REPORT ON THE FEASIBILITY OF A STUDY OF THE HEALTH CONSEQUENCES TO THE AMERICAN POPULATION FROM NUCLEAR WEAPONS TESTS CONDUCTED BY THE UNITED STATES AND OTHER NATIONS

Volume 1
Technical Report

Prepared for the U.S. Congress
by the

Department of Health and Human Services
Centers for Disease Control and Prevention
and the
National Cancer Institute

May 2005

Acknowledgment

This report is the culmination of an effort involving many individuals who contributed technically or provided other support. Foremost, we offer our thanks to the authors of each chapter for the time and expertise they dedicated to this project. We also wish to acknowledge the valuable efforts of the science staff of the Centers for Disease Control and Prevention and the National Cancer Institute and contractors, and communications staff from both agencies. We would like to thank the Office of the Deputy Assistant Secretary for Science Policy of the Department of Health Human Services for valuable guidance in the development of this report, the Advisory Committee for Energy-Related Epidemiology Research and members of the public for their thoughtful comments during the development of the draft report, and the National Academy of Sciences' review committee for their comments and recommendations on the draft report.

Charles Miller, Ph.D.
Co-Principal Investigator
Radiation Studies Branch
National Center for Environmental Health
Centers for Disease Control and Prevention

André Bouville, Ph.D.
Co-Principal Investigator
Radiation Epidemiology Branch
Division of Cancer Epidemiology and Genetics
National Cancer Institute
National Institutes of Health

Inquiries and requests for copies should be directed to:

Charles Miller, PhD
Radiation Studies Branch
National Center for Environmental Health
Centers for Disease Control and Prevention
Mail Stop E39
1600 Clifton Road NE
Atlanta, GA 30333

List of Contributors
(in alphabetical order)

Centers for Disease Control and Prevention

Paul Garbe
Charles W. Miller
Joan Morrissey
Claudia Parvanta
Judy Qualters
J. Felix Rogers
James M. Smith
Diana Swindel
Robert C. Whitcomb, Jr.
Charles M. Wood

National Cancer Institute

André Bouville
Betsy Duane-Potocki
Ethel Gilbert
Charles Land
Anne Lubenow
Nicholas Luckyanov
Kiyohiko Mabuchi
Elaine Ron
Steven L. Simon
Robert M. Weinstock

Consultants

Lynn R. Anspaugh
Harold L. Beck

Abstract

For the first time, doses and risks of related health effects have been estimated for representative persons in all counties of the contiguous United States from a set of important radionuclides produced from testing of nuclear weapons from 1951 through 1962 by the United States and other nations. The estimated doses and risks, while rudimentary in nature, demonstrate that it is feasible to conduct a more detailed study of the health impact on American people as a result of exposure to radioactive fallout from the testing of nuclear weapons in the United States and abroad. However, significant resources would be required to implement such a study, and careful consideration should be given to public health priorities before embarking on that path. To assist in the process of making a decision about conducting future fallout-related research, five different options were developed for consideration and were subsequently reviewed by the National Academy of Sciences. Those options were:

Option 1: Conduct no additional fallout-related work;
Option 2: Retrieve and archive only the historic documentation related to radioactive fallout from nuclear weapons testing conducted by the United States and other nations;
Option 3: Conduct a more detailed dose reconstruction of radioactive fallout from global nuclear weapons testing for Iodine-131, the most significant radionuclide identified in this study;
Option 4: Conduct a more detailed dose reconstruction for multiple radionuclides in radioactive fallout from both Nevada Test Site and global nuclear weapons testing;
Option 5: Conduct a detailed study of the health effects of nuclear weapons testing fallout including, in a single project, dose estimation, risk analysis, and communication of the results to interested parties.

Precise estimates of the resources needed to complete each option considered have not been developed. However, the actual cost of some past projects is presented in the report for purposes of illustration only.

The National Academy of Sciences' Committee on Assessment of CDC Radiation Studies, in its review of the feasibility study, recommended that Options 2 and 3 should be further considered by CDC and NCI.

Table of Contents

Volume 1: Technical Report

Page

Acknowledgment ii
List of Contributors iii
(in alphabetical order) iii
Abstract iv
List of Figures vii
List of Tables ix
Executive Summary 1
Chapter 1 12
Introduction 12
1.1 Background 12
1.2 Scope of work 13
1.3 Issues outside the scope of this report 15
1.4 Organization of this report 16
Chapter 2 18
Fallout from Nuclear Weapons 18
2.1 Fallout Production Mechanisms 18
2.2 Brief Review of Nuclear Weapons Tests 20
2.3 List of Nuclear Weapons Tests 21
Chapter 3 25
Estimation of Doses from Fallout 25
3.1 Introduction 25
3.2 NTS Fallout 27
3.3 Global Fallout 55
3.4 Comparison of NTS and Global Fallout Doses 79
3.5 Summary 81
3.6 Considerations for Further Research 89
Chapter 4 99
Potential Health Consequences from Exposure of the United States Population to Radioactive Fallout 99
4.1 Introduction 99
4.2 Health Effects of Ionizing Radiation 100
4.3 Risk Analysis 107
4.4 Conclusions 122
Chapter 5 129
Communications Approach 129
5.1 Introduction 129
5.2 Components of a Proposed Communications Plan 130
5.3 Using NCI's ^{131}I/NTS Communications Project as a Model 131
5.4 Audience Profiling and Message Development 135
5.5 Developing Working Partnerships 149

5.6 Coordinating with Other Programs 150
5.7 Implementation 153
5.8 Additional Work Outside the Scope of this Report 157
5.9 Conclusion 157
Chapter 6 162
Conclusions and Options for Future Work 162
6.1 Introduction 162
6.2 Options for Future Work 162
6.3 Conclusions 168
Glossary 170

Volume 2: Appendices

Appendix A: CDC and NCI Responses to Key NAS Recommendations
Appendix B: Summary of the National Cancer Institute Report
Appendix C: ACERER Issues
Appendix D: Document Preservation and Retrieval: Current and Potential Future Activities
Appendix E: External Dose Estimates from NTS Fallout
Appendix F: Internal Dose Estimates from NTS Fallout
Appendix G: External Dose Estimates from Global Fallout
Appendix H: Internal Dose Estimates from Global Fallout
Appendix I: Communications Materials

List of Figures

Page

Figure 2.1. Locations of sites where tests were conducted prior to 1963 with greater than one megaton total explosive yield. 22

Figure 3.1. Total ^{137}Cs (Bq) deposited in the United States from NTS tests as a function of year of tests 33

Figure 3.2. Cesium-137 deposition density (Bq/m^2) due to all NTS tests. 33

Figure 3.3. Strontium-90 deposition density (Bq/m^2) due to all NTS tests. 34

Figure 3.4. Plutonium (239+240) deposition density (Bq/m^2) due to all NTS tests. 35

Figure 3.5. Estimated fractions of total ^{137}Cs deposited in the United States from NTS by year of test. 36

Figure 3.6. External dose (mGy) to the red bone marrow and the thyroid gland for both children and adults resulting from all NTS tests. 40

Figure 3.7. Fraction of food that is assumed to be locally produced for several different food categories. Values for eggs are the same as those for milk. From Whicker and Kirchner (1987). 43

Figure 3.8. Consumed fraction of non-leafy vegetables and fruits assumed to be freshly produced. From Whicker and Kirchner (1987). 44

Figure 3.9. Monthly values of integrated intake for four age groups for ^{90}Sr. Data were derived from Whicker and Kirchner (1987). 45

Figure 3.10. Monthly values of integrated intake for four age groups for ^{131}I. Data were derived from Whicker and Kirchner (1987). 45

Figure 3.11. Monthly values of integrated intake for four age groups for ^{137}Cs. Data were derived from Whicker and Kirchner (1987). 46

Figure 3.12. Internal dose (mGy) to red bone marrow of persons born 1 January 1951 from all NTS tests. 48

Figure 3.13. Internal dose (mGy) to the thyroid of persons born 1 January 1951 from all NTS tests. 48

Figure 3.14. Total (external + internal) dose (mGy) to the red bone marrow of adults in 1951 from all NTS tests. 53

Figure 3.15. Total (external + internal) dose (mGy) to the red bone marrow of persons born on 1 January 1951 from all NTS tests. 54

Figure 3.16. Total (external + internal) dose (mGy) to the thyroid of adults in 1951 from all NTS tests. 54

Figure 3.17. Total (external + internal) dose (mGy) to the thyroid of persons born on 1 January 1951 from all NTS tests. 55

Figure 3.18. Cesium-137 deposition density (Bq/m^2) due to global fallout. 61

Figure 3.19. External dose (mGy) to the red bone marrow and the thyroid gland resulting from global fallout. 63

Figure 3.20. Contribution to external exposure from global fallout from individual radionuclides as a function of year. 65
Figure 3.21. Time-dependence of external dose (population-weighted or per capita) from global fallout from individual radionuclides and as sum total. 66
Figure 3.22. Cumulative (1953 through 1963) thyroid dose as a function of birth year. The cumulative dose for an adult, or a person who was born before 1 January 1933, is about 400 μSv. 70
Figure 3.23. Annual dose as a function of time following the release of 1 PBq of ^{3}H to the atmosphere of the northern hemisphere. Results are based upon the NCRP (1979) model of tritium in the hydrological cycle. 71
Figure 3.24. Annual effective dose normalized to intake (μSv PBq^{-1}) following the release of 1 PBq of ^{14}C to the atmosphere of the northern hemisphere. Results are based upon the model of Titley et al. (1995). 73
Figure 3.25. Internal dose (mGy) to red bone marrow of adults in 1951 from global fallout. 76
Figure 3.26. Total (external + internal) dose (mGy) to the red bone marrow of adults in 1951 from global fallout. 76
Figure 3.27. Total (external + internal) dose (mGy) to the red bone marrow of persons born 1 January 1951 from global fallout. 77
Figure 3.28. Cesium-137 deposition density (Bq/m^2) due to NTS and global fallout. 81
Figure 3.29. External dose (mGy) to the red bone marrow of adults resulting from NTS and global fallout. 82
Figure 3.30. Internal dose (mGy) to red bone marrow of persons born 1 January 1951 from NTS and global fallout. 83
Figure 3.31. Total dose (mGy) to the red bone marrow of adults in 1951 from NTS and global fallout. 83
Figure 3.32. Total dose (mGy) to red bone marrow of persons born 1 January 1951 from NTS and global fallout. 84
Figure 3.33. Total dose (mGy) to red bone marrow of persons from 10 years of exposure to natural gamma radiation from the terrestrial environment (based on data provided by the U.S. Geological Survey). 85
Figure 3.34. Total dose (mGy) to red bone marrow persons from 10 years of exposure to cosmic ray radiation. (Map courtesy of Geological Survey of Canada.) 86
Figure 5.1 Selecting Target Audiences. 137

List of Tables

Page

Table 1. Summary of average thyroid and red bone marrow doses (milliGray [mGy]) from NTS and global fallout received as a result of exposure to the most important radionuclides 3

Table 2.1. A summary of atmospheric nuclear tests by major site and country (UNSCEAR 2000) 23

Table 3.1. Nuclear weapons tests conducted at NTS that are considered in the feasibility study (based on NCI 1997) 28

Table 3.2. Radionuclides in NTS fallout for which deposition densities (Bq m^{-2}) were explicitly calculated on a county-by-county basis 30

Table 3.3. Total deposition and population-weighted mean deposition density for selected radionuclides for NTS fallout. 37

Table 3.4. Collective external dose and country-average dose from NTS fallout as a function of year of testing 41

Table 3.5. Food-consumption rates used in the PATHWAY code (Whicker and Kirchner 1987). Estimates are based primarily on data summarized by Rupp (1980) for rural families. 43

Table 3.6. Population-weighted red marrow and thyroid doses from all NTS tests (mGy). 49

Table 3.7. Population-weighted (adult) effective dose from ingestion, calculated through year 2000, specified by year of testing. 49

Table 3.8. Population-weighted (adult) effective dose from ingestion for the 16 nuclear explosions giving largest predicted doses. 50

Table 3.9. Comparison of population-weighted (adult) external dose, internal red bone marrow and thyroid dose from all tests at the NTS according to radionuclide, calculated through the year 2000. 51

Table 3.10. Estimates of population-weighted (adult) organ dose and effective dose from ingestion through the year 2000 from all NTS tests. 52

Table 3.11. Estimates of Fission and Fusion Yields (Mt) by Year 56

Table 3.12. Radionuclides deposited in global fallout for which deposition densities and doses were calculated. 59

Table 3.13. Total deposition and population-weighted deposition density of selected radionuclides for NTS fallout and global fallout (sorted by decreasing half-life). 62

Table 3.14. Collective dose and population-weighted external dose versus year of exposure 64

Table 3.15. Percentage of external dose contributed by various fission products from global and NTS fallout. 66

Table 3.16. Population-weighted (adult) organ doses (mGy) and effective dose (mSv) from ingestion of ^{131}I deposited in global fallout during 1953-1963. 69

Table 3.17. Population-weighted (child) organ doses (mGy) and effective doses (mSv) to an individual born on 1 January 1951 from ingestion of ^{131}I deposited in global fallout during 1953-1963. 69
Table 3.18. Effective dose (mSv) from ingestion from the creation or release of ^{3}H and ^{14}C during the testing of large fusion weapons in the Northern Hemisphere..... 74
Table 3.19. Total population-weighted organ (mGy) and effective doses (mSv) from the deposition of ^{90}Sr and ^{137}Cs in global fallout during 1953–1972. Upper values are for those who were adults in 1951; lower values are for a person born on 1 January 1951. 75
Table 3.20. Comparison of fallout doses from internal irradiation from NTS and from global fallout sources. 78
Table 3.21. Comparison of effective dose from reported concentrations of ^{90}Sr, ^{131}I, and ^{137}Cs in milk with predicted doses from models used in this report. 79
Table 3.22 Summary of population-weighted effective (mSv) and organ doses (mGy) from NTS and global fallout as a result of exposure to the most important radionuclides. Unless otherwise specified, the values are for adults at the time of the tests. 80
Table 5.1. Broad Target Population Groups, Assumptions and Potential Communications Channels and Activities 140