

# CONSEQUENCES OF NUCLEAR TESTING IN THE MARSHALL ISLANDS

## *Guest Editors*

Steven L. Simon

*Board on Radiation Effects Research  
National Research Council  
National Academy of Sciences  
2101 Constitution Avenue, N.W.  
Washington, D.C. 20418*

Richard J. Vetter

*B-31 Medical Sciences Building  
Mayo Clinic  
Rochester, MN 55905*

Reproduced from the journal *Health Physics* with  
permission from the Health Physics Society



WILLIAMS & WILKINS

---

# HEALTH PHYSICS

## The Radiation Protection Journal

### Official Journal of the Health Physics Society

---

**Kenneth L. Miller**, Editor-in-Chief

**Leilyn Perri**, Managing Editor

**Deanna D. Baker**, Editorial Assistant

**Richard V. Griffith**, News Editor

**Michael T. Ryan**, Book Editor

**George J. Vargo**, Software Editor

**Kevin L. Nelson**, New Products Editor

#### EDITORS

---

**Kenneth L. Miller**, Health Physics Office, Penn State University/Milton S. Hershey Medical Center, Hershey, PA 17033-0850

**Leilyn Perri**, Health Physics Office, Penn State University/Milton S. Hershey Medical Center, Hershey, PA 17033-0850

**William H. Bailey**, Bailey Research Associates, Inc., 292 Madison Ave., New York, NY 10017

**Bruce Busby**, University of Michigan, 109 Observatory Road, School of Public Health, EIH Department, Ann Arbor, MI 48109

**Ralph C. Christensen**, Division of Radiation Sciences, Room 207, 121 Washington Ave., University of Kentucky Medical Ctr., Lexington, KY 40536-0003

**Geoffrey G. Eichholz**, Georgia Institute of Technology, Nuclear Engineering and Health Physics, Atlanta, GA 30332-0225

**Ronald E. Goans**, Oak Ridge Associated Universities, P.O. Box 117, Oak Ridge, TN 37831-0117

**Richard V. Griffith**, International Atomic Energy Agency, Wagramerstrasse 5, P.O. Box 200 A-1400, Vienna, Austria/Europe, AA 008

**David M. Hamby**, Department of Environmental and Industrial Health, School of Public Health, University of Michigan, Ann Arbor, MI 48109-2029

**Robert F. Holub**, Department of Physics, Colorado School of Mines, Golden, CO 80401

**Yigal Horowitz**, Physics Department, Ben Gurion University of the Negev, P.O. Box 653, Beersheva 84005, Israel

**T. Edmond Hui**, Inn & Associates International, P.O. Box 943, Richland, WA 99352

**Nisy E. Ipe**, SLAC, MS 48, P.O. Box 4349, Stanford, CA 94309

**Kimberlee J. Kearfott**, Department of Nuclear Engineering, University of Michigan, 108 Cooley Laboratory, North Campus, Ann Arbor, MI 48109-2104

**Craig A. Little**, Oak Ridge National Laboratory, P.O. Box 2567, Grand Junction, CO 81501

**David W. Miller**, Plant Radiation Protection, RR3 Box 678, Clinton, IL 61727

**Robert P. Miltenberger**, Brookhaven National Laboratory, Building 129B, Upton, NY 11973

**Kevin L. Nelson**, Radiation Safety Office, Mayo Clinic Jacksonville, 4500 San Pablo Road, 243N-2 Jacksonville, FL 32224

**Michael P. Nunno**, Physics Department, Cooper Hospital/University Medical Center, One Cooper Plaza, Camden, NJ 08103

**Mark J. Rudin**, UNLV College of Health Sciences, 4505 Maryland Parkway, #453037, Las Vegas, NV 89154-3037

**Michael T. Ryan**, 768 Glossy Ibis Lane, Kiawah Island, SC 29455  
**Arthur G. Scott**, 2020 South Millway, Mississauga, Ontario L5L 1K2, Canada

**Steven L. Simon**, Board on Radiation Effects Research, Commission on Life Sciences, National Academy of Sciences, 2101 Constitution Ave., N.W. Washington, D.C. 20418

**C.S. Sims**, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831-6106

**Michael G. Stabin**, Oak Ridge Associated Universities, P.O. Box 117, Oak Ridge, TN 37831

**Graham Stevenson**, CERN CH-1211, Geneva 23, Switzerland

**Tore Straume**, Lawrence Livermore National Laboratory, P.O. Box 808, L-453, Livermore, CA 94551-9900

**Daniel J. Strom**, Pacific Northwest National Laboratory, Battelle Boulevard, Richland, WA 99352-0999

**Allan B. Tanner**, 12125 Captiva Court, Reston, VA 20191-1204

**Mark Tulchinsky**, Nuclear Medicine Department, Penn State University/M.S. Hershey Medical Center, 500 University Drive, Hershey, PA 17033-0850

**George J. Vargo**, Pacific Northwest National Laboratory, Battelle Boulevard, Richland, WA 99352-0999

#### HEALTH PHYSICS ADVISORY BOARD

---

**Chairman: Phil Metcalf** (IRPA Publications Director), Council for Nuclear Safety, Hennopsmeer, South Africa

**K. Duftschmid** (IRPA President), Austrian Research Centre, Seibersdorf, Austria

**C.J. Huyskens** (IRPA Executive Officer), Eindhoven University of Technology, Netherlands

**R. Maushart** (IRPA Treasurer), Pappelweg 38 D-7541, Straudenhardt, Germany

---

# HEALTH PHYSICS

## The Radiation Protection Journal

July 1997

Volume 73

Number 1

ISSN 0017-9078

---

### CONTENTS

#### NEWS ON THE NET

---

##### On-Line Tools Revisited

Bruce Busby

1

#### GUEST EDITORIAL

---

##### Editor's Remarks

Steven L. Simon and Richard J. Vetter

3

##### Map of the Marshall Islands

4

#### CONTRIBUTED PAPERS

---

##### HISTORY

##### A Brief History of People and Events Related to Atomic Weapons Testing in the Marshall Islands

Steven L. Simon

5

##### Monitoring Distant Fallout: The Role of the Atomic Energy Commission Health and Safety Laboratory during the Pacific Tests, with Special Attention to the Events Following BRAVO

Merril Eisenbud

21

##### A History of the People of Bikini Following Nuclear Weapons Testing in the Marshall Islands: with Recollections and Views of Elders of Bikini Atoll

Jack Niedenthal

28

##### RADIOLOGICAL MONITORING

##### The Northern Marshall Islands Radiological Survey: Data and Dose Assessments

W. L. Robison, V. E. Noshkin, C. L. Conrado, R. J. Eagle, J. L. Brunk, T. A. Jokela, M. E. Mount, W. A. Phillips, A. C. Stoker, M. L. Stuart, and K. M. Wong

37

##### Past and Present levels of Some Radionuclides in Fish from Bikini and Enewetak Atolls

V. E. Noshkin, W. L. Robison, K. M. Wong, J. L. Brunk, R. J. Eagle, and H. E. Jones

49

##### Findings of the First Comprehensive Radiological Monitoring Program of the Republic of the Marshall Islands

Steven L. Simon and James C. Graham

66

##### DOSE ASSESSMENT

##### <sup>137</sup>Cs Exposure in the Marshallese Populations: An Assessment Based on Whole-Body Counting Measurements (1989-1994)

L. C. Sun, J. H. Clinton, E. Kaplan, and C. B. Meinhold

86

##### An Updated Dose Assessment for Resettlement Options at Bikini Atoll—A U.S. Nuclear Test Site

William L. Robison, Kenneth T. Bogen, and Cynthia L. Conrado

100

##### Uncertainty and Variability in Updated Estimates of Potential Dose and Risk at a U.S. Nuclear Test Site—Bikini Atoll

Kenneth T. Bogen, Cynthia L. Conrado, and William L. Robison

115

##### Assessment of Plutonium Exposure in the Enewetak Population by Urinalysis

L. C. Sun, C. B. Meinhold, A. R. Moorthy, E. Kaplan, and J. W. Baum

127

##### A Comparison of Independently Conducted Dose Assessments to Determine Compliance and Resettlement Options for the People of Rongelap Atoll

S. L. Simon, W. L. Robison, M. C. Thorne, L. H. Toburen, B. Franke, K. F. Baverstock, and H. J. Pettingill

133

##### The Use of Comparative <sup>137</sup>Cs Body Burden Estimates from Environmental Data/Models and Whole Body Counting to Evaluate Diet Models for the Ingestion Pathway

William L. Robison and Casper Sun

152

##### Gastrointestinal Absorption of Plutonium by the Marshall Islanders

L. C. Sun and C. B. Meinhold

167

##### HEALTH EFFECTS

##### Historical Events Associated with Fallout from BRAVO Shot—Operation Castle and 25 Y of Medical Findings

E. P. Cronkite, R. A. Conard, and V. P. Bond

176

(Continued)

---

Health Physics (ISSN 0017-9078) is the Official Journal of the Health Physics Society and is published monthly by Williams and Wilkins, 351 West Camden Street, Baltimore, MD 21201-2436. Periodicals postage paid at Baltimore, MD, and at additional mailing offices. Annual institutional subscription rate, US \$633.00; Members of the Health Physics Society may receive the journal as part of their annual membership dues (\$10.00 of which is designated for the subscription). Air mail subscriptions extra. For Japanese rates, please contact: Igaku-Shoin MYW Ltd., 3-23-14 Hongo, Bunkyo-Ku, Tokyo 113 JAPAN. Phone: (03) 5689-5400 or 5401. FAX: (03) 5689-5402. Subscription prices are subject to change without notice. The GST number for Canadian subscribers is 123394371. C.P.C. International Publication Mail #0561126. Indexed in *Current Contents (Life Sciences, Science Citation Index, SciSearch Database, ISI/BioMed, Research Alert), BIOSIS, Index Medicus, MEDLINE, Excerpta Medica, Chem. Abstr., WRC Info., Environ. Per. Bibl., Cancer Journals and Serials, Applied Health Phys. Abstr., Aqualine Astr., Current Awareness in Biological Sciences, Energy Res. Abstr., Congress. Info. Serv. Index, ASSIA, Cambridge Scientific Service, PASCAL-CNRS Database, and Energy Database.* Copyright © 1997 by Health Physics Society.

Reproduced from the journal Health Physics with permission from the Health Physics Society

# CONTENTS *(continued)*

## **Mortality of Veteran Participants in the CROSSROADS Nuclear Test**

J. Christopher Johnson, Susan Thaul, William F. Page, and Harriet Crawford 187

## **Thyroid Disease among the Rongelap and Utirik Population—An Update**

Jean E. Howard, Ashok Vaswani, and Peter Heotis 190

## **An Investigation into the Prevalence of Thyroid Disease on Kwajalein Atoll, Marshall Islands**

T. Takahashi, K. R. Trott, K. Fujimori, S. L. Simon, H. Ohtomo, N. Nakashima, K. Takaya, N. Kimura, S. Satomi, and M. J. Schoemaker 199

## **ENVIRONMENTAL STUDIES**

### **University of Washington's Radioecological Studies in the Marshall Islands, 1946–1977**

Lauren R. Donaldson, Allyn H. Seymour, and Ahmad E. Nevissi 214

### **The Ecosystem Study on Rongelap Atoll**

Richard B. Walker, Stanley P. Gessel, and Edward E. Held 223

### **Assessment of a Radioactive Waste Disposal Site at Enewetak Atoll**

Victor E. Noshkin and William L. Robison 234

### **Resuspension Studies in the Marshall Islands**

Joseph H. Shinn, Donald N. Homan, and William L. Robison 248

## **ADDITIONAL PAPERS**

### **A Compilation of Nuclear Weapons Test Detonation Data for U.S. Pacific Ocean Tests**

S. L. Simon and W. L. Robison 258

### **Some Reflections on the Role of the Scientific Advisory Panel to the Marshall Islands Nationwide Radiological Study**

A. C. McEwan, S. L. Simon, K. F. Baverstock, K.-R. Trott, K. Sankaranarayanan, and H. G. Paretzke 265

## **CORRESPONDENCE**

### **Beyond Linearity**

Kenneth L. Mossman 270

### **Response to Mossman**

H. Wade Patterson 270

## **Plutonium Distribution in the Environs of Rocky Flats**

J. Beyea and M. M. Hoenig 271

## **Response to Beyea and Hoenig**

M. I. Litaor 271

## **Accounting for Random Error in Radon Exposure Assessment**

R. William Field, Daniel J. Steck, and John S. Neuberger 272

## **BOOK REVIEWS**

### **Work Management in the Nuclear Power Industry—A Manual prepared for the NEA Committee on Radiation Protection and Public Health by the ISOE Expert Group on the Impact of Work Management on Occupational Exposure**

Reviewed by Michael T. Ryan 274

### **Nuclear Wastelands A Global Guide to Nuclear Weapons Production and Its Health and Environmental Effects**

Reviewed by Stephen V. Musolino 274

## **OTHER CONTENT**

News and Notices 275

Instructions for Submission of New Product Announcements 287

Author Guidelines 288

Submissions 291

Health Physics Society Prospectus 292

Health Physics Society Affiliate Members 293

Advertisers Guide Appears at the back of this issue

Advertisers Index Appears at the back of this issue

Up and Coming Appears at the back of this issue

*On the cover:* A reproduction of a classic photograph printed in newspapers around the world from the second nuclear test at Bikini Atoll in July 1946. There were about 42,000 observers of the test including 40,000 U.S. servicemen. Photograph courtesy of the National Archives.

## **A MESSAGE TO OUR SUBSCRIBERS**

Williams & Wilkins and most other publishers seal issues of professional journals in polywrap bags to mail to subscribers. Although these bags are very effective in protecting issues from damage during transport, they are not biodegradable and pose serious environmental problems. A number of you have written to us to suggest that we change to biodegradable plastic or paper wrappers or no wrappers at all. We have considered the alternatives and have chosen the one imposing the least environmental threat—no wrappers for issues mailing to addresses within the United States. Periodicals postage regulations require that wrappers be used to mail issues outside the United States.

We hope your issues of HEALTH PHYSICS arrive in good condition. If they do not, please call us at 1-800-638-6423.

ALMA J. WILLS  
President  
Periodical Publishing

## EDITORS' REMARKS

It is with great pleasure that we, along with Editor-in-Chief Ken Miller and the Health Physics editorial staff, bring you this special issue, *Consequences of Nuclear Testing in the Marshall Islands*. Many readers undoubtedly are thinking: Why report on the Marshall Islands now? There are several answers to that question, but certainly an important one is that the issues of radiation protection made necessary by the nuclear testing program, are still relevant today, and the assessments of health, social and ecological impacts, are still going on. Furthermore, radiation protection issues in the Marshall Islands have similarity to issues in other countries that have experienced similar events.

The genesis of this issue was in 1993 at the mid-year Health Physics Society meeting in Coeur d'Alene, ID. We began a dialogue then to discuss the possibility and the relevance of an issue devoted entirely to the Marshall Islands. It was particularly fitting at that time to plan for such a publication since two commemorative dates were approaching: (1) 1994 would mark 40 years since the infamous BRAVO test that seriously exposed Marshallese on Rongelap and neighboring atolls, and (2) 1995 would mark 50 years that the Bikini people had been gone from their traditional home, originally displaced by the nuclear testing program. Though it was not possible to publish the issue in 1994 or 1995, this issue serves to commemorate those events.

We agreed that the papers presented here needed to be scientifically based but we felt that it was also important to go beyond the hard facts of radioactivity measurements and dose assessments to provide some information on the impact that nuclear weapons testing had on the culture and society of the island country as well as the context of the events in the history of the time. Thus, you will observe a slight departure from the usual content of this Journal though all papers have undergone the customary level of anonymous peer review.

The papers presented here were authored by scientists ranging in age from those well into mature careers at the time of nuclear testing program to those who were just youngsters, too young to understand the events taking place. It is impressive just how many scientists over the decades have applied themselves to studying and solving the problems brought about by nuclear testing in the Marshall Islands, and a cross-section of those are represented by the authors of these papers.

The response of the scientific community to a formal Call-For-Papers was enthusiastic; consequently, this issue is one of the largest ever published by *Health Physics*. The papers have been arranged into what we feel to be a logical sequence: (a) History, (b) Radiolog-

ical Monitoring, (c) Dose Assessment, (d) Health Effects, (5) Environmental Studies, and (6) Additional Papers. The only topic that seemed essential for completeness but that could not be included was a description of the programs and the criteria for the radiological cleanup of Enewetak Atoll which took place from 1978 to 1980.

We are indebted to the authors, reviewers, editors and our publisher for the efforts they extended to assist in producing this special issue. In particular, we would like to acknowledge the financial support of this publication by the Office of International Health Programs of the U.S. Department of Energy. Publication cost for authors working within DOE supported programs as well as for independent authors without institutional affiliation or provisions was supported. We sincerely appreciate the assistance of the Department of Energy for making this issue possible.

We, as well as many other scientists, believe that it is worthwhile and imperative to publish these papers today. Other countries on several different continents are grappling with the same issues as in the Marshall Islands: environmental damages, health consequences, societal fear of radiation and cancer and financial issues, including costs of remediation, community rebuilding and compensation. Thus, information from the Marshall Islands should be useful in a global sense, and that fact increases the value of the information presented here.

Finally, we should all be aware of a problem that is rather difficult for us to accept: that the zealotry with which the scientific community approaches studies of radiation effects sometimes leads to a misunderstanding by those who have been exposed or believe themselves to have been exposed. The opportunity to learn from our mistakes is invaluable, but the tendency of scientists to poke and prod and sample *ad infinitum* can sometimes be misunderstood as evidence of having purposefully created the injury. We understand that the opportunity to conduct research that may be of far-reaching value has no relation to the circumstances that led to the injury. This conclusion was reached by President Clinton's investigative panel on Human Radiation Experiments in relation to the Marshall Islands exposures. As specialists in radiation protection, we owe our attention and our best efforts to the Marshallese, and in that spirit we present this issue on *Consequences of Nuclear Testing in the Marshall Islands*.

STEVEN. L. SIMON  
National Research Council  
National Academy of Sciences  
Washington, DC

Richard J. Vetter  
Mayo Clinic

Rochester, MN

