmental engineering (New York, N.Y.)
901 ##$cSer
936 ##$aDec. 1984
945 ##$bJournal of environmental engineering.
948 ##$aLTI 09/01/2008
948 ##$aLTI 04/14/2009
948 ##$aLTI 10/19/2010

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Search anything



Advanced Search

All items ▾that contain my query words ▾anywhere in the record ▾

For optimum display, please use Chrome or Firefox. Safari users may not be able to see all the relevant information.



JOURNAL

Journal of environmental engineering (New York, N.Y.)

American Society of Civil Engineers. Environmental Engineering Division

c1983-

Available at Linda Hall Library Closed Stacks - Serials (Journal of environmental engineering.) and other locations

Top

Send to

Email

Permalink

Citation

EasyBib

Export RIS

Export to Excel

Top

Send to

Get It

Details

Virtual Browse

Links

Get It

LOCATIONS

Linda Hall Library

Available , Closed Stacks - Serials ; Journal of environmental engineering.

Holdings: v.109(1983)-v.139;no.12(2013:Dec.)-

Note: Annual index in last issue of year.

Go to Location Items

Linda Hall Library

Available , Closed Stacks - Compact Storage Microfilm

Holdings: Vol. 109 (1983) - Vol. 128 (2002)

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Other title

Creator/Contributor

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Journal of environmental engineering (New York, N.Y.)

Journal of environmental engineering (New York, N.Y.)

J. environ. eng. (New York, N.Y.)

Journal of environmental engineering (New York, N.Y.)

A.S.C.E. environmental engineering

ASCE environmental engineering

American Society of Civil Engineers. Environmental Engineering Division

Environmental engineering -- Periodicals

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ISSN : 0733-9372

OCLC : (OCoLC)8675387

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Publisher

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Frequency

Citation/References note

Earlier title : [American Society of Civil Engineers. Environmental Engineering Division. Journal of the Environmental Engineering Division](#)

New York, N.Y. : American Society of Civil Engineers, Environmental Engineering Division  
Vol. 109, no. 1 (Feb. 1983)-

c1983-

Bimonthly

Bibliography of agriculture 0006-1530 Vol. 112, no. 1, 1986.  
Applied science & technology index 0003-6986  
ASCE annual combined index 0742-1753 1983-  
ASCE publications information 0734-1962 1983-  
Transactions of the American Society of Civil Engineers 0066-0604 1983-  
Abstract bulletin of the Institute of Paper Chemistry 0020-3033  
Canadian Environment  
Chemical abstracts 0009-2258 1983-  
Coal abstracts 0309-4979  
Energy research abstracts Feb. 1983- 0160-3604  
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Journal of environmental engineering (New York, N.Y.) ...

c1983-

Journal of environmental engineering (New York, N.Y.) ...

c1983-

Journal of environmental health. ...

1963

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## **APPENDIX KOGELSCHATZ01**

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222 #0$aApplied surface science
245 00$aApplied surface science.
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300 ##$av. : $bill. ; $c24 cm.
310 ##$a18 no. a year, $b<Mar. 1, 1993->
321 ##$aBimonthly, $bJune/July 1985-
321 ##$aMonthly, $b<Dec. 1991->
362 0#$aVol. 24, no. 1 (June/July 1985)-
500 ##$a"A journal devoted to the properties of interfaces in relation to the synthesis and the behaviour of materials."
500 ##$aEditors: 1985- L.C. Feldman, W.F. van der Weg.
506 ##$aAlso available online
510 2#$aChemical abstracts $x0009-2258 $b1985-
510 2#$aComputer & control abstracts $x0036-8113 $b1985-
510 2#$aElectrical & electronics abstracts $x0036-8105 $b1985-
510 2#$aPhysics abstracts. Science abstracts. Series A $x0036-8091 $b1985-
555 0#$aIndex: 21-30(1985-87)(incl. earlier title) bound with vol. 30 and index to every ten volumes thereafter bound with last volume covered.
590 ##$aSelected volumes/issues gift of Aerospace Corporation.
650 #0$aSurfaces (Technology) $vPeriodicals.
650 #0$aSurfaces (Physics) $vPeriodicals.
700 1#$aFeldman, Leonard C.
700 1#$aWeg, W. F. van der.
780 00$tApplications of surface science $x0378-5963 $w(OCOLC) 3525005 $w(DLC) 78644118
850 ##$aAAP $aArU $aAzU $aCLSU $aCPT $aCSt $aCU $aCU-A $aCU-I $aCU-RivP $aCU-S $aCU-SB $aCaOLU $aCaOTU $aCaOWtU $aCaQMU $aCoFS $aCoU $aCtU $aCtW
890 ##$aApplied surface science.
901 ##$cSer
936 ##$aVol. 64, no. 3 (Mar. 1, 1991) surrogate LIC
945 ##$aApplied surface science. $bApplied surface science.
948 ##$aLTI 04/26/2017

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Feldman, Leonard C.; Weg, W. F. van der.  
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Indexes: Vol. 111-180 (1997)...

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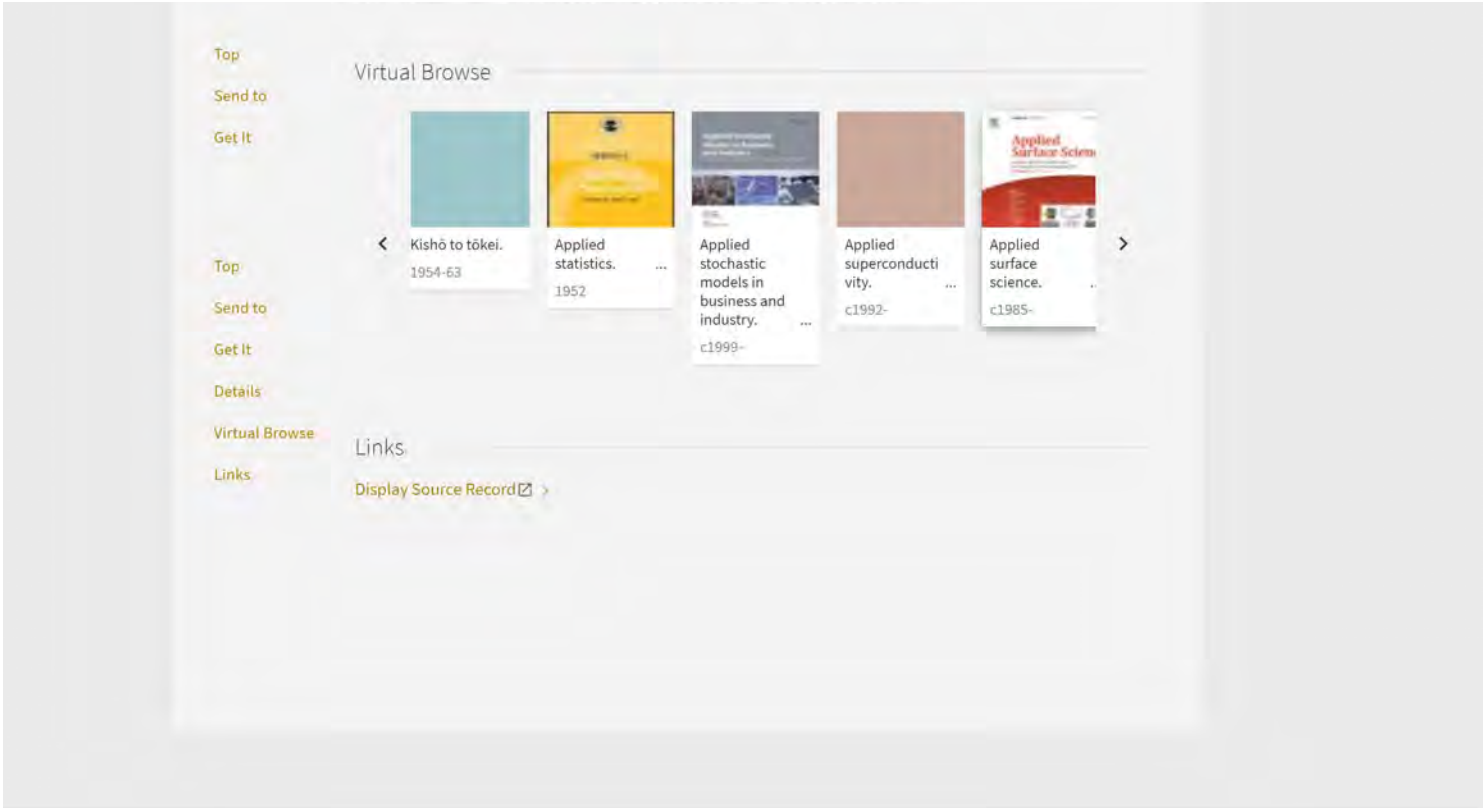
Holdings: Vol. 169-170 (2001)...

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Details

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|-----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Title                       | Applied surface science                                                                                                                                                                                    |
| Other title                 | Appl. surf. sci.<br>Applied surface science                                                                                                                                                                |
| Creator/Contributor         | Feldman, Leonard C. ><br>Weg, W. F. van der. >                                                                                                                                                             |
| Subjects                    | Surfaces (Technology) -- Periodicals ><br>Surfaces (Physics) -- Periodicals >                                                                                                                              |
| Identifier                  | ISSN : 0169-4332<br>OCLC : (OCoLC)12605690                                                                                                                                                                 |
| Related title               | Earlier title : Applications of surface science >                                                                                                                                                          |
| Publisher                   | Amsterdam ; New York : North-Holland<br>Vol. 24, no. 1 (June/July 1985)-                                                                                                                                   |
| Creation date               | c1985-                                                                                                                                                                                                     |
| Format                      | v. : ill. ; 24 cm.                                                                                                                                                                                         |
| Frequency                   | 18 no. a year, <Mar. 1, 1993->                                                                                                                                                                             |
| General notes               | "A journal devoted to the properties of interfaces in relation to the synthesis and the behaviour of materials."<br>Editors: 1985- L.C. Feldman, W.F. van der Weg.                                         |
| Restrictions on access note | Also available online                                                                                                                                                                                      |
| Citation/References note    | Chemical abstracts 0009-2258 1985-<br>Computer & control abstracts 0036-8113 1985-<br>Electrical & electronics abstracts 0036-8105 1985-<br>Physics abstracts. Science abstracts. Series A 0036-8091 1985- |
| Local notes                 | Selected volumes/issues gift of Aerospace Corporation.                                                                                                                                                     |



## **APPENDIX LODISH01**




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040 a| DLC b| eng c| DLC d| DLC

050 0 0 a| QH581.2 b| .M655 2000

050 4 a| QH581.2 b| .D37 2000

082 0 0 a| 571.6 2| 21

245 0 0 a| Molecular cell biology / c| Harvey Lodish ... [and others].

250 a| Fourth edition.

264 1 a| New York : b| W.H. Freeman, c| [2000]

264 4 c| ©2000

300 a| 1 volume (various pagings) : b| illustrations (some color); c| 29 cm + e| 1 computer laser optical disc (4 3/4 in.)

336 a| text b| txt 2| rdacontent

337 a| unmediated b| n 2| rdamedia

338 a| volume b| nc 2| rdacarrier

500 a| Second edition's main entry under the heading for Darnell.

504 a| Includes bibliographical references and index.

505 0 0 g| Part I t| Chemical and Molecular Foundations -- g| 1 t| Life Begins with Cells -- g| 2 t| Chemical Foundations -- g| 3 t| Protein Structure and Function -- g| Part II t| Genetics and Molecular Biology -- g| 4 t| Basic Molecular Genetic Mechanisms -- g| 5 t| Molecular Genetic Techniques -- g| 6 t| Genes, Genomics, and Chromosomes -- g| 7 t| Transcriptional Control of Gene Expression -- g| 8 t| Post-transcriptional Gene Control -- g| Part III t| Cell Structure and Function -- g| 9 t| Visualizing, Fractionating, and Culturing Cells -- g| 10 t| Biomembrane Structure -- g| 11 t| Transmembrane Transport of Ions and Small Molecules -- g| 12 t| Cellular Energetics -- g| 13 t| Moving Proteins into Membranes and Organelles -- g| 14 t| Vesicular Traffic, Secretion, and Endocytosis -- g| 15 t| Cell Signaling I: Signal Transduction and Short-term Cellular Responses -- g| 16 t| Cell Signaling II: Signaling Pathways that Control Gene Activity -- g| 17 t| Cell Organization and Movement I: Microfilaments -- g| 18 t| Cell Organization and Movement II: Microtubules and Intermediate Filaments -- g| 19 t| Integrating Cells into Tissues -- g| Part IV t| Cell Growth and Development -- g| 20 t| Regulating the Eukaryotic Cell Cycle -- g| 21 t| Cell Birth, Lineage, and Death -- g| 22 t| The Molecular Cell Biology of Development -- g| 23 t| Nerve Cells -- g| 24 t| Immunology -- g| 25 t| Cancer.

538 a| System requirements for accompanying computer disc: IBM PC or compatible computer; Pentium processor or equivalent; 24 MB RAM; 6 MB of free hard disk space; color monitor capable of displaying 16-bit at 640 x 480 pixels (minimum); 4x cd-rom drive or faster; Apple's QuickTime for Windows version 4.0 or later.

590 a| Acquired for the Penn Libraries with assistance from the Class of 1924 Book Fund.

650 0 a| Cytology. 0| <http://id.loc.gov/authorities/subjects/sh85035240>

650 7 a| Cytology. 2| fast 0| <http://id.worldcat.org/fast/886282>

650 0 a| Molecular biology. 0| <http://id.loc.gov/authorities/subjects/sh85086577>

650 7 a| Molecular biology. 2| fast 0| <http://id.worldcat.org/fast/1024734>

650 2 a| Cell Biology. 0| <https://id.nlm.nih.gov/mesh/D003585>

650 2 a| Molecular Biology. 0| <https://id.nlm.nih.gov/mesh/D008967>

700 1 a| Lodish, Harvey F. 0| <http://id.loc.gov/authorities/names/n85363874>

700 1 a| Darnell, James E. 0| <http://id.loc.gov/authorities/names/n85363997>

710 2 a| Class of 1924 Book Fund. 5| PU

856 4 2 3| The Class of 1924 Book Fund Home Page u| <http://hdl.library.upenn.edu/1017.12/366301>

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998 s| 9110

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## Molecular cell biology / Harvey Lodish ... [and others].

Publication: New York : W.H. Freeman, [2000]

Format/Description: Book  
1 volume (various pagings) : illustrations (some color); 29 cm + 1 computer laser optical disc (4 3/4 in.)

Edition: Fourth edition.

Status/Location:

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| <b>Available</b>   | Holman Biotech Commons Oversize QH581.2 .D37 2000 - 1 v. + disc -       |
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| <b>Available</b>   | Levy Dental Medicine Library - Stacks QH581.2 .D37 2000 - disc -        |
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Medical subjects: [Cell Biology.](#)  
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Contents: Part I Chemical and Molecular Foundations  
1 Life Begins with Cells  
2 Chemical Foundations  
3 Protein Structure and Function  
Part II Genetics and Molecular Biology  
4 Basic Molecular Genetic Mechanisms  
5 Molecular Genetic Techniques  
6 Genes, Genomics, and Chromosomes  
7 Transcriptional Control of Gene Expression  
8 Post-transcriptional Gene Control  
Part III Cell Structure and Function  
9 Visualizing, Fractionating, and Culturing Cells  
10 Biomembrane Structure  
11 Transmembrane Transport of Ions and Small Molecules  
12 Cellular Energetics  
13 Moving Proteins into Membranes and Organelles  
14 Vesicular Traffic, Secretion, and Endocytosis  
15 Cell Signaling, Signal Transduction, and Short-term Cellular Responses

15 Cell Signaling I: Signal Transduction and Short-term Cellular Responses  
16 Cell Signaling II: Signaling Pathways that Control Gene Activity  
17 Cell Organization and Movement I: Microfilaments  
18 Cell Organization and Movement II: Microtubules and Intermediate Filaments  
19 Integrating Cells into Tissues  
Part IV Cell Growth and Development  
20 Regulating the Eukaryotic Cell Cycle  
21 Cell Birth, Lineage, and Death  
22 The Molecular Cell Biology of Development  
23 Nerve Cells  
24 Immunology  
25 Cancer.

Notes: Second edition's main entry under the heading for Darnell.  
Includes bibliographical references and index.

Local notes: Acquired for the Penn Libraries with assistance from the Class of 1924 Book Fund.

Contributor: [Lodish, Harvey F.](#)  
[Darnell, James E.](#)  
[Class of 1924 Book Fund.](#)

ISBN: 0716731363

OCLC: 41266312

Web link: [The Class of 1924 Book Fund Home Page](#)



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☐ **Ostomy/wound management.**

**Record info:**

|                               |                                                                                                          |
|-------------------------------|----------------------------------------------------------------------------------------------------------|
| Format                        | <input checked="" type="checkbox"/> Serial<br><input type="checkbox"/> Journal                           |
| Other Titles                  | <a href="#">Ostomy wound management</a>                                                                  |
| Previous Title                | <a href="#">Ostomy management</a>                                                                        |
| Previous Title ISSN           | 0274-7944                                                                                                |
| Published/Created             | [King of Prussia, Pa. : Health Management Publications, 1980s (exact date unknown)]                      |
| Language                      | English                                                                                                  |
| Current Publication Frequency | Quarterly                                                                                                |
| Numbering                     | One issue per v.                                                                                         |
| Peculiarities Note            |                                                                                                          |
| Note                          | Description based on: Vol. 11 (summer 1986); title from cover.                                           |
| Physical Description          | v. : ill., ports.                                                                                        |
| ISSN                          | 0889-5899                                                                                                |
| OCLC Number                   | 14088884                                                                                                 |
| Subjects (Other)              | <a href="#">Ostomy -- periodicals.</a><br><a href="#">Wounds and Injuries -- therapy -- periodicals.</a> |

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| 222 | 0   | a Ostomy/wound management                                                                                                                                                                           |
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| 246 | 1 0 | a Ostomy wound management                                                                                                                                                                           |
| 260 |     | a [King of Prussia, Pa. :  b Health Management Publications,                                                                                                                                        |
| 300 |     | a v. :  b ill., ports.                                                                                                                                                                              |
| 310 |     | a Quarterly                                                                                                                                                                                         |
| 500 |     | a Description based on: Vol. 11 (summer 1986); title from cover.                                                                                                                                    |
| 515 |     | a One issue per v.                                                                                                                                                                                  |
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| 650 | 2   | a Wounds and Injuries  x therapy  x periodicals.<br> 0 http://id.nlm.nih.gov/mesh/D014947                                                                                                           |
| 780 | 0 0 | t Ostomy management  x 0274-7944  w (DLC)sn 80001515                                                                                                                                                |
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| 959 |     | a (notis)FLBAD4937                                                                                                                                                                                  |
| 995 |     | a 20                                                                                                                                                                                                |
| 998 |     | c djh                                                                                                                                                                                               |
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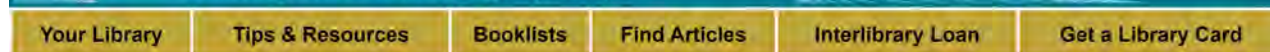
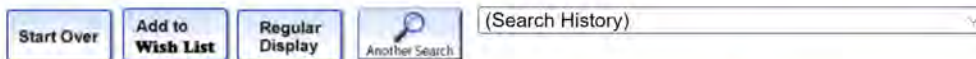
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PART II OF THREE PARTS

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# The Effects of UV Irradiation and Gas Plasma Treatment on Living Mammalian Cells and Bacteria: A Comparative Approach

Edward A. Sosnin, Eva Stoffels, Michael V. Erofeev, Ingrid E. Kieft, and Sergey E. Kunts

**Abstract**—Living mammalian cells and bacteria were exposed to irradiation from narrow-band UV lamps and treated with a nonthermal gas plasma (*plasma needle*). The model systems were: *Chinese Hamster Ovary* (CHO-K1) cells (fibroblasts) and *Escherichia Coli* bacteria. UV irradiation can lead to cell death (necrosis) in fibroblasts, but the doses that cause such damage are much higher than those needed to destroy *Escherichia Coli*. The usage of UV radiation in combination with active oxygen radicals lowers the UV dose sufficient to kill the cells. However, in any case the fibroblasts seem to be fairly resistant to UV radiation and/or radicals. Possibly, the lamps may be used for decontamination of infected wounds. The most important active species in an atmospheric plasma are the radicals; the role of UV is less pronounced. Treatment of CHO-K1 cells with the plasma needle can lead to cell necrosis under extreme conditions, but moderate doses cause only a temporary interruption of cell adhesion. Plasma needle may be used for fine tissue treatment (e.g., controlled cell removal without inflammation) and also for bacterial decontamination.

**Index Terms**—Bacterial decontamination, fibroblast cells, plasma treatment, UV radiation.

## I. INTRODUCTION

NONTHERMAL plasmas operate at room or slightly elevated temperatures. Treatment with such plasmas has been demonstrated to be a powerful method of inactivating microorganisms [1]–[5]. Plasma treatment has many advantages in comparison with other bacterial inactivation methods, such as dry heat or hot steam sterilization, irradiation by UV/gamma rays and other techniques [1]. Plasma decontamination is usually fast, efficient, and safe in terms of thermal, chemical, or irradiation damage.

Nonthermal plasmas are easiest to generate under reduced pressures (less than 1 mbar) in specially designed vacuum reactors. In the last decennia, these plasmas found a broad spectrum of applications in material technology. The idea of employing low-pressure plasmas for bacterial inactivation was introduced long ago [2]. Primarily, it was assumed that the key agent in plasma sterilization is the chemistry (highly reactive unstable

species—radicals). However, Soloshenko *et al.* [3] showed that also the 160–220-nm UV radiation plays an important role in low-pressure plasma sterilization.

Nowadays, a general trend has arisen both in material processing and biotechnology: vacuum reactors are often being replaced by atmospheric plasma sources. There are already various principles and designs, which deliver plasmas operating at temperatures not higher than several tens of degrees. Examples include atmospheric jets [5], dielectric barrier discharges [6], and microplasmas [7]. These new developments allow treatment to materials, which can withstand neither high temperature nor low pressure (e.g., biological tissues). Anti-bacterial properties of atmospheric nonthermal plasmas are already well established [4], [5]. The inactivation of microorganisms proceeds faster than at low pressures; it is ascribed to radical interactions with the membrane, while the role of UV is less important [4].

In parallel to plasma sterilization, treatment with UV radiation alone is a subject of extensive investigations [8]–[14]. Effective bacterial inactivation was demonstrated for many kinds of bacteria and viruses; various sources were used and the wavelength dependence was determined [12]–[14]. Furthermore, the synergy of active oxygen radicals and UV was studied [15]. For this purpose, photosensitizers like  $H_2O_2$  were used. This particular molecule produces OH, peroxy, and hydroperoxy radicals upon irradiation. It was shown that the joint action of radicals and photons facilitates bacterial inactivation.

In the mentioned studies, UV and plasma treatment was performed *ex vivo*. One is reluctant to apply these media to living tissues because of the risk of cellular damage by UV [16] and radicals [17]. However, we have noticed that the lethal doses for bacteria are surprisingly low. Therefore, in this paper, we investigate the possibility of *in vivo* treatment, selective bacterial inactivation without harming the cells. For this purpose, one has to establish what doses of UV or plasma exposure can be applied without extensive tissue damage. We study the reaction of living mammalian cells to UV radiation, using narrow-band UV lamps (excilamps) and *Chinese Hamster Ovary* (CHO-K1) cells in culture as a model system. These cells are fibroblasts, a basal cell type, which is involved in many processes, e.g., wound repair. We compare the effects of UV radiation on cells with data on UV bacterial deactivation. Furthermore, the case when irradiated cells are immersed in a hydrogen peroxide solution (a photosensitizer) is considered.

Finally, we present some facts on *in vivo* treatment by means of a novel nonthermal plasma source (the plasma needle [7]). A fundamental study has been undertaken to identify all possible

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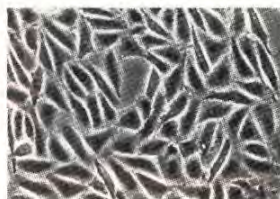


Fig. 1. CHO-K1 cells in culture, used for UV and plasma treatment. Untreated sample. Cells are about 30  $\mu\text{m}$  long.

responses of living objects exposed to the plasma. This may lead to development of new techniques, like disinfection of tissues or removal of cells without inflammatory response, and on a longer time scale to new methods in the health care.

## II. EXPERIMENTAL SETUP

### A. Cell Culture Preparation

CHO-K1 cells were cultured in flasks containing Ham's F-12 medium with stable L-glutamin (Bio Whittaker, Europe) containing 9.0% of Fetal Bovine Serum [(FBS), Biochrom, AG] and 0.45% of Gentamycin (10 mg/ml, Biochrom AG). The cells were stored in an incubator at 37 °C with 5% CO<sub>2</sub>. To prepare samples for UV treatment, the cells were trypsinized (0.05% Trypsin/0.02% EDTA solution in PBS, Biochrom AG) and transferred into Petri dishes. For plasma treatment, the same procedure was followed, but the cells were transferred onto sterilized object glasses (26 × 10 × 1 mm, adapted to fit into the plasma chamber) and placed in multiwell dishes. The cells were incubated for 2 or 3 days, or until nearly confluent (see Fig. 1).

Just before treatment, the medium was removed and the samples were rinsed twice with phosphate buffered saline (PBS). During irradiation or plasma exposure the cells were covered with a thin film of PBS (typically 0.3 mm) in order to prevent them from drying.

### B. Bacterial Sample Preparation

A pure culture of *Escherichia Coli*, belonging to the main species of the enterobacteria group, was used. *E. Coli* is one of the most resistant species within enterobacteria group, so it is frequently used in a study of UV disinfection and sanitation, performed at the Scientific Research Institute of Balneology (Tomsk, Russia). The *E. Coli* was supplied by the American National Academy, and had a series number K12 ATCC 25 922.

The culture of *E. Coli* was supported on beef-extract agar (BEA) and kept at the temperature of 4 °C. The optimal concentration of microbial dredge was found based on the method of multiple dilutions.

### C. Ultraviolet Radiation Sources

Irradiation was performed using two low-pressure capacitive discharge UV lamps developed at Laboratory of Optical Radiation, High Current Electronics Institute, Siberian Branch of the Russian Academy of Science [18]–[22]. These lamps are confined in quartz tubes (38-mm inner diameter and 300-mm-long silica tube with 80% transparency at  $\lambda = 200$  nm). The first of these lamps is a new excimer lamp, filled with Xe and Br<sub>2</sub>

mixture (Type XeBr\_LERA\_5); the active radiating species is XeBr\*. Excimer lamps (or so-called excilamps) are a subclass of electric discharge lamps emitting in UV or vacuum UV spectral ranges. Excilamps provide UV irradiance up to 10 mW/cm<sup>2</sup> and their efficiency is typically 7%–30%. The main feature which distinguishes excilamps from other UV sources is that their spectra consist of narrow bands (the band halfwidth rarely exceeds 5–8 nm). The B→X band emission adds to as much as 80%–90% of the total radiation of excilamp. By varying the composition of the working mixture it is possible to select a required wavelength. Therefore, excilamps are suited to study wavelength-specific effects of UV radiation on various objects, including microorganisms. The XeBr-excilamp employed in our experiments produces a spectrum with an emission peak at  $\lambda \sim 282$  nm and weak D → X and C → A bands. As confirmed in our previous experiments [14], the XeBr-lamp is most efficient in sterilization. This is because the inactivation of bacteria is mainly related to the DNA/RNA damage, and the maximum absorption of DNA and RNA occurs at the photon wavelength between 240 and 300 nm.

The second light source is a low-pressure lamp (Type LLERA\_5) filled with iodine vapor [19]. The Iodine lamp produces a spectrum with a narrow peak of I\* emission at  $\lambda \sim 206$  nm.

### D. Low-Temperature Plasma

A small-size nonthermal plasma (*plasma needle*) has been developed for the purpose of studying plasma interactions with living species [7]. A plasma needle is an atmospheric glow initiated under helium atmosphere by applying radio-frequency (about 10 MHz) electric voltage to a sharp metal pin. The plasma operates under gentle conditions; the voltage needed to sustain the discharge is low (200–400 V peak-to-peak), and the electric power consumption is only 10–300 mW. The size of the glow is 0.1–1 mm. It has been previously established that the gas temperature in the plasma is at most a few degrees above the room temperature. Also, energy fluxes from the plasma have been determined for different operation parameters, using a calibrated probe. The total energy flux (radiation, radical, and ion contribution) ranges from 0 to 2 W/cm<sup>2</sup>. The plasma can be applied to heat-sensitive materials or human skin (see Fig. 3) without any thermal damage or pain sensation. From spectral measurements, it follows that this plasma is a poor UV source. Most of the emission (helium lines, nitrogen, and oxygen bands) lies within the visible range. Some N<sub>2</sub> bands are detected between 300 and 400 nm, no emission can be found below 300 nm (see typical spectra in Fig. 4). Possibly, the plasma could emit radiation in the vacuum UV range (<100 nm, originating from the helium transitions), which we cannot detect using the present equipment. However, these short-wavelength photons cannot propagate outside the plasma; they are efficiently cut off by air and water (absorption coefficient in water is 10<sup>7</sup> m<sup>-1</sup> at 100 nm).

The experimental arrangement for cell treatment is shown in Fig. 5. The chamber was filled with helium at the flow rate of 2 l/min. Flat samples were placed on the bottom of the chamber, where an externally manipulated stage is installed. The distance between the sample surface and the needle tip was adjusted by means of another manipulator.

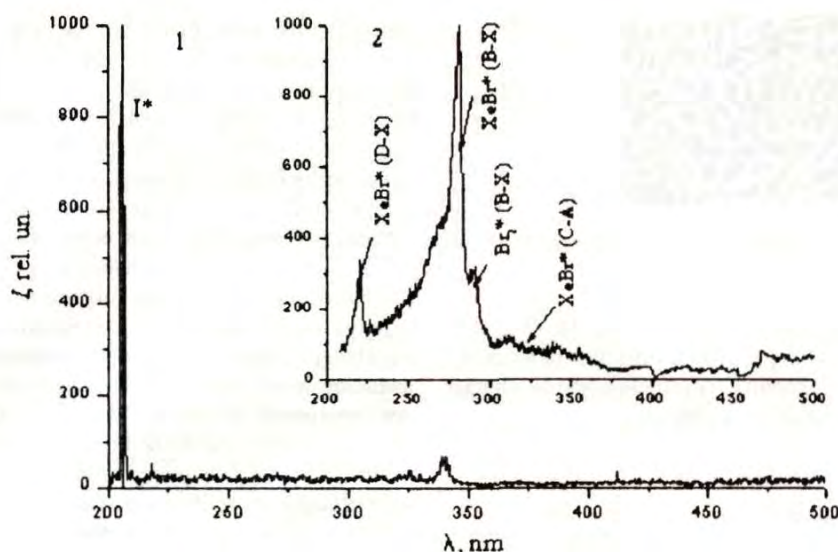


Fig. 2. Emission spectra (range 200–500 nm) from two different UV light sources: (1) iodine lamp and (2) XeBr-excilamp.

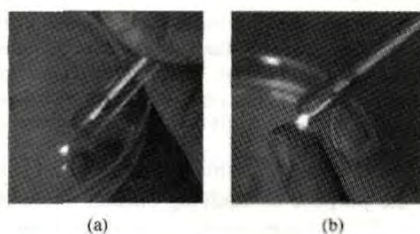


Fig. 3. Plasma needle: plasma is created at the tip of a sharp metal needle. (a) Treatment of cells in culture placed in a Petri dish (for precise positioning another setup was used, see Fig. 5). (b) Glow spreads over the surface of the tissue.

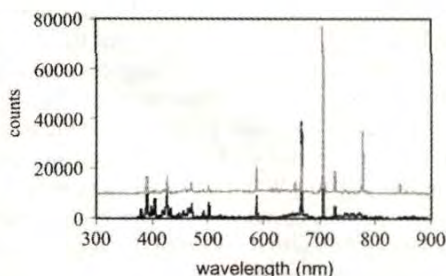


Fig. 4. Typical spectra of the plasma: in pure helium (gray line, given an offset of 10 000 counts) and in a mixture of 90% helium and 10% nitrogen (black line). Latter case, atomic helium lines are suppressed and some  $N_2$  bands emerge below 400 nm.

### E. Sample Treatment

For UV treatment, Petri dishes were placed at a 5.5-cm distance from the UV lamp. At this distance, the heating effect of substrate was minimized, while the irradiance could be sufficiently high. The uniformity in the radiation dose over the surface of the sample was about 10%. UV radiation was dosed by varying the treatment time between 2 and 5 min, while the lamp irradiance was kept constant at  $4 \text{ mW/cm}^2$  for the XeBr lamp and  $3 \text{ mW/cm}^2$  for the I-lamp. All experiments were repeated at least three times.

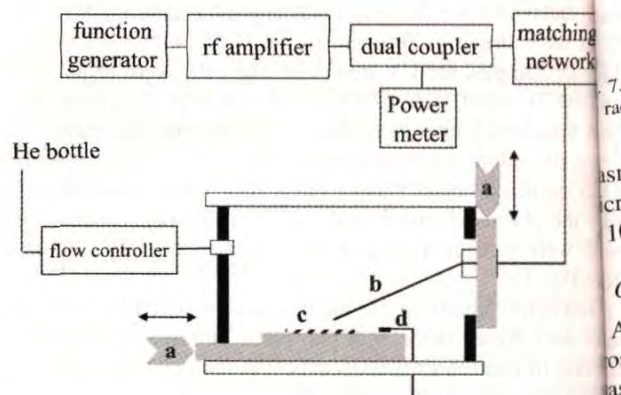


Fig. 5. Experimental arrangement for cell treatment with the plasma needle: rectangular metal/plastic box filled with helium. (a) Manipulators to move the sample and to adjust the needle—sample distance, (b) needle, (c) sample, and (d) thermocouple to control the temperature.

UV treatment of *E. Coli* bacteria was performed in Tomsk Petri dishes with *E. Coli* cultures were irradiated from several seconds to several minutes at a 5-cm distance and at different levels of UV irradiance (up to  $10 \text{ mW/cm}^2$ ). Each exposure was repeated four to five times. For control, several dishes were left not irradiated. The number of survivors was determined by the method of bacterial inoculation in dense media (the Koch method of bacterial inoculation in agarized media in Petri dishes). The inoculations were cultivated at the temperature of  $20^\circ\text{C}$ – $23^\circ\text{C}$ . After 72 h, the number of surviving microorganisms was determined.

During plasma treatment, the object glasses containing the CHO-K1 cells were placed on the moving stage at the bottom of the chamber. A plasma needle was brought to a 1.5-mm distance to the sample; visually, the glow was just touching the surface of the PBS solution. Typical treatment time was 1 min, during which the sample was moved by the manipulator over a typical distance of 1 cm. This produces a typical “track” of

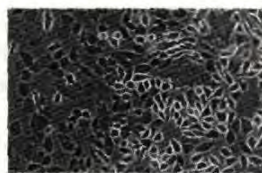


Fig. 6. CHO-K1 sample irradiated by the iodine lamp at  $0.6 \text{ J/cm}^2$ . Most of the cells are necrotic.

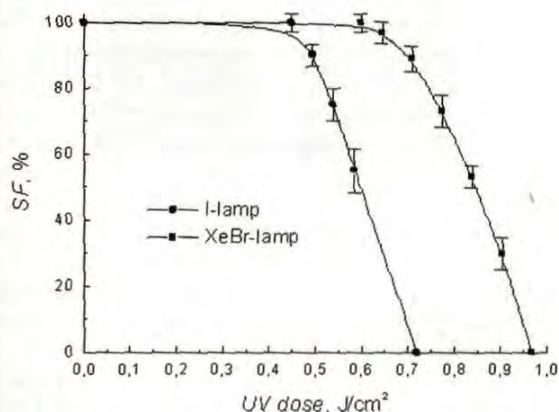


Fig. 7. Survival curve of CHO-K1 after treatment with UVB (■) and UVC (●) radiation. Cells were irradiated at  $37^\circ\text{C}$ .

plasma-treated cells, which can be easily recognized under the microscope. Individual cells on this track were irradiated for 1 to 10 s.

#### F. Observation

After treatment, the samples were observed under a light microscope. Trypan blue (0.5% in physiological saline, Biochrom) was applied in order to distinguish between dead and living cells. Trypan blue penetrates only the cells with membrane leakage (dead cells) and colors the whole cytoplasm blue; the living cells remain colorless. Dead and living cells were counted and the fraction of survivors was determined. The surviving fraction (SF) is defined by  $N/N_0 \cdot 100\%$ , where  $N_0$  is the initial number of cells and  $N$  the number of surviving cells. Mean values were calculated from numbers found in five different places of a Petri dish.

In some cases (mainly after plasma treatment), no trypan blue was applied, but the samples were incubated for several hours in order to study the long-term post-treatment phenomena.

### III. RESULTS AND DISCUSSION

As expected, high UV doses result in cell damage and death by necrosis (rupture of cell membranes). It can be seen in Fig. 6, where a sample treated with the iodine lamp at  $0.6 \text{ J/cm}^2$  and subsequently stained with trypan blue contains a mixture of dead and surviving cells. The dependence of the fraction of SF on the irradiation dose is displayed in Fig. 7. The most striking feature is the presence of a threshold. The process of inactivation begins only after some critical dose of radiation, which is about  $0.5 \text{ J/cm}^2$  for the iodine and  $0.7 \text{ J/cm}^2$  for the XeBr lamp. All cells within the irradiated area are dead when the dose exceeds

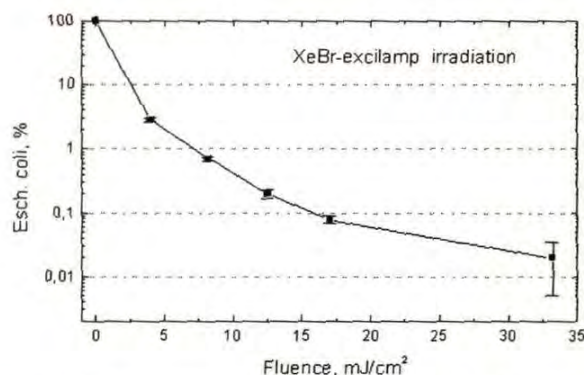


Fig. 8. Survival curve of *Escherichia coli* irradiated with UVB (XeBr-excilamp).

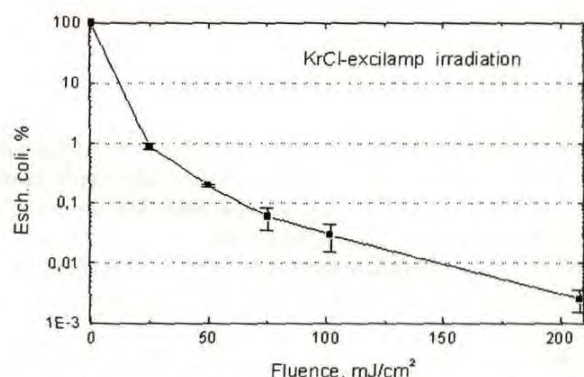


Fig. 9. Survival curve of *Escherichia coli* after irradiation with a KrCl-excilamp (222 nm).

$0.7 \text{ J/cm}^2$  for iodine and  $1 \text{ J/cm}^2$  for XeBr lamp. The UV dose (threshold and lethal dose) is lower for UVC (I-lamp) than for UVB (XeBr lamp). This can be easily understood because absorption of UV radiation by lipids in cell membranes is highest for  $\lambda < 230 \text{ nm}$  [23] and the irradiated power of the iodine lamp lies mainly in this range (Fig. 2).

The presence of the threshold dose for cell deactivation (Fig. 7) makes these results significantly different from the ones obtained for deactivation of *Escherichia Coli* and other bacteria, widely reported in the literature [10]–[15]. For comparison, we include typical bacterial survival curves, resulting from the irradiation of *E. Coli* with XeBr and KrCl ( $\lambda = 222 \text{ nm}$ ) excilamps (both developed in the High Current Electronics Institute, Tomsk). These are given in Figs. 8 and 9, respectively. First of all, one can immediately see that UV doses needed to deactivate *E. Coli* are much lower than the ones that cause necrosis in fibroblasts. Besides, already very low UV doses reduce the bacterial population by two decades. At higher doses, the killing rate is somewhat tempered, and the survival curves display exponential tails. Decontamination to 0.01% of the original population is achieved by UV doses, which are still too low to affect fibroblasts (at least not on the short term, or on a typical time scale of 2 days during which CHO-K1 cells can be maintained in the incubator). This shows that fibroblasts are extremely resistant to UV. Irradiation with UV lamps may become a method of selective bacterial decontamination of wounds without killing the body cells that strive to repair the wound.

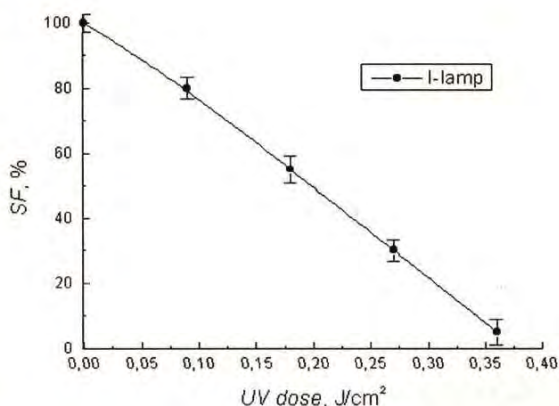


Fig. 10. Survival curve of CHO-K1 after irradiation with the iodine lamp in presence of 3%  $\text{H}_2\text{O}_2$  aqueous solution. Cells were irradiated at 37 °C.

Note that the survival curve of fibroblasts (Fig. 7) does not have an exponential tail. This is most likely because the cell counting after irradiation was done after two-step flushing with PBS solution. In this way, small amounts of alive cells could be flushed away. Besides, we could not apply UV doses much higher than 1 J/cm<sup>2</sup>, because of cell desiccation due to a too long treatment time or heat damage at a too short distance from the lamp.

In order to simulate the conditions characteristic for plasma treatment, it is necessary to supply active radicals simultaneously with UV irradiation. This can be performed using a photosensitizer, such as  $\text{H}_2\text{O}_2$ , which produces reactive oxygen species upon UV irradiation. Possibly, in the current experiment, the conditions were similar to those described by Soloshenko *et al.* [3], who performed effective bacterial inactivation in a low-pressure plasma. However, it is difficult to compare the exact UV doses, because a low-pressure plasma emits also photons with a shorter wavelength (<200 nm). These photons are normally lost by absorption in air at ambient pressure, but they can reach the surface when the sterilized object is surrounded by plasma under low-pressure conditions.

We used radiation with  $\lambda = 206$  nm (I-lamp), which is not efficiently absorbed in air or water. A 3% aqueous  $\text{H}_2\text{O}_2$  solution was applied to the CHO-K1 culture just before irradiation; the layer of fluid was about 1-mm thick. The  $\text{H}_2\text{O}_2$  solution alone (without lamp irradiation) also has some toxic effects on cells, because small amounts of reactive oxygen species are released by decomposition of  $\text{H}_2\text{O}_2$  by ambient light. However, the cells could survive in this environment for several minutes. The UV lamp in Fig. 10 was applied to cell/ $\text{H}_2\text{O}_2$  samples for up to 5 min. The last points, corresponding to long treatment times, may be influenced by natural toxicity of peroxide solution. However, when the UV was applied, we observed a major increase of the killing rate, even at short treatment times. Fig. 10 demonstrates that the usage of  $\text{H}_2\text{O}_2$  together with UVC lowers the lethal radiation dose by a factor of two (compare with Fig. 7). Moreover, there is no threshold in the inactivation curve; the fraction of dead cells increases approximately linearly with increasing UV dose.

Similar studies of the effect of 1%  $\text{H}_2\text{O}_2$  in combination with 254-nm radiation on bacteria were described by other authors

[15]. They reported an efficient reduction of bacterial population; the UV doses needed to inactivate 99.99% of microorganisms were in some cases even ten times lower than in absence of a photosensitizer.

From the above results, it can be concluded that the effect of UV (alone or in combination with active radicals) on fibroblasts is by far not so drastic as on bacteria. The rate of killing cells is much lower than that for *E. Coli* (compare linear scales in Figs. 7 and 10 with logarithmic scales in Figs. 8 and 9), and the cells can withstand relatively large UV and radical doses. However, at present, we cannot decide on possible DNA damage in cells, which have survived the UV treatment. For this purpose, cells should be observed for a long time, and CHO-K1 is not the most suitable cell line for such studies. Furthermore, at present, we cannot decide on the performance of UV lamps in *in vivo* disinfection. For this purpose, more tests must be performed on various kinds of bacteria. The bacterial spores must be investigated, because they may be more resistant to irradiation.

A UV lamp in combination with  $\text{H}_2\text{O}_2$  may be compared to a low-pressure plasma [3], because the latter is a reasonable UV source (after all, the excilamps described here are also based on low-pressure plasmas). In case of the atmospheric plasma needle, the conditions are milder. As stated before, a plasma needle is a poor UV emitter. The plasma-related effects are rather of chemical nature (radicals). It is known that radicals alone are also capable of inactivating bacteria, though not as efficient as in combination with UV. Recently, bacterial inactivation with the plasma needle was performed on *E. Coli* [24]. The reduction of bacterial population by two decades (99%) was achieved within 1–2 min at the power level of about 10 mW. This dose does not cause any reaction in CHO-K1, which again confirms the particularly high sensitivity of *E. Coli* bacteria to UV/plasma treatment. Therefore, we are confident that it is possible to find plasma conditions under which the bacteria are eliminated, but cells remain alive. When higher plasma doses are applied (>10 mW), interesting cell reactions are induced. We shall describe some general features of plasma interactions with CHO-K1 cells.

Plasma treatment of living cells can have many consequences. Naturally, a high dose leads to cell death (necrosis). Typically, necrosis occurs when the plasma power is higher than 0.2 W and the exposure time is longer than 10 s (per treated spot). In terms of energy dose, this corresponds to 20 J/cm<sup>2</sup>, which is very high. However, even upon such harsh treatment the cells are not disintegrated, but they retain their shape and internal structure (see Fig. 11).

When the power and treatment time were substantially reduced (to 50 mW and 1 s per spot), no necrosis was observed. The cells remained negative to trypan blue. In Fig. 12, it can be seen that the cells (partly) detach from the sample surface. Characteristic voids are created in the sheet of cells [Fig. 12(a)]. The partly detached cells assume a rounded shape [Fig. 12(b)]. Careful observation of treated samples showed that detachment is not an instantaneous reaction; it can occur within seconds or even up to 1 min after treatment. Viability of detached (rounded) cells was studied using assays described elsewhere [25]. Here, we can state that the interruption of cell adhesion is a temporary effect. The cells remain unharmed and after several (2 to



Fig. 11. Necrotic cells after treatment with the plasma needle at 0.3 W. These cells are stained with trypan blue (the membranes are damaged).

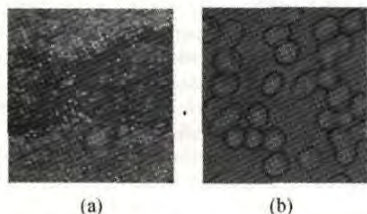


Fig. 12. Treatment of CHO-K1 cells by the plasma needle at low power (50 mW) results in cell detachment. (a) Plasma-treated spot (track) in the sample, with a typical void resulting from cell detachment. (b) Close-up of the edge of the treated area, partly detached cells. When cell adhesion is interrupted, they assume a rounded shape (not spread over the surface like in Fig. 1). This situation is temporary; the contact between cells is restored within several hours.

4) hours the attachment is restored. It seems that plasma treatment induces a temporary disturbance in the cell metabolism, which is expressed (among others) by loss of adhesion. The reactive agent, responsible for this behavior has not been identified yet. It was checked that radio-frequency electric fields and static electricity do not induce such effects. Detachment is most likely caused by plasma species, which are in direct contact with the cell (under PBS solution). The role of active radicals cannot be ruled out. However, these are probably not the oxygen species created in photosensitized UV treatment with  $H_2O_2$ , because in the latter case no cell detachment was observed. In the near future, we shall investigate whether positive ions from the plasma can trigger this specific cell reaction.

Cell detachment without severe damage is a refined way of cell manipulation. The loosened cells can be removed from a tissue, but as they are still alive, no inflammatory response should be induced. The area of plasma action is always well defined; the influenced cells are strictly localized and the borders between affected and unaffected zones are very sharp. This demonstrates the locality and precision of plasma treatment.

#### IV. CONCLUSION

The effect of UVB and UVC radiation on CHO-K1 cells in culture was studied. These cells are fibroblasts, a cell type that is important in tissue repair. The UV radiation was supplied by two novel lamps, which are characterized by a narrow-band spectrum with 80%–90% of the irradiated power lying in the UVB and UVC range, respectively. The UV dose that leads to necrosis in fibroblasts is more than ten times higher than the one needed for deactivation of *E. Coli* bacteria. The deactivation curve for CHO-K1 cells displays a rather high threshold of 0.5–0.7 J/cm<sup>2</sup>; above this value, the number of survivors decreases approximately linearly with increasing UV dose. The lethal UV doses (no survivors) for the fibroblasts are 1 J/cm<sup>2</sup> for UVB and 0.7 J/cm<sup>2</sup> for UVC radiation. In contrast, the threshold for inactivation of *E. Coli* (if existing) is extremely low, and the number

of survivors decreases with increasing dose in a bi-exponential way.

When the photosensitizer ( $H_2O_2$ ) was used together with the UV source, the cells were destroyed more readily than in the case of UV irradiation alone; this is due to the joint action of UV and *in situ* formed active oxygen radical species. The threshold UV dose is drastically lowered, but the amount of survivors versus UV dose is still linear. The effects of UV and the photosensitizer on *E. Coli* bacteria are much more drastic than on the cells.

Photosensitized UV treatment bears some resemblance to plasma treatment, but the UV emission from the lamp is usually more intense than plasma emission. We treated the fibroblast cells with a nonthermal plasma, which is an efficient source of radicals, but a poor source of UV. Under low-power conditions plasma treatment does not cause cell necrosis at all. However, an interesting cell reaction was observed, a temporary disturbance in cell adhesion. The loosened cells are viable and can be removed or rearranged on the substrate.

In the view of future *in vivo* applications, UV treatment may provide a method to decontaminate tissues. However, we realize that the presented results are valid for one kind of bacteria (*E. Coli*). Although *E. Coli*, as a gram-negative type, is fairly resistant, there might be other species that are more difficult to eliminate; especially, the efficiency of spore deactivation must be investigated. Therefore, additional studies are needed to assess the performance of UV decontamination. Plasma treatment offers possibilities of sophisticated tissue modification, like local removal or manipulation of cells without damage to the tissue. However, before the UV lamp and plasma techniques may be implemented, extensive studies of long-term effects of UV and plasma on living tissues must be performed. These studies should involve assays for possible DNA damage and *in vivo* tests on animals.

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 210 0 J. gen. physiol  
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 260 New York, N.Y. :|bRockefeller Institute for Medical  
 Research,|cc1918-  
 300 v. :|bill. ;|c26 cm  
 310 Monthly,|b<, Apr. 1975>  
 321 Bimonthly,|b1918-  
 362 0 Vol. 1, no. 1 (Sept. 1918)-  
 500 Title from cover  
 510 1 Excerpta medica  
 510 1 Biological & agricultural index|x0006-3177  
 510 1 General science index|x0162-1963  
 530 Also available in online version  
 550 Official organ of the Society of General Physiologists,  
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 550 Published by the Rockefeller Institute for Medical  
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| <b>Former</b>    | Bimonthly, 1918-                             |
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| <b>Note</b>      | Title from cover                             |
| <b>Issuing</b>   | Official organ of the Society of General     |
| <b>Body</b>      | Physiologists, Sept. 1960-                   |
| <b>Indexed</b>   | Excerpta medica                              |
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245 1 0 a| Atomic and molecular pulsed lasers V h| [electronic resource] : b| 15-19 September 2003, Tomsk, Russia / c| Victor F. Tarasenko, Georgy V. Mayer, Gueorgii G. Petrash, chairs/editors ; organized by Institute of Atmospheric Optics, SB RAS (Russia) [and others] ; sponsored by Russian Academy of Sciences (Russia) [and others].

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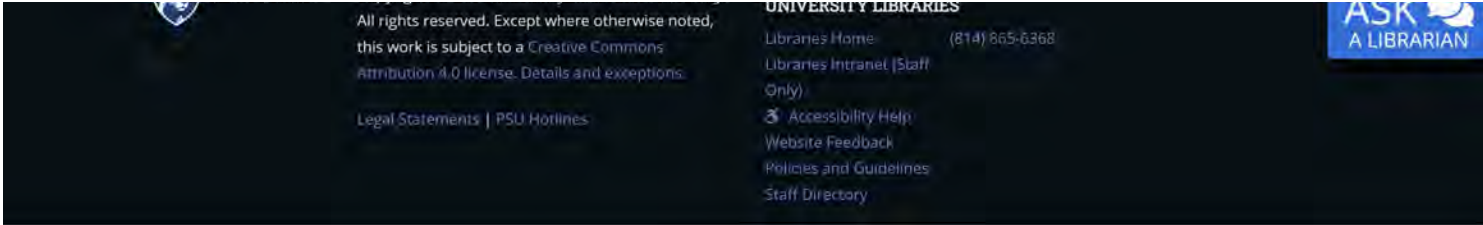
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## INCOHERENT UV AND VUV SOURCES AND LASER OUTPUT CONVERSION

### **Excimer lamps: history, discharge physics, and industrial applications** ([/conference-proceedings-of-spie/5483/0000/Excimer-lamps-history-discharge-physics-and-industrial-applications/10.1117/12.563006.full](#)) Paper

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**The VUV dimer spectra excited in condensed krypton** ([/conference-proceedings-of-spie/5483/0000/The-VUV-dimer-spectra-excited-in-condensed-krypton/10.1117/12.563012](https://doi.org/10.1117/12.563012))  Paper

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**Compact XUV excimer radiation sources and their application** ([/conference-proceedings-of-spie/5483/0000/Compact-XUV-excimer-radiation-sources-and-their-application/10.1117/12.563015](https://doi.org/10.1117/12.563015))  Paper

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**Modeling of barrier filaments as miniglow discharge: Xe<sub>2</sub> (172 nm) and XeCl (308 nm) excilamps** ([/conference-proceedings-of-spie/5483/0000/Modeling-of-barrier-filaments-as-miniglow-discharge--Xe2-172/10.1117/12.563016](https://doi.org/10.1117/12.563016))  Paper

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**New bactericidal UV light sources: excilamps** ([/conference-proceedings-of-spie/5483/0000/New-bactericidal-UV-light-sources-excilamps/10.1117/12.563017](https://doi.org/10.1117/12.563017))  Paper

*Edward A. Sosnin* ([/profile/Eduard.Sosnin-17612](https://doi.org/10.1117/12.563017)), *Larisa V. Lavrent'eva*, *Mikhail V. Erofeev*, *Yana V. Masterova*, *Eugenia N. Kuznetzova*, *Victor F. Tarasenko* ([/profile/Victor.Tarasenko-8571](https://doi.org/10.1117/12.563017)).

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**Biological objects pretreatment optimization using XeBr excilamps for mercury concentration control by ASVA method** ([/conference-proceedings-of-spie/5483/0000/Biological-objects-pretreatment-optimization-using-XeBr-excilamps-for-mercury-concentration/10.1117/12.563018](https://doi.org/10.1117/12.563018))  Paper

*Valentina N. Batalova, Oksana A. Bylatskaya, Edward A. Sosnin* ([/profile/Eduard.Sosnin-17612](https://doi.org/10.1117/12.563018)).

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**Study of photocatalytic effect of narrow band irradiation at 206 and 282 nm on oil in aqueous solution using TiO<sub>2</sub>** ([/conference-proceedings-of-spie/5483/0000/Study-of-photocatalytic-effect-of-narrow-band-irradiation-at-206/10.1117/12.563011](https://doi.org/10.1117/12.563011))  Paper

*Yuri P. Meshalkin, Elena S. Samoilova* ([/profile/Elena.Samoilova-36243](https://doi.org/10.1117/12.563011)), *Edward A. Sosnin* ([/profile/Eduard.Sosnin-17612](https://doi.org/10.1117/12.563011)), *Victor F. Tarasenko* ([/profile/Victor.Tarasenko-8571](https://doi.org/10.1117/12.563011)).

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**Small-sized KrCl, XeCl, and XeBr excilamps** ([/conference-proceedings-of-spie/5483/0000/Small-sized-KrCl-XeCl-and-XeBr-excilamps/10.1117/12.563013](https://doi.org/10.1117/12.563013))  Paper

*Mikhail V. Erofeev, N. L. Medvedev, Edward A. Sosnin* ([/profile/Eduard.Sosnin-17612](https://doi.org/10.1117/12.563013)), *Victor F. Tarasenko* ([/profile/Victor.Tarasenko-8571](https://doi.org/10.1117/12.563013)).

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**Spontaneous UV source based on pulsed discharge in Xe (Kr, Ar)** ([/conference-proceedings-of-spie/5483/0000/Spontaneous-UV-source-based-on-pulsed-discharge-in-Xe-Kr/10.1117/12.563014](https://doi.org/10.1117/12.563014))  Paper

*Mikhail I. Lomaev* ([/profile/Mikhail.Lomaev-422901](https://doi.org/10.1117/12.563014)), *D. V. Rybka, Victor F. Tarasenko* ([/profile/Victor.Tarasenko-8571](https://doi.org/10.1117/12.563014)), *Mahadevan Krishnan, J. Thompson*

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## **APPENDIX SOSNIN04**

# PROCEEDINGS OF SPIE

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## New bactericidal UV light sources: excilamps

Edward Sosnin, Larisa Lavrent'eva, Mikhail Erofeev, Yana Masterova, Eugenia Kuznetzova, et al.

Edward A. Sosnin, Larisa V. Lavrent'eva, Mikhail V. Erofeev, Yana V. Masterova, Eugenia N. Kuznetzova, Victor F. Tarasenko, "New bactericidal UV light sources: excilamps," Proc. SPIE 5483, Atomic and Molecular Pulsed Lasers V, (3 May 2004); doi: 10.1117/12.563017

**SPIE.**

Event: Atomic and Molecular Pulsed Lasers V, 2003, Tomsk, Russian Federation

# A new bactericidal UV light sources – excilamps

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## ABSTRACT

A reliable bactericidal effect on *Escherichia coli* cells irradiation by excilamps has been established. Both on primary and secondary irradiation there exists the reciprocally proportional dependence between irradiation dose (or exposure time) and survived cells number. The microorganisms survived after primary irradiation are shown to have not changed sensitivity to excilamps irradiation. The best results have been obtained during XeBr-excilamp irradiation. Owing to their technical parameters, the excilamps are promising systems for UV-sterilization. Comparison of capacitive discharge excilamp characteristics with other conventional UV light sources is presented.

A comparative study on UV dose effect of a barrier discharge KrCl-excilamp ( $\lambda = 222$  nm) on *Staphylococcus aureus* and *Escherichia coli* inactivation was carried out. KrCl-excilamp emission power is 65 W, and emitting area is 0.1 m<sup>2</sup>. It has been demonstrated that *Staphylococcus aureus* cell sensitivity to UV radiation at this wavelength is higher than that of *Escherichia coli*.

**Key words:** excimer lamp (excilamp), UV-inactivation, *Escherichia coli*, germicidal lamps.

## 1. INTRODUCTION

Today there are various disinfection means and sterilization of glass-ware, and one of them is UV irradiation. The specificity of biological action of various ranges of UV spectra was established in the end XIX century by Russian scientist A.M. Maklakov<sup>1</sup>. In 1942 L.J. Stadler and F.M. Uger have found out that the nuclear acids served as basic target at lethal and mutagenic action of UV radiation<sup>2</sup>. The further researches have shown that germicidal effect of UV light on viruses and bacteria is primarily due to the formation of thymine, thymine-cytosine(pyrimidine) and cytosine dimers in DNA (they are listed in the order of prevalence). The most effective action has the radiation with wavelengths in a range 200-295 nm (so-called *bactericide* or *germicide* range).

For the purpose of creation of an economic germicide light source the uviol mercury-argon low pressure lamps (for example, the domestic lamps series БУБ) were developed in 1936-1940. In its spectrum there is a rather intensive resonant line at 253.7 nm appropriate to a maximum of absorption of number of nuclear acids. Besides for the micro-organisms inactivation purposes the powerful high-pressure mercury-quartz lamps (it corresponds domestic lamps series ППК) have received wide acceptance among another sterilisation methods. The spectrum of these lamps is a broadband continuum but in the wavelength range from 200 to 300 nm no more than 20% of emitting power concentrates.

The comparative analysis of conventional bactericide lamp characteristics (see Table 1) has shown that its bactericide efficiency is low (bactericide efficiency is the ration between light power emitting in the wavelength range 200-295 nm and complete watt consumption). The lamps such as БУБ provide rather small luminance (not exceed mW/cm<sup>2</sup>), but the share of bactericide radiation in general radiant flow exceeds 50 %. And vice versa, the luminance of lamps such as ППК at the expense of significant watt consumption can be essentially increased but the share of bactericide radiation in a spectrum is small.

The listed drawbacks of conventional UV-light systems stimulate the search for new ways and modes of UV-processing.. For example, in <sup>4</sup> the high-voltage source of radiation with pulse power up to ~ 10 MW was used. The treated bacterial populations of *Escherichia coli*, *Salmonella enteritidis* and *Bacillus cereus* were reduced by ~ 8 log orders after 1000 light-pulses of the higher UV intensity light and fungal counts had a corresponding reduction of 4.5 log orders. In <sup>5</sup> for *Bacillus subtilis* inactivation the exciplex KrF-laser ( $\lambda=248$  nm) was applied. The energy per pulse was ~ 120 mJ at 10 Hz in an area of ~ 1 by 3 cm<sup>2</sup>. The pulse duration was nominally 14 ns. It was shown, that the dose of laser radiation in a range up to ~

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104 J/cm<sup>2</sup> renders action similar to action of the same dose from low pressure bactericide lamp. The disadvantages of these UV-light systems <sup>4,5</sup> are it's relative expensiveness and additional factors of danger in service of the system (for example, the use of high-voltage up to 30-40 kV).

Table 1. Germicidal lamps characteristics <sup>1,3</sup>

| Lamp model   | Demand power, W | Design germicide power, W | Germicidal efficiency, % | Share of bactericidal power in lamp emission, % |
|--------------|-----------------|---------------------------|--------------------------|-------------------------------------------------|
| БУВ-30       | 30              | 2                         | 6.6                      | ~ 60                                            |
| БУВ-15       | 15              | 0.8                       | 5.3                      | ~ 60                                            |
| ПРК-7        | 1000            | 35.0                      | 3.5                      | < 20                                            |
| XeBr-JIEPA-5 | 81              | 11.4                      | 14                       | > 85                                            |

Attractive alternative to the above-described systems are so-called excilamps, which active study is conducted last 5-10 years. Independently on the excitation discharge type, spectra of these sources consist of narrow bands, and the main contribution into radiation is made by two excited states, namely,  $^1\Sigma_u^+$  and  $^3\Sigma_u^+$ , at transition to repulsive state  $^1\Sigma_g^+$  (the so-called band B→X), and the band halfwidth rarely exceeds 8-10 nm. It is remarkable that the band B→X possesses over 80-90 % of the total radiation of lamp. According to a working molecule, the band B→X is located in different places of UV range (see Tab. 1). For brevity, in [12] it was suggested to call such devices (as a subclass of discharge lamps) radiating at the expense of decay of excimer or exciplex molecules as *excilamps*. If it is the lamp based on molecules of inert gas R\*<sub>2</sub>, it is called then *excimer lamp* [1]. Efficiency of such excilamps can achieve 7-30% [9].

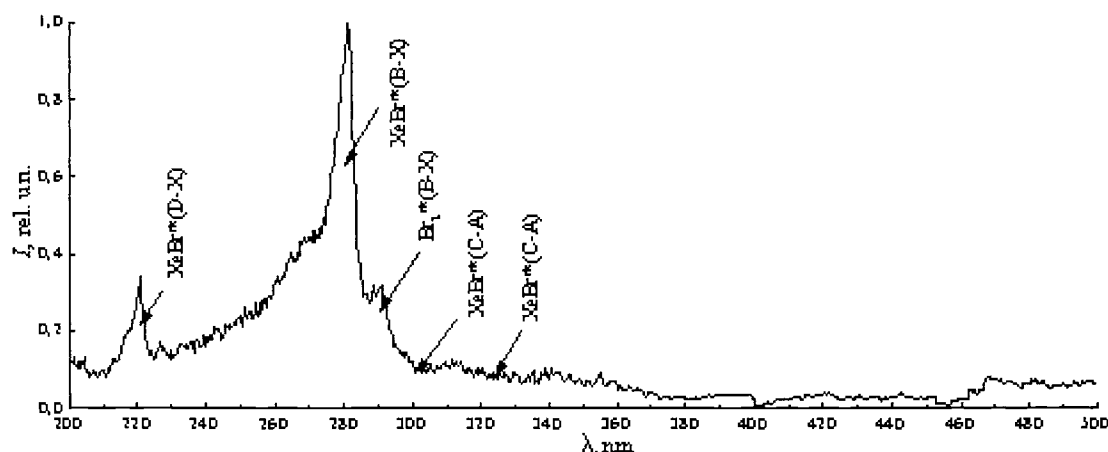


Fig. 1. Capacitive discharge XeBr-excimer lamp spectra.

In comparison with conventional middle-pressure UV-lamps the warming of excilamps bulbs is relatively low, and in western articles it's still named as *cold emission sources*. For example, in <sup>6</sup> for the first time were proposed and tested capacitive discharge excilamps with a simple design of bulb and high lifetime suitable due to absence of contact between a working mixture and metal electrodes. The important advantage of the excilamps is the absence of mercury in gas mixture. Owing to this, UV-system becomes safe in operation and removes a problem of expensive recycling of lamp bulbs. Development of these low-cost, effective light sources promises enormous potential for materials' processing. One of potential application area is disinfection.

This paper is devoted to experimental study of inactivation process of *Escherichia coli* using different capacitive discharge excilamps на *Escherichia coli* under primary and secondary treatment. The second aim of the present work was the comparative study of bactericidal action of barrier discharge KrCl-excimer lamp irradiation on *Escherichia coli* and *Staphylococcus aureus*.

Let us note, that in articles dedicated to UV-sterilisation known for us, for example in <sup>4,5</sup>, the estimation of secondary treating of radiation was not carried out.

## 2. METHODS

### 2.1. UV lighting sources

Irradiation was performed within various time, irradiation dose, and use various type excilamps developed at Laboratory of Optical Radiation, High Current Electronics Institute SB RAS: KrCl-, XeCl- and XeBr-capacitive discharge cylindrical excilamps<sup>3,6</sup> with following parameters: discharge gap 20, 20 and 21 cm, tube diameter 3.8, 4.2 and 4.2 cm, wavelength (B-X transition) 308, 222 and 282 nm, specific power density of UV radiation up to 10, 20, and 12 (mW/cm<sup>2</sup>), efficiency up to 15, 15 and 20 %, correspondingly. The barrier discharge KrCl-excilamp<sup>7</sup> created at the Laboratory of optical radiation of the Institute of High-Current Electronics Institute SB RAS was also used in experiments. The lamp emission power was 65 W, emitting area as 0.1 m<sup>2</sup>. Figure 2 shows KrCl-excilamp radiation spectrum. Commonly, excilamps have radiation spectrum maximum displaced in direction of short-wave UV radiation being close to the DNA absorption maximum. The last explains the high rate of bactericidal effect of excilamps. Photodetector FEK22-SPU was used in experiments to determine illumination. Irradiation dose (J/cm<sup>2</sup>) was defined by the product of illumination (W/cm<sup>2</sup>) and irradiation time (s).

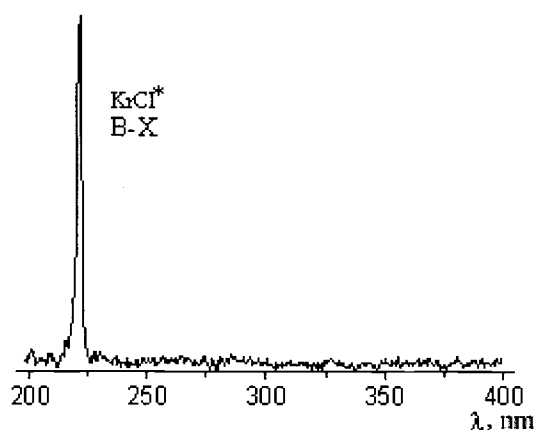


Fig.2. Radiation spectrum of barrier discharge KrCl-excilamp.

### 2.2. Bacterial cultures

The object of study was the pure culture of *Escherichia coli* and *Staphylococcus aureus*, provided by the Scientific Research Institute of Balneology (Tomsk, Russia). Our selection of colibacillus for study was determined by its belonging to the main species of the enterobacterium group taken for sanitation of disinfection efficiency by UV radiation. Besides that, the *Esch. coli* has one of the most high resistance coefficients among enterobacteria group. The culture *S. aureus* is widely spread test-object in investigations on action of disinfection matters and antibiotics on gram-positive bacteria since this culture is characterised by high adaptability to adverse effects due to its high conjugation between cells.

The bacterial cultures were supported on beef-extract agar (BEA) and kept at the temperature of 4°C. In preliminary study, based on the method of multiple dilutions, the optimal concentration of microbial dredge was found for

experiments.

Primary and secondary irradiation of culture *E. coli* by capacitive discharge excilamps radiation during various periods of time were carried out. Usually, the exposure was made 5 cm distant from the lamp. Thereby the heating effect of substrate was minimised and values of irradiation were kept high. Each exposure was repeated 4-5 times. For control, several dishes were left non-irradiated. The number of the survived micro-organisms was defined by the method of bacterial inoculation in dense media (the Koch method of bacterial inoculation in agarized media in Petri dishes). The inoculates were cultivated at temperature of 20-23°C. The evaluation of the number of survived micro-organisms was made in 72 hours.

The micro-organisms survived after irradiation by a dose leading to inactivation of 99.9 % of *E. coli* allocated in pure culture and subjected to a repeated treatment. The qualitative and quantitative analysis, estimation of bacterial colonies morphology (size, form, consistence, character of edge<sup>1</sup>) were conducted.

For statistics of inactivation results, arithmetic average, standard deviation, and error in mean were found using standard program package Statistica 5.0 for Windows, and confidence level was defined by criterion Wilcoxon-Mann-Whitney.

## 3. RESULTS

### 3.1. Primary and secondary irradiation of culture *E. coli* by capacitive discharge excilamps

From the experiments performed it may be concluded that all the excilamps can provide pronounced bactericidal effect on testing cultures both to primary and secondary UV-irradiation.

<sup>1</sup> Distinctions from initial culture from other attributes is not marked.

The certainty of bactericide radiation effect on microorganisms number was established by the use of variance analysis (significance value  $p < 0.05$ ).

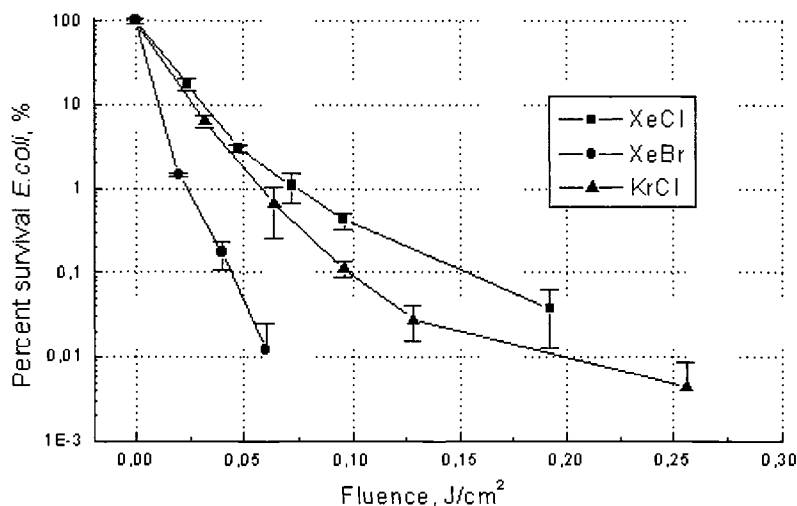


Fig. 3. Inactivation of surface-inoculated *Esch. coli* using different fluences and excilamps under primary irradiation.

primary and secondary irradiation. The number of viable cells is reduced at increase of dose and exposure ( $r = -0.846$ ,  $p < 0.05$  at primary influence and  $r = -0.876$ ,  $p < 0.05$  at secondary one).

The negative correlation between number of the survived cells *E. coli* and irradiation dose (time) is specific to XeCl-

KrCl-excilamp irradiation leads to inactivation 99.9 % of *E. coli* during 8 seconds of exposure at primary irradiation and during 6 seconds at the secondary irradiation (Fig. 4). With increase of irradiation dose and exposure time the number of microorganisms is reduced. For radiation of KrCl-excilamp ( $\lambda \sim 222$  nm) the negative correlation between number of the survived bacteria and irradiation dose (time) was found out. Factor of correlation ( $r$ ) is equal  $-0.960$  ( $p < 0.05$ ) at primary irradiation, and  $-0.896$  ( $p < 0.05$ ) at secondary one.

Inactivation of 99.9 % of microorganisms at influence of XeBr-excilamp ( $\lambda \sim 282$  nm) was provided during 6 seconds both at

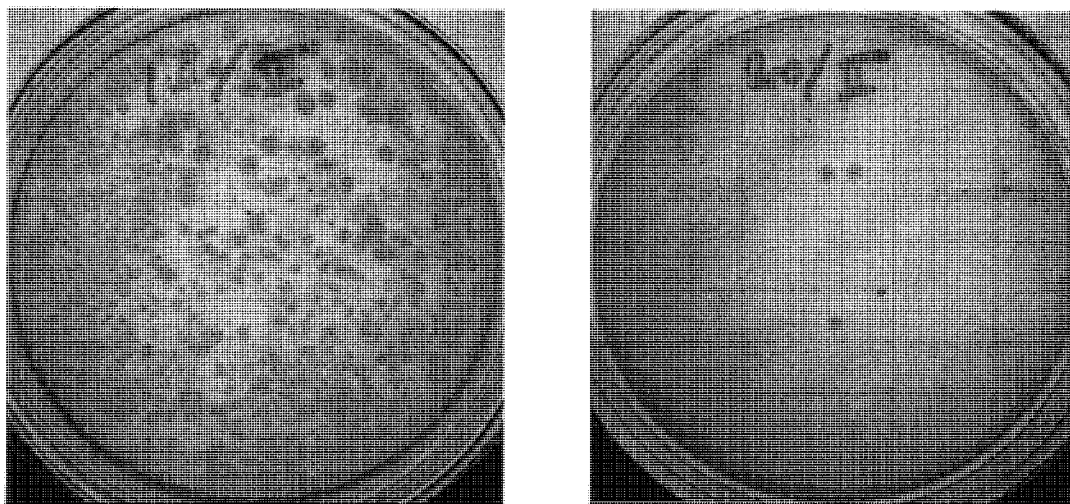


Fig. 4. Photos of survived cultures of *Esch. coli* after 10 seconds (from the left) and 20 seconds (from the right) irradiation by KrCl-excilamp.

excilamp ( $\lambda \sim 308$  nm) radiation. Correlation factor at primary irradiation is equal  $-0.967$  ( $p < 0.05$ ) and  $-0.979$  ( $p < 0.05$ ) for the secondary one. Inactivation of 99.9 % of *E. coli* occurs at exposition of 16 seconds at primary treatment and after 32 seconds at the secondary one.

At comparison of efficiency of primary and secondary irradiation the authentic distinctions are not revealed (significance value  $> 0.05$ ). It suggests that the sensitivity of culture *E. coli*, survived after primary irradiance has not changed.

Comparative study on bactericidal effect of excilamps suggests that the best results can be obtained using XeBr-excilamp under primary as well as secondary irradiation (Fig. 3). This is consistent with photobiology data about nuclear acids radi-

tion absorption<sup>2</sup>. We included the performance parameters of XeBr-excilamp into Table 1. It is evident that this lamp has the best characteristics in respect to power expenses for producing of bactericide radiation.

### 3.2. The comparative study of bactericidal action of barrier discharge KrCl-excilamp irradiation on *Escherichia coli* and *Staphylococcus aureus*

Inoculation of test-cultures was irradiated by barrier discharge KrCl-excilamp. For each exposure there were three retries. Part of dishes was left non-irradiated for control. Bacterial inoculations were cultivated at room temperature within three days. Then, the number of colonies in dishes was calculated and survival of *E. coli* and *S. aureus* cells was evaluated in percents versus the control samples. On investigation KrCl-excilamp irradiation influence on the cultures gross bactericidal effect has been reached. The percentage of survived cells decreased with UV dose increasing to 21-25 mJ/cm<sup>2</sup>, but with further dose increase the part of colonies increased too from 0.1 to 0.4% in experiments with *E. coli* and from 0.3 to 0.7% in experiments with *S. aureus* (Figs. 4,5). The last may be connected with penetration of unintentional cultures into investigated ones with increase of exposure time.

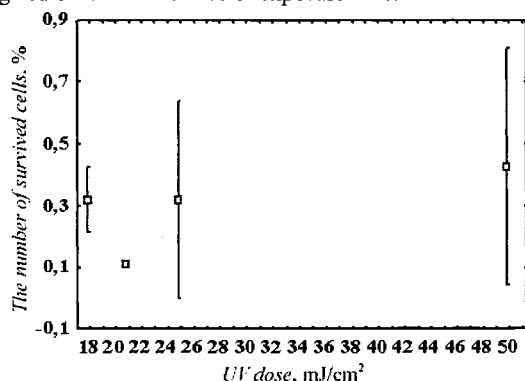


Fig. 4. The number of survived *E. coli* cells.

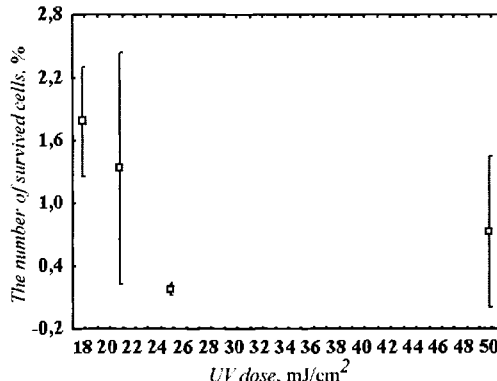


Fig. 5. The number of survived *S. aureus* cells.

## CONCLUSION

Thus, a reliable bactericidal effect on *Escherichia coli* cells irradiation by excilamps has been established. Both on primary and secondary irradiation there exists the reciprocally proportional dependence between irradiation dose (or exposure time) and survived cells number. The microorganisms survived after primary irradiation are shown to have not changed sensitivity to excilamps irradiation. The best results have been obtained during XeBr-excilamp irradiation. Owing to their technical parameters, the excilamps are promising systems for UV-sterilization.

During the work performed it was clearly defined that radiation of the barrier discharge KrCl-excilamp exerts strong bactericidal action on the both cultures, namely *E.coli* and *S.aureus*. With increase in UV irradiation dose as 21-25 mJ/cm<sup>2</sup> the KrCl-excilamp bactericidal effect became stronger. Hence, increase in exposure time results in increasing of the number of non-inactivated cells from 0.1 to 0.3% for *E. coli*, and from 0.4 to 0.7% for *S. aureus*.

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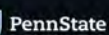
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## **APPENDIX NIOSH02**

# NIOSH

A Recommended Standard for Occupational Exposure to.....

## Ultraviolet Radiation

A criteria document for protection against ultraviolet radiation has been prepared in accordance with sections 6 (b) (7) and 20 (a) (3) of the Occupational Safety and Health Act was transmitted to the Occupational Safety and Health Administration, U.S. Department of Labor, December 20, 1972, for review and consideration in the Standard setting process.

The standard is based on criteria developed from the results of numerous investigations of the effects of ultraviolet energy on the exposed eye and skin. In the development of the proposed standard the eye was selected as the organ for protection because the eye is much more sensitive than the skin to ultraviolet radiation. A significant safety factor for the skin is thereby provided. The proposed standard represents a complete criteria document, but recognizes present difficulties in the measurement of broadband ultraviolet energy. Evaluation for compliance is based on three different approaches depending upon the wavelength of the ultraviolet energy; these are:

1. Utilization of available instrumentation whenever applicable with recognition of instrument shortcomings.
2. Utilization of data on energy output from a specific source such as lamps.
3. Utilization of work practices when suitable instrumentation or energy output data are not available.

Exposure to ultraviolet radiation occurs in welding, metal cutting, plasma torch operation, glass manufacture, furnace and foundry operations and in bacteriologic control. Outdoor

workers who are exposed to sunlight may also receive significant ultraviolet radiation, and the problem of non-occupational exposure to sunlight is recognized. An estimated 320,000 industrial workers are potentially exposed to artificial sources of ultraviolet energy, and approximately 4.8 million outdoor workers are potentially exposed to sunlight.

The recommendations for an occupational exposure standard for ultraviolet radiation take into consideration available information on health effects and limited data on technical feasibility of achieving various levels of exposure.

The criteria document was reviewed by four knowledgeable consultants, two professional societies, and government agencies with interest and responsibility in occupational safety and health. No response was obtained from the solicitation in the *Federal Register*.

It was the feeling of the reviewers that the ultraviolet radiation standard as proposed in this document, which has been adapted from the American Conference of Governmental Industrial Hygienists, is appropriate and that no additional information that would affect the standard is available at this time.

The substantial changes incorporated into the criteria document as a result of the reviewers' comments involved recognition of the limited use of present measuring devices and the need for use of work practices and protective clothing and goggles.

The following is the first chapter of the criteria document. It contains the NIOSH recommendations for controlling worker exposure to Ultraviolet Radiation.

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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE  
Public Health Service  
Center for Disease Control  
National Institute for Occupational Safety and Health

## 1. RECOMMENDATIONS FOR AN ULTRAVIOLET RADIATION STANDARD

The National Institute for Occupational Safety and Health (NIOSH) recommends that occupational exposure to ultraviolet energy in the workplace be controlled by compliance with the following sections. Ultraviolet radiation (ultraviolet energy) is defined as that portion of the electromagnetic spectrum described by wavelengths from 200 to 400 nm. (For additional definitions and conversion factors, see Appendix II.) Adherence to the recommended standards will, it is believed, prevent occupational injury from ultraviolet radiation, that is, will prevent adverse acute and chronic cutaneous and ocular changes precipitated or aggravated by occupational exposure to ultraviolet radiation.

Sufficient technology exists to prevent adverse effects on workers, but technology to measure ultraviolet energy for compliance with the recommended standard is not now adequate, so work practices are recommended for control of exposure in cases where sufficient measurement or emission data are not available.

These criteria and the recommended standard will be reviewed and revised when relevant information warrants.

### Section 1 — Exposure Standards

(a) For the ultraviolet spectral region of 315 to 400 nm, total irradiance incident on unprotected skin or eyes, based on either measurement data or on output data, shall not exceed 1.0 mW/cm<sup>2</sup> for periods greater than 1000 seconds, and for exposure times of 1000 seconds or less the total radiant energy shall not exceed 1000 mW·sec/cm<sup>2</sup> (1.0 J/cm<sup>2</sup>).

(b) For the ultraviolet spectral region of 200 to 315 nm, total irradiance incident on unprotected skin or eyes, based on either measurement data or on output data, shall not exceed levels described below. Measurement techniques are discussed in Appendix I.

(1) If the ultraviolet energy is from a narrow-band or monochromatic source, permissible dose levels for a daily 8-hour period can be read directly from Figure I-1, or, for selected wavelengths, from Table I-1.

(2) If the ultraviolet energy is from a broad-band source, the effective irradiance ( $I_{eff}$ ) relative to a 270-nm monochromatic source shall be calculated from the formula below. From  $I_{eff}$  the permissible exposure time in seconds for unprotected skin or eyes shall be computed by

dividing 0.003 J/cm<sup>2</sup>, the permissible dose of 270-nm radiation, by  $I_{eff}$  in W/cm<sup>2</sup>.

$$I_{eff} = \sum I_{\lambda} S_{\lambda} \Delta_{\lambda}$$

where  $I_{eff}$  = effective irradiance relative to a monochromatic source at 270 nm.

$I_{\lambda}$  = spectral irradiance in W/cm<sup>2</sup>/nm.

$S_{\lambda}$  = relative spectral effectiveness (unitless); see Table I-1 for values of  $S_{\lambda}$  at different wavelengths.

$\Delta_{\lambda}$  = band width in nm.

Table I-2 lists permissible exposure times corresponding to selected values of  $I_{eff}$  in  $\mu$ W/cm<sup>2</sup>.

If radiation intensity from a point source is known at some distance from the worker, for example, from measurement at another point or from output data at a known distance from the ultraviolet source, attenuation of radiation from that point to the worker can be calculated from the principle that radiation decreases with the square of the distance it must travel. For example, an object 3 feet away from a radiation source receives 1/9 the energy of an object 1 foot away. This assumption is conservative in some instances, since ultraviolet radiation, especially at very low wavelengths, may be absorbed by some components of the atmosphere. Where information on atmospheric absorption of ultraviolet radiation is known, further correction may be applied. The calculation of intensity of radiation at any given point by use of the inverse square formula explained above does not take into consideration reflected energy.

The recommended standard is not proposed for application as a standard to lasers. It should be recognized that significant non-occupational exposure to ultraviolet radiation can occur from exposure to sunlight, particularly during the summer months.

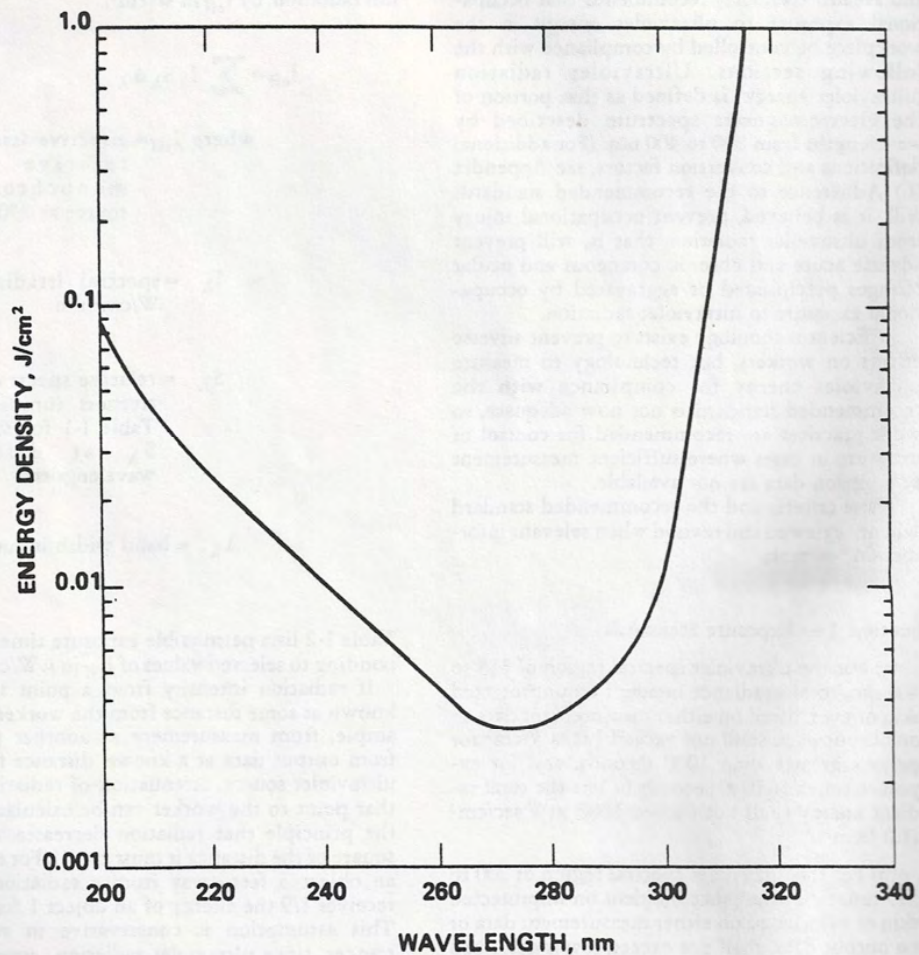


Figure I-1. Recommended Ultraviolet Radiation Exposure Standard  
This figure was adapted from a figure developed and published by the American Conference of Governmental Industrial Hygienists in "Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1972".

**Table I-1**  
**Total Permissible 8-Hour Doses and**  
**Relative Spectral Effectiveness of Some**  
**Selected Monochromatic Wavelengths**

| Wavelength<br>(nm) | Permissible 8-hour<br>dose (mJ/cm <sup>2</sup> ) | Relative spectral<br>effectiveness ( $S_{\lambda}$ ) |
|--------------------|--------------------------------------------------|------------------------------------------------------|
| 200                | 100.0                                            | 0.03                                                 |
| 210                | 40.0                                             | 0.075                                                |
| 220                | 25.0                                             | 0.12                                                 |
| 220                | 25.0                                             | 0.12                                                 |
| 230                | 16.0                                             | 0.19                                                 |
| 240                | 10.0                                             | 0.30                                                 |
| 250                | 7.0                                              | 0.43                                                 |
| 254                | 6.0                                              | 0.50                                                 |
| 260                | 4.6                                              | 0.65                                                 |
| 270                | 3.0                                              | 1.00                                                 |
| 280                | 3.4                                              | 0.88                                                 |
| 290                | 4.7                                              | 0.64                                                 |
| 300                | 10.0                                             | 0.30                                                 |
| 305                | 50.0                                             | 0.06                                                 |
| 310                | 200.0                                            | 0.015                                                |
| 315                | 1000.0                                           | 0.003                                                |

This table was adapted from a table developed and published by the American Conference of Governmental Industrial Hygienists in "Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1972".

**Table I-2**  
**Maximum Permissible Exposure Times**  
**for Selected Values of  $I_{\text{eff}}$**

| Duration of<br>exposure per day | Effective irradiance,<br>$I_{\text{eff}}$ ( $\mu\text{W}/\text{cm}^2$ ) |
|---------------------------------|-------------------------------------------------------------------------|
| 8 hrs                           | 0.1                                                                     |
| 4 hrs                           | 0.2                                                                     |
| 2 hrs                           | 0.4                                                                     |
| 1 hr                            | 0.8                                                                     |
| 30 min                          | 1.7                                                                     |
| 15 min                          | 3.3                                                                     |
| 10 min                          | 4.0                                                                     |
| 5 min                           | 10.0                                                                    |
| 1 min                           | 50.0                                                                    |
| 30 sec                          | 100.0                                                                   |

This table was adapted from a table developed and published by the American Conference of Governmental Industrial Hygienists in "Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1972."

## Section 2 — Medical Recommendations

(a) The worker's past medical history should be obtained to determine if the worker suffers from any condition that is exacerbated or aggravated by exposure to sunlight.

(b) A worker who gives a history of such a condition should not be permitted to work in an area exposed to ultraviolet radiation.

(c) The worker should be advised that any blemish that appears on skin exposed to long term ultraviolet radiation should be examined by a physician.

## Section 3 — Appraisal of Employees of Hazards From Exposure to Ultraviolet Energy.

(a) Each employee who may be exposed to high intensity artificial sources of ultraviolet energy shall be apprised of all hazards, relevant symptoms and precautions concerning exposure. This appraisal of hazards shall include:

(1) Information as to the proper eye protection and protective clothing to be used.

(2) Instruction on how to recognize the symptoms of eye and skin damage due to ultraviolet radiation.

(3) Information as to special caution that shall be exercised in situations where employees are exposed to toxic agents and/or other stressful physical agents which may be present in addition to and simultaneously with ultraviolet radiation.

(b) Highly susceptible (i.e. light skinned, easily sunburned) employees who regularly work out of doors and are exposed to sunlight should be apprised of possible long term effects of sun exposure and of the desirability of preventing these effects by use of protective clothing or sun-screens.

## Section 4 — Labeling

All sources, work areas, and housings specified in Table I-3 shall carry the following warning:

CAUTION

HIGH INTENSITY ULTRAVIOLET  
ENERGY

PROTECT EYES AND SKIN

## Section 5 — Work Practices

Worker exposure to ultraviolet energy from 200 to 400 nm shall be controlled by adherence to the standard set forth in Section 1 or the preventive procedures described in this Section, as applicable. Compliance with the standard, based on measurement data or emission data, or adherence to the work practice procedures will protect against injury from ultraviolet energy.

Exposure to ultraviolet energy can be controlled by enclosures, shields, protective clothing, skin creams, gloves, goggles, or face shields. Workers shall be protected from eye or skin exposure to ultraviolet radiation.

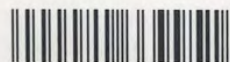
Specific protective measures to be used for various types of ultraviolet exposure are noted below.

(a) **Sunlight.** Susceptible persons working outside in strong sunlight should be protected. Protective clothing, such as long-sleeved shirts, trousers or skirt, and face and neck protection will normally be adequate. Face and neck protection can be afforded by a broad-brimmed hat, by a billed hat or cap, or by a neck shield (if the neck is not protected by hair). Hard hats may have bills or face shields to protect the face, and may have neck shields. Alternatively, face and eye

Table I-3

| <u>Radiation Source</u>                   | <u>Lamp or Instru-<br/>ment</u> | <u>Housing</u> | <u>Work Area</u> | <u>Container<br/>(Shipping or Storage)</u> |
|-------------------------------------------|---------------------------------|----------------|------------------|--------------------------------------------|
| 1. Low Pressure Mercury                   | Yes                             | Yes            | No               | Yes                                        |
| 2. Sunlamp                                | Yes                             | No             | No               | Yes                                        |
| 3. Black light lamp                       | No                              | No             | No               | No                                         |
| 4. Pressure Type Arc lamps*               | No                              | Yes            | Yes              | Yes                                        |
| 5. Open Arcs* and Incandescent Sources    | No                              | Yes            | Yes              | Yes                                        |
| 6. Welding                                | Yes                             | —              | Yes              | Yes                                        |
| 7. Plasma Torches                         | Yes                             | Yes            | Yes              | Yes                                        |
| 8. Other artificial UV generating sources | Yes                             | Yes            | Yes              | Yes                                        |

\*Lamps cannot be labeled because of their high operating temperatures.



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protection can be achieved by barrier creams and goggles or spectacles.

(b) **Low-intensity ultraviolet sources.** Examples of sources of low-intensity ultraviolet sources are low-pressure mercury vapor lamps, sunlamps, and black-light lamps.

Glass or plastic (1/8-inch thickness or greater) spectacles, goggles or shields provide adequate eye protection. Skin can be protected by lightweight clothing, by absorbing skin creams containing benzophenones or p-aminobenzoic acid, or by barrier creams containing titanium dioxide or zinc oxide.

(c) **High-intensity ultraviolet sources.** Examples of high-intensity ultraviolet sources are high-pressure mercury vapor lamps, high-pressure xenon arcs, xenon-mercury arcs, carbon arcs, plasma torches, and welding arcs.

For eye protection, workers shall wear goggles, face shields or masks. For shade required for this eye protection, consult Section 7 of American National Standards Institute Z49.1-1967 (ANSI Z49.1). However, in some welding operations such as gas-shielded arc welding, workers with inadequate visual acuity may have to wear a shade of less absorbance (greater transmission) to facilitate their locating the electrodes and prevent starting the arc before putting their masks or goggles in place; eye protection must be used at all times while the arc is operating, and, if necessary in order to see the operation, shade 8 may be used in place of a shade of greater absorbance.

Skin must also be protected. Clothing of densely woven flannelette, poplin, or synthetic fabric will give sufficient protection. Facial skin can be protected by face shields of shades specified in ANSI Z49.1 or by barrier creams containing titanium dioxide or zinc oxide.

Because many synthetic clothing fibers can

melt or catch fire and thereby cause severe thermal burns, clothing of synthetic fibers should be flame-resistant if operations involve great heat, sparks, or flame.

Welders' helpers and others working nearby may also require protection. Shielding such as the welder's booth guard against accidental exposure of other people. Reflection from lamp housings, walls, ceilings, and other possible reflective surfaces should be kept to a minimum by coating such surfaces with a pigment-based paint of low ultraviolet reflectance. Where such shielding and non-reflective surfaces are not used, welders, helpers and others near the welding operation should wear protective clothing, skin creams, gloves, goggles, or face shields.

**Additional hazards.** There are other hazards from some ultraviolet sources that must also be prevented. There is a shock hazard in some operations involving arcs, because of the high starting voltages required; wiring and connections must be adequately insulated, and persons handling the equipment must wear gloves and face shields. There must be adequate ventilation to prevent build-up of ozone and oxides of nitrogen. There may also be an explosion hazard from some ultraviolet operations, and the wearing of gloves and face shields will reduce the consequences of an explosion.

Arc welding on plates wet with unsaturated chlorinated hydrocarbons (perchloroethylene and trichloroethylene) must be avoided unless well vented, because of possible production of phosgene and hydrogen chloride.

#### Section 6 — Recordkeeping

Because measurement of exposure of workers to ultraviolet energy is not required, records are not required.

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