PROGRESS REPORT

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

A 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

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PROGRESS REPORT TO CONGRESS

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Executive Summary

In 1998, the Congress requested that the Department of Health and Human Services (HHS) 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. This request resulted in a joint project by scientists at the Centers for Disease Control and Prevention (CDC) and the National Cancer Institute (NCI). This Progress Report summarizes the technical results of the project. It has been prepared for HHS' transmittal to the U.S. Senate Appropriations Committee.

In this project, for the first time, preliminary dose estimates for representative persons in all counties of the contiguous United States have been estimated for the most important radionuclides produced as a result of nuclear weapons testing from 1951 through 1962 by the United States and other nations. This Progress Report includes a summary of average doses to two organs of the body, the thyroid and the red bone marrow, as a result of exposure to 19 radionuclides contained in fallout. The values are presented for both adults and children at the time of the tests.

Some estimates of the average risk to the United States population for the categories all cancers, leukemia, and thyroid cancer specifically have been developed using the preliminary dose estimates from this feasibility study and previous work by the NCI. These risks are summarized in this Progress Report. On the basis of the preliminary estimates of dose and risk developed in this feasibility study, fallout radiation appears to have the greatest impact on risks for thyroid cancer. Risks for leukemia would be lower. 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 and the lower doses to most organs, the uncertainties associated with these estimates would be extremely large. With regard to non-cancer health outcomes, a quantitative risk analysis is not feasible in the near term.

An extensive two-volume draft Technical Report that provides the details of the work completed by this project and discussed in this Progress Report has been prepared. The draft Technical Report will be peer reviewed by the National Academy of Sciences' Committee on Assessment of CDC Radiation Studies. No formal recommendations concerning future fallout-related work should be made until peer review of the draft Technical Report for this feasibility project is complete.

Introduction

In 1998, the Congress requested that the Department of Health and Human Services (HHS) 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 that request, HHS has developed preliminary estimates of dose and health risks from exposure to radioactive fallout from nuclear weapons tests conducted from 1951 through 1962 at the Nevada Test Site (NTS), as well as at other sites throughout the world ("global" tests).

In developing this assessment, HHS has actively solicited input from the public and from the Advisory Committee for Energy-Related Epidemiologic Research (ACERER). Both written and oral progress reports have been given to ACERER and Congressional staff during the course of the project. Copies of previous, 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 Technical Report.

Timeline for Technical Report Completion

Scientists at the CDC and at the NCI have prepared an extensive two-volume Technical Report providing details on the scientific methods and conclusions of this feasibility study. The draft Technical Report will be peer reviewed by the National Academy of Sciences' Committee on Assessment of CDC Radiation Studies. A report from that committee is expected six to nine months after initiation of the committee's deliberations. In addition, the Technical Report will be available in draft for public review on the Internet at http://www.cdc.gov/nceh/radiation/default.htm. A printed copy of the draft will also be available from the Radiation Studies Branch, Division of Environmental Hazards and Health Effects, National Center for Environmental Health, Centers for Disease Control and Prevention, Mail Stop E39, 1600 Clifton Road NE, Atlanta, Georgia 30333; phone: (404) 498-1800; fax: (404) 498-1811; email: NTS and Global Fallout Report@cdc.gov

All comments received will be carefully considered in the preparation of the final version of the Technical Report. No formal recommendations concerning future fallout-related work should be made until peer review of the draft Technical Report for this feasibility project is complete.

Summary of Activities

The activities undertaken during this project can be divided into five major areas:

- Document location and retrieval;
- Radiation dose estimation;
- Review of epidemiologic literature;
- Risk assessment; and
- Development of a health communication strategy.

Some preliminary findings from each of these areas are discussed in the sections that follow.

Document Location and Retrieval. An extensive search has been made for documents related to nuclear weapons fallout. 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 located and archived soon. Documents related to nuclear weapons testing will always be valuable to the scientific and health community.

Radiation Dose Estimation. At the beginning of this project, information on radiation doses received by the American people across the continental United States from nuclear weapons testing was sparse. Some estimates were presented in the NCI report on Iodine-131 exposures from the tests conducted at the NTS (NCI, 1997) and in the reports of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (for example, UNSCEAR, 2000), in which dose estimates from all nuclear weapons tests are averaged for the populations of large latitude bands. In addition, an abundant, but highly fragmented, literature was available on measurements of radionuclides in various environmental media and on dose estimates for specific locations or regions. In this project, for the first time, preliminary dose estimates for representative persons in all counties of the contiguous United States have been estimated for 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. For persons employed in the nuclear industry at this time, these fallout doses would have been in addition to any occupational doses they may have received. Fallout doses were estimated separately for the tests conducted at the NTS and for the tests conducted at other sites throughout the world (global testing) and then combined, partly for the following three reasons: (1) the data available for estimating fallout were not of the same type for the tests conducted at the NTS and for the global tests, so different methods had to be used; (2) fallout from these two sources resulted in dissimilar geographic patterns of deposition of radioactivity across the contiguous United States; and (3) the relative importance of the various radionuclides was not the same for the tests conducted at the NTS and for the global tests, resulting in differences in the relative importance, by organs, of the doses.

Lifetime dose estimates were calculated separately for external and for 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. In this feasibility study, two approximations were made: external dose to the red bone marrow is equal to external dose to the thyroid gland, and external dose does not depend on age. On the other hand, internal irradiation results from the decay of radionuclides incorporated into the body by inhalation or ingestion, with levels of exposure varying according to the distribution of radionuclides in the organs and tissues of the body; for example, radioiodines concentrate in the thyroid gland, whereas radiostrontium is mainly found in bone tissues. In this feasibility study, particular attention was given to the dose estimates for the thyroid gland and for the red bone marrow, as thyroid diseases and leukemia were presumed to be potential health effects resulting from fallout exposures.

Because the purpose of the project was only to determine feasibility, there was no intention in the required timeframe 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, preliminary doses have been calculated on the basis of a detailed review of a limited number of reports and 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 estimates, these doses should not be used to estimate health effects for specific individuals or for subpopulations. The goal of these calculations was to determine feasibility only, and, therefore, the magnitude of the uncertainty of these doses has not always been evaluated. Although the computed county-specific deposition densities and doses (presented in a series of maps in the Technical Report) are uncertain, dose maps, such as shown in the Figure, are useful to illustrate general spatial patterns of fallout exposure for average individuals across the United States.

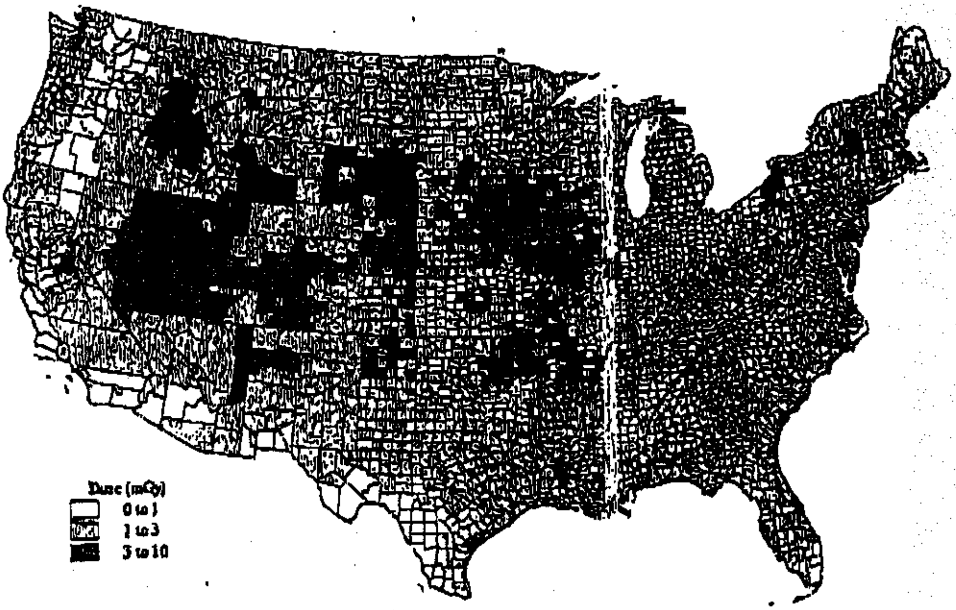

Figure. Preliminary estimates of the total radiation dose (milliGray [mGy]) to the red bone marrow of children born 1 January 1951 from NTS and global fallout for all radionuclides.

As examples of results from this study, a summary of doses averaged over the contiguous United States is presented in the Table at the end of this report. 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). Thyroid cancer, non-cancer thyroid disease, and leukemia, which arises from the red bone marrow, are health effects that could be studied if a more detailed evaluation is conducted.

Review of Epidemiologic Literature. Mainly because of the results of the ongoing studies of atomic bomb survivors in Hiroshima and Nagasaki and of patients receiving medical radiation, a great deal is known about a wide variety of health effects resulting from acute external irradiation delivered at relatively high dose levels. There is, however, only limited knowledge of health effects from chronic, low doses of internal irradiation from radionuclides such as Iodine-131. A number of populations outside the United States have been exposed to higher levels of radioiodine and other radionuclides than the United States population. These populations include residents of the Republic of the Marshall Islands; people living near the nuclear weapons test site in Semipalatinsk, Kazakhstan; people exposed to large releases from the Chernobyl nuclear power station accident in Ukraine; and people living near the Mayak nuclear fuel reprocessing plant in Russia. Ongoing dosimetric and epidemiologic studies of these populations, as well as other groups such as workers exposed on the job, have provided some useful initial data that may advance our knowledge of the health consequences of radiation exposure resulting from radionuclide intakes. In particular, preliminary results from the Chernobyl studies indicate that internal exposure to Iodine-131 in childhood can increase the risk of developing thyroid cancer, although the magnitude and duration of the risk cannot yet be quantified accurately. Also, ongoing studies of populations living near the Mayak nuclear fuel reprocessing plant in Russia may improve the risk estimate for leukemia associated with protracted radiation exposure. Expansion or enhancement of these investigations may be useful to better characterize radiation risks associated with chronic, low doses resulting from exposure to fallout.

Epidemiologic studies conducted so far in the United States have suggested an association between exposure to NTS fallout and thyroid neoplasms as well as leukemia, although these findings are not definitive. The University of Utah is extending the follow-up for a previous epidemiologic study of children who lived in the vicinity of the NTS in the 1950s; results are expected to be available in a few years.

Risk Assessment. The relation between the dose from radioactive materials and the risk for 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. These risk models also involve assumptions needed in extrapolating risk data from relatively high doses to chronic low doses and also from laboratory animal species to humans. 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 take into account their uncertainty. 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 all cancers, leukemia, and thyroid cancer have been developed using the preliminary doses estimated for this feasibility study and thyroid doses from previous work by NCI on NTS fallout. With the exception of thyroid cancer, the examples were developed using simple approaches. Because uncertainty in the preliminary doses estimated for this feasibility study has not been quantified, uncertainty in the risk of all cancer and leukemia cannot be fully evaluated. These risks are used to illustrate the feasibility of a more detailed study and to provide a preliminary estimate of the potential impact of fallout radiation on the American population.

The NCI has previously conducted a detailed reconstruction of doses to the thyroid gland for Iodine-131 from tests in Nevada (NCI 1997). These doses were subsequently used to estimate that between 11,300 and 212,000 thyroid cancers would be expected to occur among the United States population from exposure to Iodine-131 from the NTS (IOM 1999). The wide range in the number of thyroid cancers predicted (11,300 - 212,000) illustrates the large uncertainty that such estimates carry. Consideration of global fallout would likely increase these estimates by about 10 percent. However, the global dose estimates have a larger degree of uncertainty and, therefore, the range of the number of predicted cancers would become relatively larger. This example for thyroid cancer illustrates the possibility of estimating risks with their inherent uncertainties.

In this feasibility study, the average external dose from all radionuclides from both NTS and global fallout is estimated to be about 1.2 mGy (Table). It is estimated that about 11,000 extra deaths from all cancers, including leukemia, would occur among the population of the United States who were alive at any time during the years 1951-2000 as a result of external exposure to fallout. (The predicted number of incident cases [including non-fatal cases] would be about double the number of deaths or about 22,000) More informative are deaths from cancer estimated for persons born in specific years. For example, among the 3.8 million people born in the United States in 1951 there will likely be fewer than 1,000 additional fatal cancers as a result of fallout exposures in contrast to 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 that group of persons born in 1951, because, on average, this group received higher doses at younger ages than groups born earlier or later. Radiation doses from external exposure are more uniform over geographic areas and do not substantially vary 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 of thyroid cancer from NTS Iodine-131 exposure. This lack of obviously high exposure areas or populations makes it more difficult to identify groups with particularly large risks.

Leukemia is of special interest primarily because it has been strongly linked with radiation in many epidemiological studies and because bone-seeking radionuclides, such as Strontium-90, are found in fallout. In estimating leukemia risk, predictions of lifetime leukemia mortality approximate lifetime leukemia incidence. About 10 percent or 1,100 of the 11,000 cancer deaths from external exposure may be predicted to be from leukemia. It is estimated that an additional 550 deaths (cases) from leukemia may occur among the population of the United States who were alive at any time during the years 1951-2000 as a result of internal exposure to the red bone marrow from fallout radionuclides. For the approximately 3.8 million persons born in 1951, it is estimated that 17 excess deaths (cases) from fallout-related leukemia will occur in this group (a risk of 1 in 220,000) from internal exposure.

On the basis of the preliminary estimates of dose and risk developed in this feasibility study, fallout radiation appears to have the greatest impact on risks for thyroid cancer. Risks for leukemia would be lower. 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 and the lower doses to most organs, the uncertainties associated with these 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 will remain highly uncertain. In addition, 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, e.g., a difference in their dose from the predicted value, their lifestyle patterns, other environmental exposures, 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 non-cancer health outcomes, a quantitative risk analysis is not feasible in the near term. For most non-cancer outcomes, more fundamental research is needed to quantify the relation between low, protracted radiation dose and disease and the uncertainty associated with the estimated risk. However, among these non-cancer 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 implications of performing a detailed dosimetric and risk analysis study is the need to communicate clearly the results of the study to the American public and healthcare providers. The results obtained during the feasibility study are too preliminary 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, explaining carefully 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 are especially important.

Any education and public awareness plan would need to focus on communication and education for the general public and on training healthcare providers. It would be prudent public health practice 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, so that 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 be directed toward physicians and other health-care providers so they can serve as a source of information for the public and can help with the decision-making process of the patients.

Although communication is an integral part of a more detailed study, the scope and design of any plans would need to carefully balance the desires of stakeholders with the public health priority of fallout exposures. For example, the American 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/Nevada Test Site Communications Project. If that model proves effective, Federal agencies and non-Federal groups could use it to communicate information as it is developed regarding dose estimates and health risks for other exposures from the NTS and global testing.

Conclusions

Scientists at CDC and NCI have prepared an extensive two-volume draft Technical Report that provides the details of the work completed by this project and discussed in this Progress Report. The draft Technical Report will be available for public and scientific review and it will be peer reviewed by the National Academy of Sciences' Committee on Assessment of CDC Radiation Studies. All comments received will be carefully considered in the preparation of the final version of the Technical Report. No formal recommendations concerning future fallout-related work should be made until peer review of the draft Technical Report for this feasibility project is complete.

References

IOM. Institute of Medicine. National Research Council. *Exposure of the American People to Iodine-131 from Nevada Nuclear-Bomb Tests. Review of the National Cancer Institute Report and Public Health Implications.* Washington, DC: National Academy Press; 1999.

NCI. National Cancer Institute. *Estimated Exposures and Thyroid Doses Received by the American People from Iodine-131 in Fallout Following Nevada Atmospheric Nuclear Bomb Tests.* Bethesda, MD: NCI; 1997.

UNSCEAR. United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and Effects of Atomic Radiation. *Sources and Effects of Ionizing Radiation.* New York: United Nations; 2000.

Table. 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. 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[a]	External Dose[b] (mGy)	Thyroid Internal Dose (mGy)	Red Bone Marrow Internal Dose (mGy)	External Dose[b] (mGy)	Thyroid Internal Dose (mGy)	Red Bone Marrow Internal Dose (mGy)
Tritium	12.3 y					0.07	0.07
Carbon-14	5730 y					0.1	0.1
Manganese-54	313 d				0.04		
Strontium-89	52 d		0.001	0.03			
Strontium-90	28.5 y			0.02		0.0009 [0.002][c]	0.2 [0.5][c]
Zirconium/Niobium-95	64 d	0.08			0.2		
Zirconium/Niobium-97	17 h	0.02					
Ruthenium-103	39 d	0.03			0.02		
Ruthenium-106	368 d		0.001	0.002	0.04		
Antimony-125	2.7 y				0.03		
Iodine-131	8 d	0.02	5 [30][c]	0.001		0.4 [2][c]	0.00009 [0.0002][c]
Tellurium/Iodine-132	3.3 d	0.1	0.06	0.001			
Iodine-133	0.9 d	0.02	0.04				
Cesium-136	13 d		0.002	0.002			
Cesium-137	30 y	0.01	0.009	0.009	0.3	0.1	0.1
Barium/Lanthanum-140	13 d	0.2		0.006	0.05		
Cerium-144	284 d				0.02		
Neptunium-239	2.4 d	0.02					
Rounded totals: - Adults - Child born 1 January 1951		0.5	5 [30][c]	0.1	0.7	0.7 [2][c]	0.6 [0.9][c]

[a] y=years; d=days; h=hours.
[b] The external dose is equal for all organs of the body.
[c] Values in brackets are for a child born 1 January 1951