

MEDICINE AND BIOLOGY

*Sydney*  
*Journal of*  
*Research*

---

Alberto Mantovani

Rudolf E. Schramm and William D. Lubell

REGENERATION  
New M. LaVail and Robert E. Anderson

XXIX  
Richard K. Harrison and Duane F. Bruley

CANCER PROGRESSION  
Richard and Eileen White

GREEN CELL FACTORIES  
José Zaván and Emilio Fernández

Robert H. Hackett and Peter D. Wagner

CYANOBACTERIAL BLOOMS:  
STATE OF SCIENCE AND RESEARCH NEEDS

---

Series. A continuation order will bring delivery  
of the next issue. Volumes are billed only upon actual  
order to the publisher.

H. Kenneth Hudnell  
Editor

# Cyanobacterial Harmful Algal Blooms: State of the Science and Research Needs

 Springer

*Editor*  
H. Kenneth Hudnell  
United States Environmental Protection  
Agency  
Triangle Park, NC  
USA

*Series Editors*  
Nathan Back  
State University of New York at Buffalo  
USA

Abel Lajtha  
Center for Neurochemistry  
Division of the Nathan S. Kline Institute  
for Psychiatric Research, Orangeburg  
NY, USA

Rodolfo Paoletti  
Department of Obstetrics and  
Gynecology  
University of Milan, Italy

Irun R. Cohen  
The Weizmann Institute of Science  
Rehovot, Israel

John D. Lambris  
University of Pennsylvania

ISBN: 978-0-387-75864-0 e-ISBN: 978-0-387-75865-7  
DOI: 10.1007/978-0-387-75865-7

Library of Congress Control Number: 2007939828

© 2008 Springer Science + Business Media, LLC  
All rights reserved. This work may not be translated or copied in whole or in part without the written permission of the publisher (Springer Science+Business Media, LLC., 233 Spring Street, New York, NY 10013, USA), except for brief excerpts in connection with reviews or scholarly analysis. Use in connection with any form of information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed is forbidden. The use in this publication of trade names, trademarks, service marks, and similar terms, even if they are not identified as such, is not to be taken as an expression of opinion as to whether or not they are subject to proprietary rights.

Printed on acid-free paper

9 8 7 6 5 4 3 2 1

springer.com

## Contents

Preface .....	
Interagency ISOC-HAB	
ISOC-HAB Executive	
Invited Participants .....	
Occurrence Workgr	
Causes, Prevention,	
Cyanotoxin Charact	
Analytical Methods	
Human Health Effect	
Ecosystem Effects	
Risk Assessment W.	

## Overview

Chapter 1: An Overview  
Symposium on Cyanobacteria  
(ISOC-HAB): Advancing  
of Freshwater Harmful  
*H Kenneth Hudnell, Qu*

Chapter 2: A Synopsis of  
at the Interagency, Inter-  
on Cyanobacterial Harm  
*H Kenneth Hudnell, Qu*

## Occurrence Workg

Chapter 3: Occurrence of  
Workgroup Report .....

*Edited by Anthony Friseta*  
*Workgroup Co-chairs: Ja*  
*Workgroup Members: Jul*  
*JoAnn Burkholder, John I*  
*William Frazier, Steve L i*

Group Poster Abstracts .....559

Cyanotoxin Production..... 559  
*Geoffrey FM, Codd GA*

in the Great Lakes, USA..... 561  
*Wetzel GL, Millie DF*

Bacterial Populations  
in Levels .....563  
*McMillan L*

Mass Spectrometry  
Application .....565  
*Brien I, Furey A, James KJ*

in Aquatic Plants..... 567  
*James KJ, Furey A*

Using Mass  
Spectrometry ..... 569  
*James M, Furey A*

Marine ..... 571

Using the PDS® Biosensor ..... 573  
*Wetzel R*

Detection of  
Cyanobacteria in Supply Reservoirs..... 575  
*Burkholder JM*

Cyanobacteria in SE USA ..... 577

---

Group Report.....579  
*Fournie, John W Fournie  
Chernoff, Neil Chernoff,  
MacPhail, Robert MacPhail,*

Chapter 27: Health Effects Associated with Controlled  
Exposures to Cyanobacterial Toxins..... 607  
*Ian R Falconer*

Chapter 28: Cyanobacterial Poisoning in Livestock,  
Wild Mammals and Birds – An Overview..... 613  
*Ian Stewart, Alan A Seawright, Glen R Shaw*

Chapter 29: Epidemiology of Cyanobacteria and their Toxins..... 639  
*Louis S Pilotto*

Chapter 30: Human Health Effects Workgroup Poster Abstracts ... 651

Serologic Evaluation of Human Microcystin Exposure ..... 651  
*Hilborn ED, Carmichael WW, Yuan M, Soares RM, Servaites JC,  
Barton HA, Azevedo, SMFO*

Characterization of Chronic Human Illness Associated  
with Exposure to Cyanobacterial Harmful Algal Blooms  
Predominated by Microcystis ..... 653  
*Shoemaker RC, House D*

---

**Ecosystem Effects Workgroup**

---

Chapter 31: Ecosystem Effects Workgroup Report..... 655  
*Workgroup Co-chairs: John W Fournie, Elizabeth D Hilborn  
Workgroup Members: Geoffrey A Codd, Michael Coveney,  
Juli Dyble, Karl Havens, Bas W Ibelings, Jan Landsberg, Wayne Litaker*

Chapter 32: Cyanobacterial Toxins: A Qualitative  
Meta-Analysis of Concentrations, Dosage and Effects  
in Freshwater, Estuarine and Marine Biota..... 675  
*Bas W Ibelings, Karl E Havens*

Chapter 33: Cyanobacteria Blooms: Effects  
on Aquatic Ecosystems ..... 733  
*Karl E Havens*

Chapter 34: Ecosystem Effects Workgroup Poster Abstracts..... 749

Local Adaptation of *Daphnia Pulicaria* to Toxic Cyanobacteria..... 749  
*Sarnelle O, Wilson AE*

Cytotoxicity of Microcystin-LR to Primary Cultures  
of Channel Catfish Hepatocytes and to the Channel  
Catfish Ovary Cell Line..... 752  
*Schneider JE Jr, Beck BH, Terhune JS, Grizzle JM*

# Characterization of chronic human illness associated with exposure to cyanobacterial harmful algal blooms predominated by *Microcystis*

Shoemaker RC<sup>1</sup>, House D<sup>1</sup>

<sup>1</sup>Center for Research on Biotoxin Associated Illness, Pocomoke, Md

## Introduction

Health effects from exposure to surface waters in the USA experiencing blooms of toxigenic cyanobacteria have not been well characterized. We initially evaluated seven cases of chronic illness following exposure to Lake Griffin, a member of the St. John's chain of lakes in Florida, during a bloom of *Microcystis* that was reported by the St. John's Water Management District. All seven people complained of multiple-system symptoms and demonstrated deficits in visual contrast sensitivity (VCS). Differential diagnoses based on medical histories, physical examinations, complete blood counts, comprehensive metabolic profiles, and assessments of both potentially confounding factors and toxic exposures indicated that exposure to the *Microcystis* bloom was the likely cause of illness. Patient reevaluations after 2 weeks of cholestyramine (CSM) therapy to bind and eliminate toxins demonstrated a statistically significant decrease in the number of symptoms and increase in VCS. The evidence indicated that exposure to the *Microcystis* bloom caused a biotoxin-associated illness similar to those previously reported in association with exposures to waters with high levels of toxigenic dinoflagellates and with exposures to water-damaged indoor environments exhibiting microbial amplification, including toxigenic fungi. We currently report a cohort of 10 patients exposed to *Microcystis* blooms who were evaluated before and after CSM therapy.

## Hypotheses

Exposures to *Microcystis* blooms are associated with: (1) chronic illness characterized by multiple-system symptoms and VCS deficits; 2) increased blood levels of leptin and MMP9; 3) decreased blood levels of aMSH, ADH/osmolality, VEGF and ACTH/cortisol, and; 4) symptom resolution, and normalization of VCS and all biomarkers following CSM therapy.

## Methods

Ten cases of chronic illness following exposure to *Microcystis* blooms were evaluated using the methods described above. Exposures to *Microcystis* blooms were determined to be the likely cause of illness. Three cases were exposures to blooms predominated by *Microcystis* and reported by the St. John's Water Management District, whereas six cases were exposed to *Microcystis* blooms reported by the Maryland Department of Natural Resources. The number of symptoms, VCS, and blood levels of leptin, cortisol, osmolality, MMP9, VEGF, aMSH, and ACTH, were measured before and after CSM therapy, and HLA DR genotypes were identified. Repeated measurements of C3a, C4a, interleukin-10, and interferon alpha were also obtained from 3 cases. All measures were compared to those previously obtained from 239 unexposed well patients.

## Results

The mean number of symptoms reported by patients was 19.7 out of 37 assessed before CSM therapy, and 3.2 following therapy. VCS increased by about 40% after therapy. Blood levels of leptin and MMP9 were significantly higher than historical controls prior to therapy, whereas aMSH, ADH/osmolality, VEGF and ACTH/cortisol were low. All biomarkers normalized after 2 weeks of therapy except for aMSH. Two HLA DR haplotypes were significantly overrepresented in the cohort. All three cases for whom C3a, C4a, interleukin-10, and interferon alpha were measured showed elevated levels prior to therapy and normal levels following therapy.

## Conclusion

The evidence indicated that exposures to *Microcystis* blooms may cause a form of chronic, biotoxin-associated illness that is characterized by abnormalities in symptoms, VCS and multiple biomarkers that resolves with CSM therapy. A randomized, double-blind, placebo-controlled, clinical trial and methods to measure cyanotoxins in blood is needed to confirm this hypothesis.