Executive Summary

Introduction

In 1998, the U.S. Congress requested that the U.S. Department of Health and Human Services (DHHS) conduct an initial assessment of the feasibility and public health implications of a detailed study of the health impact on the American people of radioactive fallout from the testing of nuclear weapons. In response to the Congressional request, DHHS (primarily two DHHS agencies—the Centers for Disease Control and Prevention [CDC] and the National Cancer Institute [NCI]) made crude estimates of doses and health risks from exposure to radioactive fallout from nuclear weapons tests conducted from 1951 through 1962 at the Nevada Test Site (NTS) and other sites throughout the world ("global" tests). Those dose and risk estimates, though sufficient for purposes of the feasibility study, were rudimentary in their nature and precision and could likely be improved, as discussed in this report.

In developing this assessment, DHHS has actively solicited input from the public and from the DHHS Advisory Committee for Energy-Related Epidemiologic Research (ACERER) (the charter for the committee has expired and it no longer exists) during the initial stages of this project. Both written and oral progress reports were given to ACERER and Congressional staff during the course of the project. Copies of written progress reports were available for public review, and all written and oral comments received on these progress reports were carefully considered in the preparation of the draft technical report that was sent to Congress and posted on the CDC website in 2002.

The draft technical report, titled *A Feasibility Study of the Health Consequences to the American Population from Nuclear Weapons Tests Conducted by the United States and Other Nations*, was peer reviewed by the National Academy of Sciences/National Research Council (NAS/NRC) Committee to Review the CDC-NCI Feasibility Study of the Health Consequences from Nuclear Weapons Tests (NAS/NRC 2003). The recommendations and comments of the NAS/NRC committee were carefully considered. This final report was prepared in consideration of those recommendations. A copy of this final report is available on the Internet at http://www.cdc.gov/nceh/radiation/, and a printed copy is also available from the Radiation Studies Branch, Division of Environmental Hazards and Health Effects, National Center for Environmental Health, Centers for Disease Control and Prevention (CDC), Mail Stop E39, 1600 Clifton Road NE, Atlanta, Georgia 30333.

Findings

Radiation Dose Estimates. In this study, for the first time, doses for representative persons in all counties of the contiguous United States have been estimated from exposure to the most important radionuclides produced as a result of nuclear weapons testing from 1951 through 1962 by the United States and other nations. Any person living in the contiguous United States since 1951 has been exposed to radioactive fallout, and all organs and tissues of the body have received some radiation exposure. Doses were estimated separately for the tests conducted at NTS and the tests conducted at other sites throughout the world (global testing).

Lifetime dose estimates were calculated separately for external and internal irradiation. External irradiation results from exposure to radiation emitted outside of the body, for example, by radionuclides present on the ground. The corresponding doses are similar in most body organs and vary little with the age of the person. On the other hand, internal irradiation results from the decay of radionuclides incorporated in the body by inhalation or ingestion, with levels of exposure varying according to age and to the distribution of radionuclides in the organs and tissues of the body. For example, radioiodines concentrate in the thyroid gland, whereas radiostrontium is found mainly in bone tissues.

Because the purpose of the project was only to determine the feasibility of doing a study, there was no intention in the allowed time to develop new tools or to gather all data needed to complete an extensive study of doses to Americans from nuclear weapons tests conducted by the United States and other nations. Instead, crude dose estimates were made on the basis of reviewing a limited number of reports in details and using available dose assessment models. In some cases—particularly for the doses resulting from the intake of shorter-lived radionuclides (e.g., iodine-131) in global fallout—the doses calculated may have considerable error. Future work would improve the precision of these calculations.

The usefulness of the doses estimated in this project is limited to rudimentary evaluations of the average impact on limited health outcomes for the population of the United States. Because of the low precision of the dose estimates, they should not be used to estimate health effects for specific individuals or for subpopulations. The goal of these calculations was to determine only the feasibility of a study; therefore, the magnitude of uncertainty of these doses has not been fully evaluated. However, though the computed county-specific deposition densities and doses are uncertain, dose maps presented in this report are useful for illustrating general spatial patterns of fallout exposure for average individuals across the United States.

A summary of doses averaged over the contiguous United States is presented in Table 1 as an example of the findings from this study. Because the thyroid and red bone marrow are among the most radiosensitive organs and tissues of the body, their doses were selected as examples for presentation (Table 1). Thyroid cancer, noncancer thyroid disease, and leukemia, which arises from the red bone marrow, are the health effects that are discussed in this report.

Table 1. Summary of average thyroid and red bone marrow doses (milliGray [mGy]) from Nevada Test Site and global fallout received as a result of exposure to the most important radionuclides. The values are for adults at the time of the tests, unless otherwise specified. Blank spaces reflect negligible values of dose.

		NTS Fallout			Global Fallout		
Radionuclide	Half-life	External dose[a] (mGy)	Thyroid internal dose (mGy)	Red bone marrow internal dose (mGy)	External dose[a] (mGy)	Thyroid internal dose (mGy)	Red bone marrow internal dose (mGy)
Tritium	12.3 years					0.07	0.07
Carbon-14	5730 years					0.1	0.1
Manganese-54	313 days				0.04		
Strontium-89	52 days		0.001	0.03			
Strontium-90	28.5 years			0.02		0.0009 [0.002][b]	0.2 [0.5][b]
Zirconium/Niobium-95	64 days	0.08			0.2		
Zirconium/Niobium-97	17 hours	0.02					
Ruthenium-103	39 days	0.03			0.02		
Ruthenium-106	368 days		0.001	0.002	0.04		
Antimony-125	2.7 years				0.03		
Iodine-131	8 days	0.02	5 [30][b]	0.001		0.4 [2][b]	0.00009 [0.0002][b]
Tellurium/iodine-132	3.3 days	0.1	0.06	0.001			
Iodine-133	0.9 days	0.02	0.04				
Cesium-136	13 days		0.002	0.002			
Cesium-137	30 years	0.01	0.009	0.009	0.3	0.1	0.1
Barium/lanthanum-140	13 days	0.2		0.006	0.05		
Cerium-144	284 days				0.02		
Neptunium-239	2.4 days	0.02					
Rounded totals: • Adults		0.5	5	0.1	0.7	0.7	0.6
• Child born 1 January 1951.			[30][b]			[2][b]	[0.9][b]

[a]The external dose is equal for all organs of the body.
[b]Values in brackets are for a child born 1 January 1951.

As shown in Table 1, the estimated average total internal doses from global fallout are considerably smaller for the thyroid but greater for the red bone marrow than those from NTS fallout, whereas the doses from external irradiation are similar for NTS and global fallout. Additionally, as illustrated in Table 1, the mixture of radionuclides contained in fallout is different for the two sources of fallout. As a result, the temporal and geographic distributions of doses from NTS and global fallout differ substantially. For the nuclear weapons tests conducted at NTS, fallout occurred predominantly in the western states surrounding NTS; the short-lived radionuclides, identified by a short half-life (column 2 in

Table 1), were key components of the NTS fallout, and the highest doses to Americans were from iodine-131. In contrast, global fallout exposures were higher in areas with high precipitation rates, such as the eastern states; the long-lived radionuclides, such as cesium-137 and strontium-90, were in much greater abundance in global fallout than in NTS fallout.

Risk Assessment. The relation between the dose from radioactive materials and the risk of disease in a population may be described by models that express health risk as a function of dose and factors that modify risk, such as age at exposure and gender. Because some of the components of these models are uncertain, estimates of risk are uncertain. Any evaluation of risk depends on the development of more refined dose estimates that account for the uncertainties. To the extent that reliable dose estimates can be provided, it is feasible to estimate the lifetime risks of developing organ-specific cancer associated with fallout exposures for populations or population subgroups. It is also feasible, but difficult, to quantify the very large uncertainties in these risk estimates.

Some estimates of the average risk to the United States population for the categories of all cancers, leukemia, and thyroid cancer have been developed using the crude doses estimated in this feasibility study. With the exception of thyroid cancer, the risk estimates were developed using simple approaches, and are provided in this report for illustration only. These risks are used to illustrate the feasibility of a more detailed study, and to provide an approximate estimate of the potential impact of fallout radiation on the American population.

The NCI previously conducted a detailed reconstruction of doses to the thyroid gland for iodine-131 from tests at the Nevada Test Site (NCI 1997). Those dose reconstructions were subsequently used to estimate that between 11,300 and 212,000 (median value of 49,000) thyroid cancers would be expected to occur among the United States population from exposure to iodine-131 from NTS (IOM 1999). The wide range in the number of thyroid cancers predicted (11,300 to 212,000) illustrates the large uncertainty that such estimates carry. Consideration of global fallout would likely increase those estimates by about 15%. However, the global dose estimates have a larger degree of uncertainty; therefore, the range of the number of predicted cancers would become relatively larger. This example for thyroid cancer illustrates the issue of estimating risks with their inherent uncertainties.

The average external dose from all radionuclides over the period 1951–2000 from both NTS and global fallout is estimated to be about 1.2 mGy (Table 1), and estimates of the total cancer risk from that exposure have been made in this report. For example, the population of 3.8 million people born in the United States in 1951 will likely experience fewer than 1,000 extra fatal cancers as a result of fallout exposures, a lifetime risk of less than 0.03% or about 1 in 3800. This number may be compared with the approximately 760,000 fatal cancers that would be predicted in the absence of fallout. It is expected that the largest number of excess cancer deaths would occur in the group of people born in 1951, because, on average, this group received higher doses at younger ages than groups born earlier or later. It is also estimated that about 11,000 extra cancer deaths from all cancers, including leukemia, would be predicted to occur among the population of the United States alive at any time during the years 1951–2000 as a result of external exposure to fallout. (The predicted number of incident cases [including nonfatal cases] would be about double the number of deaths, or about 22,000.) Radiation doses from external exposure are more uniform over geographic areas than are thyroid doses and do not vary substantially according to age or lifestyle habits. Thus, cancer risks for all cancers from external exposure are likely to vary less by geographic location, birth cohort, and other factors than are risks for thyroid cancer from NTS iodine-131 exposure. This lack of obvious high-exposure areas or populations makes it less likely that there will be groups with particularly large risks.

Leukemia is perhaps of special interest because it has been strongly linked with radiation in many epidemiologic studies and because bone-seeking radionuclides, such as strontium-90, are found in fallout. About 10%, or 1,100, of the 11,000 extra cancer deaths from external exposure might be predicted to result from leukemia. It is estimated that as a result of internal exposure of the red bone marrow to fallout radionuclides, an additional 550 cases of leukemia may occur among the population of the United States that comprises people who were alive at any time during the years 1951–2000. For the approximately 3.8 million people born in 1951, it is estimated that 17 extra cases of fallout-related leukemia will occur (a risk of 1 in 220,000) from internal exposure.

On the basis of the crude estimates of dose and risk developed in this feasibility study, fallout radiation appears to have the greatest effect on risk for thyroid tumors. Risk for leukemia would be lower. Risk for cancers of other organs or tissues could be assessed as well, but because of the smaller amount of information available about radiation-associated health effects for those organs and tissues and the lower doses received by most organs, the uncertainties associated with such estimates would be extremely large.

Characterization of the cancer risk to the American people could be enhanced through improvements in methodology, for example, better quantification of uncertainties in models for expressing risks for specific cancers, identification of potentially highly exposed populations, and characterization of lifestyle and other behavioral factors that could affect the potential for exposure and for risk. However, even with these improvements, risk estimates that are developed for fallout exposures would remain highly uncertain. Additionally, such estimates represent the average risk to members of a population group who share common characteristics such as age, place of residence, and dietary factors. The true risk to individuals in the United States may vary substantially from the average for many reasons, for example, a difference between their actual dose and the predicted value, other environmental exposures, their lifestyle patterns, their individual susceptibility to radiation effects, and the random nature of the predicted risk. Hence, although it should be possible to give individuals an indication of whether their geographic location, age, or lifestyle during the years of nuclear testing have increased the likelihood of their developing certain radiation-related cancers, accurately determining the risk for specific individuals is not possible.

With regard to noncancer health outcomes, a quantitative risk analysis is not feasible in the near term. For most noncancer outcomes, more fundamental research is needed to quantify the relation between low, protracted radiation dose and disease and/or the uncertainty associated with the estimated risk. Among these noncancer physical health outcomes, diseases of the thyroid gland have the greatest potential for occurrence.

Development of a Health Communication Strategy. One of the most important public health requisites of performing a detailed dosimetric and risk analysis study is the need to clearly communicate the results of the study to the American public and to health care providers. The results obtained during this feasibility study are too rudimentary to warrant developing a plan for comprehensive nationwide education. The effort to communicate the results from the research carried out in a more detailed study would be extremely challenging. However, if a more detailed study is done, it would be especially important to carefully explain the potential health consequences associated with exposure to numerous radionuclides in fallout, the limitations of what science can provide (in particular, the uncertainty in estimates of dose and risk), and information regarding possible implications.

In regard to communication and education for the general public and for health care providers, it would be important to include right-to-know issues and to educate the American public about estimates of fallout exposures and risk factors for diseases related to radiation. With this information, people could determine their probable risk category and decide what health steps are necessary on the basis of that information. It would be equally important that a component of the communication and education be directed toward physicians and other health care providers so they can serve as a source of information to the public and can help with patients' decision making.

A communication plan as described would require significant funding and personnel resources. Whereas communication is an integral part of a more detailed study, the scope and design of any communication plans would need to carefully balance the desires of stakeholders with the public health priority of fallout exposures. For example, the public could receive information on the potential health consequences from nuclear test fallout in a phased approach, drawing on the efforts under way by NCI for the iodine-131/NTS communications project. If the model for that project proves effective, it could be used by federal agencies and nonfederal groups to communicate information regarding dose estimates and health risks from other exposures from the NTS and global testing as they are developed.

Options for Future Work

The findings of this feasibility study suggest that the health risks from exposure to fallout from past nuclear weapons tests may be small, but the findings also demonstrate that conducting a detailed study of the health impact on the American people as a result of exposure to radioactive fallout from the testing of nuclear weapons in the United States and abroad is technically possible. Significant resources would be required to implement this detailed study, however, and careful consideration should be given to public health priorities before this path is taken.

To assist decision-makers in the process of determining whether future fallout-related work is warranted, CDC and NCI have developed five different options for consideration. CDC and NCI have not developed detailed estimates of the resources needed to complete each option considered. However, the actual cost of some past projects is presented for purposes of comparison only.

Option 1. Conduct no additional fallout-related work.

The dose and risk estimates presented in this report are crude in nature, as has been discussed. Estimates of uncertainty have not been quantified for many of these estimates, they are subject to a variety of errors, and they are incomplete. Nevertheless, the dose and risk estimates presented here may be sufficient for making decisions on appropriate public health follow-up.

Option 2. Retrieve and archive the historic documentation related to radioactive fallout from nuclear weapons testing conducted by the United States and other nations.

Although a large number of summary reports related to nuclear weapons fallout have been published, many of the primary documents upon which these summary reports are based will be lost forever if they are not protected soon. Hence, documents could be collected and protected immediately. The National Center for Environmental Health (NCEH) of the Centers for Disease Control and Prevention (CDC) has been actively involved in document retrieval and document database development since 1992. Document location, retrieval, and database development have cost $3 million to $5 million and have taken 2–4 years to complete at each of three nuclear weapons research and development sites where CDC has worked.

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.

As noted earlier, the crude estimates of dose and risk discussed in this report indicate that fallout radiation has the greatest impact on risks of thyroid tumors. NCI previously completed a detailed dose reconstruction and basic risk analysis for iodine-131 fallout received from the Nevada Test Site (NCI 1997, IOM 1999). The NCI project cost approximately $3 million and took many years to complete. Follow-up activities included developing an Internet site where people can obtain an estimate of their individual dose and implementing a communications project to inform people in the United States about the results of this study and its potential public health implications (http://www.nci.nih.gov/i131).

Considering global fallout would likely increase the dose and risk estimates previously developed for iodine-131 from NTS fallout by about 15% over the entire population of the United States. However, the distribution of thyroid dose among the U.S. population would be different for NTS and global fallout because the tests occurred at several years' intervals, and the geographic patterns of deposition of iodine-131 on the ground were significantly different for the two types of tests. Therefore, it might be desirable to perform a detailed dose reconstruction and basic risk analysis for Iodine-131 in global fallout, and incorporate that information into the existing NCI Internet site and communications plan. This effort should also include collecting and protecting primary documents related to nuclear weapons testing (Option 2).

Option 4. Conduct a more detailed dose reconstruction for multiple radionuclides in radioactive fallout from both Nevada Test Site and global nuclear weapons testing.

The work that has now been completed demonstrates that it is technically possible to conduct a more detailed study of the health consequences to American people from exposure to radioactive fallout from the testing of nuclear weapons in the United States and abroad. Numerous possible subject areas exist that can be investigated to improve the present crude dose estimates provided in this report and to provide a more complete historical record of the nature of the releases from the weapons testing and the resulting exposures received by Americans from NTS and global fallout.

It would be feasible to expand on Option 3, above, and perform a detailed dose reconstruction and basic risk analysis not only for iodine-131 in global fallout but also for other radionuclides found in both NTS and global fallout. The results of that dose reconstruction and risk analysis could then be incorporated into the existing NCI Internet site and communications plan. This effort should also include collecting and protecting primary documents related to nuclear weapons testing (Option 2).

The cost and staffing requirements for implementing Option 4 would depend on the level of detail undertaken beyond that presented in the report in this report. For example, CDC's NCEH has been involved in a comprehensive dose reconstruction for the Department of Energy's nuclear weapons production site at Hanford, Washington, since 1992. That project involves portions of the states of Washington, Oregon, and Idaho, and it includes nine Native American nations. The Hanford project has cost approximately $30 million to date. Option 4 would, of course, involve 50 states, and it could include numerous population subgroups; however, the study could not be carried out with the same level of detail as the Hanford project, because the relevant information would not be available for many of the states, and because much higher staffing levels would be required.

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.

This option differs from Option 4 primarily in the type of communication campaign and in the level of risk characterization that would be undertaken. Option 4 proposes to use existing communication planning being undertaken by NCI. Option 5 would expand NCI's effort to develop a nationwide communications campaign.

Costs and staffing requirements for communications efforts are dependent on the results of the dose reconstruction and the risk assessment work and on what public health implications are learned through that work. However, other issues will also need to be considered. For example, even if results from the dose reconstruction and risk analysis do not provide a risk-based rationale for conducting a large-scale, nationwide communications campaign, public right-to-know and social justice issues may affect the scale and reach of the campaign. CDC and NCI's diethylstilbestrol (DES) National Education Campaign (a smaller-scale national campaign specific to individuals exposed to DES *in utero* and their health-care providers) is estimated to have cost $3 million to $5 million for the planning phase alone. Funding and resource needs for the implementation phase of the DES campaign are expected to increase exponentially during the implementation and distribution phase. In another example, in the late 1980s CDC mailed information on Acquired Immune Deficiency Syndrome (AIDS) to every household in the United States. This mailing cost more than $30 million.

Also, many issues have been raised in this feasibility study that transcend the mandate of DHHS. For example, the Department of Energy is responsible for maintaining many of the environmental monitoring records that are needed for a detailed study, and the Department of Defense may need to grant access to classified records required for improving some of the dose estimates. If additional research is directed, a trans-federal advisory committee could be established to provide advice on conducting future activities. Such a committee could be composed of independent scientists familiar with technical aspects of the proposed activities and representatives from appropriate federal agencies, state public health agencies, and public stakeholder groups.

For the past 8 years, CDC's NCEH has been actively working with a number of committees chartered in accordance with the Federal Advisory Committee Act, including the former ACERER. The annual cost of each of the remaining health effects advisory committees is approximately $500,000. In addition, two full-time professionals and one or two support staff members or the equivalent is required to support the activities of each advisory committee.

Recommendations of the National Academy of Sciences Committee

The recommendations of the NAS/NRC Committee to Review the CDC-NCI Feasibility Study of the Health Consequences from Nuclear Weapons Tests regarding further fallout-related work are reproduced below from the committee's report (NAS/NRC 2003). Only recommendations not already implemented are abstracted here. The previous discussion of challenges to implementing Options 1-5 also address some of the barriers to carrying out these recommendations.

Estimates of dose from Nevada Test Site and global fallout

> "CDC and NCI should consider performing a reanalysis of the ^{131}I exposures to the American public that would incorporate new dosimetry-related information from Chernobyl and elsewhere, the contribution of global fallout, a more comprehensive uncertainty analysis, and correction of acknowledged errors in previous dosimetry."

Document location and retrieval

> "The committee recommends an effort to retrieve and archive additional relevant information about the nuclear-weapons testing program."

Estimates of cancer and non-cancer risks

"The committee recommends that more emphasis be placed on levels of individual risk and the associated uncertainty and less on population risk from collective dose."

Communication with the public about exposure and cancer risk

"The committee recommends that CDC follow these steps related to communication issues:

1. Develop a detailed public summary and a communication plan for its distribution. The public summary should provide information that can be readily understood by the lay public, including comparison of background radiation with the radiation doses discussed in the report of the feasibility study and a description of the important uncertainties (related to dose and risk) that apply to the feasibility study.
2. Phase information from the feasibility study into the ^{131}I/Nevada Test Site Communication Plan in a timely fashion to give interested American citizens a more complete picture of their exposure to NTS and global fallout with appropriate explanations of relative health risks.
3. If Option 5 is adopted and important new scientific work develops, produce a timely major educational effort that builds on the efforts of the communication plan for the ^{131}I/Nevada Test Site study.
4. Make studies on radiation exposure of US citizens transparent and accessible to interested individuals. The committee recommends that interested citizens take part in the study process and, with scientific and social science experts, serve as members of advisory boards for such studies.
5. Hold a follow-up conference, similar to the one sponsored by NCI on risk communication (January 2000), as part of the continuing CDC effort to develop effective guidelines for communicating radiation risk to the American public."

Conclusions

Radiation doses and health risks to representative Americans as a consequence of exposure to radioactive fallout from NTS and testing sites located in other countries were estimated. The estimated doses and health risks should be considered as preliminary, because not all methods and sources of data to improve them have been explored yet. However, the calculations presented demonstrate that it is feasible to make such estimates and it is possible to improve the precision of the estimated doses and health risks.

The findings of this feasibility study suggest that the health risks from exposure to fallout from past nuclear weapons tests may be small but that it is technically feasible to conduct a detailed study of the health effect on American people as a result of exposure to radioactive fallout from the testing of nuclear weapons in the United States and abroad. The draft of this technical report was peer reviewed by the NAS/NRC Committee to Review the CDC-NCI Feasibility Study of the Health Consequences from Nuclear Weapons Tests. To the extent possible, the NAS/NRC committee's recommendations were taken into account in this final report.

References

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