A Perspective on Public Concerns about Exposure to Fallout from the Production and Testing of Nuclear Weapons.

2001 Annual Meeting of the National Council on Radiation Protection and Measurements

April 2001 – Crystal Springs, Virginia

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Abstract **-** Exposures to the American public occurred nationwide from the testing of nuclear weapons in the U.S., the Pacific, and the former U.S.S.R. After decades of diminished public awareness on the subject of health risks resulting from exposure to fallout, the release of the National Cancer Institute's 1997 report on nationwide exposure to I-131 from the Nevada Test Site has led to renewed interest. Public requests for information are focused on individual and family health problems, the right to credible and full disclosure of information, and the need for medical care and assistance for exposure-related health problems. Public concerns have been raised regarding:

(a) the lack of information on the potential health risks from exposure to all biologically significant radionuclides in fallout,

(b) the lack of independent oversight that includes public participation,

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(c) governmental portrayal of exposures averaged over very large segments of the population without identification of much larger values for individuals or population subgroups likely to be at highest risk, and

(d) a governmental response to known or suspected human exposures that consumes large periods of time and devotes considerable funding to various research-related activities before serious consideration is given to addressing health care responsibilities to exposed individuals.

To some extent, these complaints and concerns are rooted in the legacy of government secrecy surrounding the development and testing of nuclear weapons, public distrust of government sources of information about radiation exposures and health risks, and the injustice of past exposures imposed without informed consent.

Members of the public participating in the oversight of dose reconstruction projects and epidemiologic studies are requesting information on the total impact from all relevant sources of exposure at each site that might contribute significantly to an individual s risk, including exposure to local releases and to NTS and global fallout. Information is being requested on individual doses and risks from these cumulative exposures, with estimates of uncertainty, including estimates of the absorbed organ dose (as opposed to the effective dose), the risk of disease incidence as opposed to the risk of a cancer fatality, and the chance that a person s diagnosed disease was caused by past exposure (i.e., the probability of causation).

This paper attempts to address some of these concerns. We conclude by noting that many exposed in childhood during the 1950s to ^{131}I in fallout from nuclear weapons production and testing would qualify for compensation and medical care if the present rules for the adjudication of claims for atomic veterans and radiation workers at DOE sites were to be extended to the public.

Introduction.

During the fall of 2000, we were invited by Dr. Harold Beck to present our perspectives on public concerns about exposures to fallout from the testing of nuclear weapons. At that time, we were informed that the NCRP Coordinating Committee had considered inviting a speaker who was either a representative of public interests or was known to be a public advocate, but instead chose a scientist who was familiar with the technical aspects of dose reconstruction and the evaluation of health risk, and who has worked closely with public interest activists and concerned citizens. They felt that our presentation would be more balanced.

In April, just prior to the NCRP 2001 Annual Meeting, Scientific Committee 92 of the NCRP met with public-interest groups and with NCRP President Charles Meinhold. At that meeting the issue was again raised that the NCRP 2001 Annual Meeting on Fallout was deficient in that there was no one scheduled to represent the public interest. All speakers at this conference were perceived as being less than totally credible because our primary funding comes from government sources. Therefore, in the writing of this paper, we have invited Mr. Tim Connor, author of *Burdens of Proof* (Connor, 1997) and founding chairman of the Subcommittee for

Community Affairs of the Advisory Committee for Energy Related Epidemiological Research (ACERER), Dr. LeRoy Moore of the Rocky Mountain Peace and Justice Center, Dr. Kristen Schrader-Frechette of Notre Dame University and author of *Risk and Rationality* (Shrader-Frechette, 1991), and Ms. Trisha Pritikin, a member of the exposed community downwind from Hanford, member of the Hanford Health Effects Subcommittee, and a citizen consultant to the Subcommittee for Community Affairs of ACERER, to serve as our consultants in our writing of this paper. Though we as the primary authors have final responsibility for this paper, we are indebted to our consultants for their help and advice. Their assistance helps to ensure that this paper appropriately reflects public concerns about exposure to fallout from the production and testing of nuclear weapons.

The technical issues presented in this paper reflect our own experience in dose reconstruction and our perspective about exposure to ^{131}I from fallout from the Nevada Test Site, combined with exposures from local (e.g., Oak Ridge) releases to ^{131}I, and an update on the risk of thyroid cancer throughout the entire U.S. from exposure to Nevada Test Site fallout ^{131}I.

Who Is the Public, and Who is the Concerned Public?

Before introducing issues that are foremost on the minds of members of the public, it is important to discuss the definition of who is the public. We believe it is fair to say that the vast majority of the public are those who are relatively uninformed about fallout, exposure, and risk. This is because the information about the health risks imposed on the U.S. population by exposures that occurred 40 to 50 years ago is not fully documented and is not common knowledge. Thus, it is likely that most members of the public have no opinion or concern about fallout other than the knowledge that fallout is something that happened long ago, and they hold the impression that any risk more than likely ceased with the end to atmospheric testing as a result of the limited test ban treaties of the 1960s. Those individuals who are presently knowledgeable about issues of fallout represent a very small fraction of the total public. These few have made an effort to inform themselves and remain involved.

According to Tim Connor (2001), it is fruitless to argue about whether the concerns of an informed and vocal minority are representative of broad public sentiments. What ultimately matters is whether the intellectual basis for those concerns (as they would apply to all exposed persons, whether they are informed or ignorant of their exposures) has merit and is reasonable within the context of how a just society should approach its responsibilities for public welfare.

To a certain extent, the publication of the National Cancer Institute s 1997 report on nationwide exposure to ^{131}I released from the Nevada Test Site has led to renewed public interest. Some of the individuals who have studied the NCI (1997) and subsequent IOM/NRC (1999) reports on Nevada Test Site fallout have been involved at Department of Energy sites where historic dose reconstruction studies are either under way or have been completed. For sites such as Savannah River, Hanford, Rocky Flats, Idaho National Engineering and Environmental Laboratory, Fernald (Ohio), and Oak Ridge, openness in scientific investigations has been a strong component of the studies. Some members of the public are dedicated activists who oppose nuclear weapons or nuclear power in general, and undeniably some of these are so committed to their objectives that their beliefs will not be swayed by open discussion of scientific evidence (research has shown that similar biases may also exist among some members of the scientific community as well (Kahneman et al., 1982)). Many members of the concerned public are convinced their exposures have imposed serious health risks, and that the harm resulting from these exposures has been or is likely to be serious.

To some, these beliefs form a basis for the views that national policy should be oriented toward alternative energy sources, and alternative national defense strategies and technologies. Others have no particular views about nuclear power or nuclear weapons but are still embittered and frustrated because they believe they and their families were exposed, without notice or consent, to fallout from nuclear weapons testing. Their frustrations are exacerbated by what they perceive as official indifference to providing accurate information about exposures and risks, and official reluctance to consider meaningful public health responses (ACERER, 1998; Rush and Geiger, 1998; SCA/ACERER, 2000; Thomas, 2001; Tuler, 2001).

Public Perceptions About Fallout.

Perhaps the most important aspect of public perception about fallout studies that have been performed to date is that the U.S. government is not trustworthy as a source of information (Thomas, 2001). The U.S. government has an inherent conflict of interest. The government is known to have been responsible for the production and testing of nuclear weapons, and has also been the nearly exclusive source of funding for U.S.-based fallout monitoring, dose reconstructions, risk evaluations, epidemiological investigations, and U.S.-based radiation research in general. To this day, there is concern that the government has not fully notified the public and radiation workers about their cumulative dose and risk from multiple exposures that occurred during the Cold War. For example, Ms. Trisha Pritikin made the following request during the Third Annual University of Washington Conference on Health of the Hanford Site:

> I would like to publicly request, as I have many times before, provision of added dose and risk from I-131 and other biologically significant radionuclides released from Hanford, Nevada Test Site, and global fallout. Combined I-131 doses from Hanford, Nevada Test Site and global fallout are very important for people like me to understand the actual risk we are at of developing thyroid and parathyroid disease and thyroid cancer. This information will also help target those at highest risk from these combined I-131 exposures for any type of government sponsored medical screening or intervention. We know the doses can be added and we know that health risk can be determined (Pritikin, 1999).

The cumulative exposures and health risks received downwind of nuclear weapons production facilities and from weapons fallout occurring in the same region have seldom been considered within the scope of ongoing dose reconstruction studies, in spite of repeated public requests for this information (HHES, 2000; INEELHES, 1999; SCA/ACERER, 2000; DHHS, 2001a). The addition of exposures in the work place, exposures to the same individuals occurring offsite during off-duty hours, and exposures occurring from fallout have also seldom been accounted for in a comprehensive investigation.

It is also the concern among many, including scientists, that extensive amounts of data about worker and public exposure to fallout are either classified or intentionally left unreported. There is the demand by some for a public health and a social-justice response to follow up on the fact that millions of Americans were exposed during the Cold War Era without their consent. Although most Americans support the goal of, and necessity for, the testing of nuclear weapons during the early decades of the Cold War, some now contend that U.S. citizens could have been better protected at the time and that the Government should now take responsibility for its earlier actions. Our involuntary exposures were not fair, and it is not right to deprive us of the very basic information we need to attempt to deal with the health implications of these exposures. This is more than just an issue of right to know- in many cases it is the information we need to screen and catch early cancers before they become untreatable (Pritikin, 1999).

According to the September 18, 1998 Resolution of the DHHS Advisory Committee on Energy Related Epidemiological Research (ACERER, 1998),

> Despite the good intentions represented by the Radiation Exposure Compensation Act of 1990 (RECA), as amended, federal efforts to address the continuing health risks of populations exposed to radiation from nuclear weapons testing and nuclear materials production activities are clearly inadequate. RECA is a limited monetary compensation effort that provides $50,000 payments to people who can show they lived in designated affected areas of Nevada, Utah, and Arizona during high fallout periods and who were subsequently diagnosed with one of 13 types of cancer associated with radiation exposures. As the 1997 NCI report on iodine-131 exposures from NTS fallout makes

clear, one didn t have to live in designated areas of these three states to be exposed to fallout at levels that substantially increased the risk for cancer. Nor is cancer the only disease for which people exposed to fallout are at greater risk.

Although the most recent NCI report on nationwide exposure to fallout ^{131}I from the Nevada Test Site (NCI, 1997) has been scrutinized by the Institute of Medicine and the National Academy of Sciences (IOM/NRC, 1999), some stakeholders, including scientists, believe that these advisory committees are not entirely open and are made up of participants who are neither entirely independent nor objective (Rush and Geiger, 1998). They perceive that such national-level advisory committees are dominated by scientists who depend almost entirely on government funding for their research, and who, therefore, will be reluctant to interpret the results in ways that would create embarrassment for their sponsors. Also, they perceive that these advisory committees include medical professionals who have a vested interest in the use of radiation in medicine, and thus are predisposed not to alarm the public about the risks of low-level exposures to radiation. Their skepticism is reaffirmed when such committees (as was the case with the IOM/NRC 1999 review of the NCI 1997 fallout report) conclude that a detailed follow-up on the exposures and risks from all radionuclides in fallout is not a public health priority.

In the case of reviews conducted by the Institute of Medicine and the National Academy of Sciences, there is concern that IOM and NAS committees do not embrace active public involvement. Much of the critical information that goes into the final reports of the IOM and NRC is debated in executive session, and public representatives invited to sit in on these sessions are put at a disadvantage because they are outnumbered, and some times viewed as irrational, and thus their points of view are given less weight than viewpoints expressed by the rest of the committee (Shrader-Frechette, 1991). Some public representatives on such committees have complained that the technical jargon is virtually impenetrable and that this jargon must be assimilated and mastered in order for a person to be effective in committee debates on technical issues. It is very difficult for minority members of these panels to make a difference when the reports are written and reviewed in closed session (Shrader-Frechette, 1991). On the other hand, one committee of the National Research Council has recommended that in all cases of risk analysis, stakeholder deliberation should be given equal weight to those based on purely technical consideration (NRC, 1996).

Discrepancies Between the Level of Openness and Independence of Site-Specific Dose Reconstructions and Government Studies on Weapons Fallout.

In an attempt to achieve a high level of integrity and openness, dose reconstruction studies designed for specific nuclear weapons production facilities such as those at Savannah River, Oak Ridge, Idaho Falls, and Hanford, have independent oversight committees, and allow all phases of their work to be discussed and reviewed in an open environment. The goal of openness stems from a need to counteract past government policies of information control and secrecy as well as to allow for the accountability of work supported by public monies.

To date, such a high level of openness and accountability has not been associated with government studies on weapons fallout. A possible exception has been the 1980s investigation of the immediate downwind counties of the Nevada Test Site called the Offsite Radiation

Exposure Review Project (ORERP). This program involved the U.S. Department of Energy as the primary sponsor, and DOE contractors performed much of the technical work. But, ORERP, unlike other fallout studies, included an oversight panel, open meetings, and a public outreach program. However, this study was restricted to estimates of public exposures and dose without proceeding to estimates of health risk.

It takes a technical background to fully appreciate the implications of quantitative estimates of absorbed, equivalent, or effective dose. Most members of the public, however, can appreciate and understand estimates in terms of individual or population level health risks. If told, they will understand that two individuals with the same dose may have markedly different risks due to being different ages at time of exposure and belonging to population subgroups with distinctly different background rates of cancer (Apostoaei et al., 1999; Hoffman, 1998).

Dose reconstructions performed at a number of government facilities are perhaps the most open scientific studies conducted to date. By contrast, studies on atmospheric weapons testing and fallout neither have been as open nor have they been subject to outside scrutiny by experts independent of the DOD, DOE, or their contractors. In some cases, as was the case with the report on nationwide exposures to ^{131}I in fallout (U.S. Senate, 1998), publication or public notification of the results of the studies and follow-up activities has been delayed for years (from the time their initial results have been known to the authors of the study). Details as to the full range of exposure and risk in these studies are not presented, are obscured in appendices, or are difficult to interpret because of the amount of complex jargon that is used.

> For all of those people significantly exposed to fallout from Nevada Test Site bomb tests, this is the third major human rights violation we have endured: first, our involuntary exposure, in which many of us were exposed during infancy and childhood when we were most vulnerable; second, through the years of suffering with the health impact of these unknowing exposures (decades of untreated, severe hypothyroidism, or worse); and now being violated a third time, in having withheld from us the results of the NCI fallout report (including individual dose and risk estimates due to our exposures) for so many years (Pritikin, 1998).

An Attempt to Address Some Questions Asked By Members of the Public.

What happens when we look beyond large-scale average estimates?

Dose reconstructions on fallout are often presented as summary results averaged over a large area and population. An example of presenting estimates as a large-scale average is the per capita thyroid dose maps for the entire population (adults and children) from the Nevada Test Site fallout (Fig. 1). Because of the scale chosen for this map, most of the high doses appear to have been restricted to the mountain states of Utah, Colorado, Idaho, Wyoming, and Montana. The maximum thyroid doses appear to be between 9 and 16 cGy, although more than 1,800 counties have average per capita doses exceeding 2 cGy (the nationally averaged per capita dose). But, the per capita thyroid dose says very little about what the risk could be for individuals or population subgroups exposed to ^{131}I in Nevada Test Site fallout.

It is well known that the individuals most at risk from exposure to ^{131}I would be those who were children at the time of testing who consumed greater than average quantities of milk. The National Cancer Institute estimates that the per capita thyroid dose averaged over the entire U.S. for children under the age of 1 year in 1952 would range from 5 to 20 cGy (IOM/NRC, 1999). This would be the uncertainty in the average dose applicable to approximately 3.5 million children in that age group.

What about children who consume higher than average amounts of milk?

If we were to look in Chapter 8 of the NCI report (1997) at the county average doses for persons born on January 1, 1952, who were on an average diet and who consumed more than the average amount of milk, we notice that there are 236 counties where the average dose would have exceeded 30 cGy (Fig. 2), an additional 1,912 counties where the average dose would range between 10 and 30 cGy, and another 852 counties where the dose would range from 3 to 10 cGy on average. It is of interest to point out that the average thyroid dose to children in the Life Span Survivors Study (LSS) of those who survived the bombing of Hiroshima and Nagasaki was 27 cGy, and that 10 cGy is slightly above the lower limits of detection for a statistically significant excess relative risk found in studies of external radiation and thyroid cancer when exposures occurred in childhood (Ron et al., 1995). The median doses to epidemiological cohorts in Utah and Hanford were also about 10 cGy (Stevens et al., 1992; FHCRC, 1999).

How large is the uncertainty on these doses?

Dose reconstruction is known to be an inexact science (Hoffman, 1991). Some members of the public are not satisfied with average or central estimates. They have asked for full disclosure of what we know, what we don t know, and what we can learn about the reconstruction of exposures and doses that occurred decades ago during the time of atmospheric weapons testing and significant releases from nuclear weapons production facilities. The uncertainty associated with counting averaged estimates for an individual of a given age and given diet calculated by the National Cancer Institute is summarized in Table 1, which has been taken verbatim from page 43 of the Institute of Medicine Report (IOM/NRC, 1999). In Table 1 the limits of the 95% uncertainty range are emphasized over that of the central estimates. The 95% uncertainty range has been calculated externally from information obtained from the original NCI website (http:www2.nci.nih.gov/fallout/html), which presents only the geometric mean and geometric standard deviation of an uncertain reconstructed dose assumed to conform to the properties of a log-normal distribution.

Table 1 shows that the uncertainty associated with a county average estimate, that varies as a function of age at time of exposure and diet, can be considerable. In those locations coincident with a monitoring station that received fallout from multiple test series, the uncertainty is the smallest, less than a factor of 3 either side of a central estimate. For those locations receiving fallout from a few shots or dominated by one test series, and where the locations are far distant from a sampling station, uncertainties are larger, with the largest uncertainties being greater than a factor of 10 either side of a central estimate. Although these uncertainties appear to be extremely large, they are in fact comparable to uncertainties in other ^{131}I dose reconstructions such as those reported for Hanford (Farris et al., 1994), Oak Ridge (Apostoaei et al., 1999), and Utah (Stevens et al., 1992).

For many locations the upper bound of confidence for a child born on January 1, 1952, who consumed milk from a family owned cow, approached or exceeded 1 Gy. The lowest doses occurred for locations adjacent to the Pacific coast. The highest doses were recorded for Utah, Idaho, and Montana, but the uncertainties on these doses are so wide that major distinctions in exposures based on location are difficult to support.

What group had the highest dose?

By reviewing Table 1, it is evident that the highest doses received were among those consuming milk from a backyard or family owned goat, who were young children at the beginning of atmospheric testing. In almost all cases, the upper bound of confidence exceeds several Gy, and in some cases, exceeds 10 Gy. In most situations, the lower bound of confidence exceeds 20 cGy, meaning that one would be highly confident that the true dose to individuals consuming milk would most likely be above this level. By considering the full range of uncertainty, it becomes obvious that thyroid doses nationwide were determined more by diet than by location for a given age at time of exposure.

What s the risk?

Some of the members of the public, because of their long-term involvement with dose reconstruction studies, are familiar with the term dose, but most people would be more meaningfully informed through quantitative estimates of the anticipated health risk from exposure as opposed to the use of dose estimates as the endpoint of the investigation (Hoffman, 1991, 1998; Pritikin, 1998, 1999). The Congressional Mandate for DHHS to investigate nationwide fallout exposures gave first priority to the investigation of risk due to exposure to ^{131}I (Public Law 97-414, Sections 7(a) and (b), January 4, 1983). However, the NCI (1997) report itself includes no discussion of risk. Risk estimates of excess thyroid cancers have been made but are obtained only from searching the NCI website or from reading the IOM/NRC (1999) review of the NCI study. Assuming a relative biological effectiveness of 0.66 for ^{131}I, the NCI estimated that the excess number of thyroid cancers expected to occur over the lifetime of those first exposed in 1952 (approximately 55 million children under the age of 20 at time of first exposure) would range from 11,300 to 212,000 (95% credibility interval).

At *SENES* Oak Ridge, Inc., we made an assessment in December 1997 of the number of excess thyroid cancers to be expected in the U.S. for Nevada Test Site fallout including all known sources of uncertainty at that time, including the uncertainty in the RBE for ^{131}I. We estimated from 8,000 to 208,000 excess cases of thyroid cancer to be expected (IOM/NRC, 1999; Hoffman, 1998). Still, some believe this estimate is understated because the overall impact from total exposures to all radionuclides in all sources of fallout has not been assessed. In addition, they believe that no credit should be given to values of RBE for ^{131}I less than 1.0. Since 1997, the uncertainty associated with the relative biological effectiveness of ^{131}I assumed in 1997 has been reduced (Land et al., 2000). More weight has been given to an RBE value of 1.0 and no weight given to values below 0.25. This means that exposure to ^{131}I is probably about as equal in effectiveness to inducing thyroid cancer as is exposure to an acute dose from external radiation, with the maximum difference being no more than a factor of _ (additional reading on the RBE for ^{131}I and other sources of chronic exposure of the thyroid gland are: IOM/NRC, 1999; Thomas et al., 1999).

Updating our assumptions from 1997 to the present time would produce only a slight increase in the risk estimates for nationwide exposure to Nevada Test Site fallout (Table 2). The 95% (subjective confidence interval) would range from 11,000 excess cases of thyroid cancer to about 220,000 excess cases. About half of these cases would have occurred prior to the year 2001. These updated assumptions are based on our most recent estimate of the dose response for external sources of radiation, the low dose and low dose rate effectiveness factor (DDREF) used to account for the reduction of an effect when exposures (at the same cumulative dose) are chronic rather than acute (because of its prolonged residence time in the thyroid gland and 8-day half-life, all exposures to ^{131}I are considered to be chronic), and the background incidence rate for a cohort born in 1952 (see Table 2 for references). Note that although these risk estimates are still uncertain, they do not include zero as a plausible outcome. By contrast, the total number of thyroid cancers from all causes is expected to range from 230,000 to 440,000 cases over the lifetime of the cohort of about 55 million children who were exposed under the age of 20 in 1952 (Table 2).

In addition to estimates of the total excess thyroid cancer from ^{131}I only, some members of the public are now requesting that risk information be provided to any individual who wishes to know what his or her excess lifetime risk is for any potentially radiogenic disease from exposure to all biologically significant radionuclides in fallout, and what the cumulative risk would be for those who had significant exposures to multiple sources of fallout and releases from upwind facilities operated by the former Atomic Energy Commission (SCA/ACERER, 2000). They have also learned that it is possible to use estimates of individual risk to calculate a probability of causation for those today who have been diagnosed with a potentially radiogenic disease. (However, others oppose the calculation of probability of causation because they fear that this information is readily misused by the government to deny compensation and medical care to large numbers of individuals who have been exposed without informed consent.) Our estimates of the excess lifetime risk of thyroid cancer and the probability of causation for those with a diagnosed cancer or other thyroid neoplasm are given in Table 3 for five locations selected from Table 1.

The sources of information used to make the risk calculations and probability of causation estimates in Table 3 are (a) the age-dependent dose estimates obtained from the individual dose calculator on the NCI website (http:www2.nci.nih.gov/fallout/html) combined with (b) the Interactive Radioepidemiological Program (IREP) is being used to update the 1985 Radioepidemiological Tables (Land et al., 2000). IREP provides information on the excess relative risk per absorbed organ dose and the assigned share associated with radiation exposure. The assigned share is defined as the fraction of the number of exposed people with disease who would not have acquired the disease had they not been exposed. For the 3.5 million children under the age of 1 in 1952 (Table 2), the calculated assigned share (assuming a per capita thyroid dose ranging from 5 to 20 cGy) ranges from 8% to 79% C.I. with a central estimate of 39%. This means that from 8% to 79% of the thyroid cancers manifested over the lifetime of these persons would not have occurred had those individuals not been exposed to Nevada Test Site ^{131}I. For a reference individual, the concept of assigned share is interpreted as a surrogate for the probability of causation. We note that at the time of the writing of this paper, the calculations in IREP are still undergoing revision; however, at the present time, no major modifications are anticipated for the assumptions used in calculating the assigned share for radiation induced thyroid cancer.

What about diseases other than cancer?

Some people are concerned that the focus of risks associated with exposure to ^{131}I in fallout has been too narrow. The focus should include diseases other than excess thyroid cancer, and should be extended to radionuclides other than ^{131}I. In this paper, we have not included an estimate of health risks due to exposures to radionuclides other than ^{131}I. However, in looking at exposures to ^{131}I from Nevada testing alone, we believe that there is the potential for radiation induction of non-cancerous neoplasms, or benign nodules, and autoimmune thyroiditis in some people. The IOM/NRC (1999) states that radiation-induced autoimmune thyroiditis may be induced by thyroid doses below 1 Gy, but is unlikely below doses of 10 to 20 cGy. It is clear from the information presented in Table 1 (for children born in 1952 who consumed milk from a family-owned cow or goat), that ^{131}I thyroid doses were received from exposure to Nevada Test Site ^{131}I that were sufficiently high for the risk of autoimmune thyroiditis to be an issue. If other sources of ^{131}I exposure were to be added to ^{131}I from the Nevada Test Site, the thyroid doses could only get higher, leading to an increase in the chance of radiation induced hypo- or hyperthyroidism of an autoimmune origin.

What about the cumulative effect due to multiple exposures from fallout and releases from upwind facilities?

In the U.S., several instances of multiple sources of exposure to ^{131}I occurred: Hanford, Idaho Falls, Oak Ridge, and Savannah River. At Hanford, about 30 PBq (800,000 curies) of ^{131}I were released (Heeb, 1994; Hoffman, 1999). At Oak Ridge (Apostoaei et al., 1999), the estimate currently ranges from 0.37 to 1.5 PBq (10,000 to 40,000 curies) of ^{131}I (with some indication that adjustments to this number may be necessary pending further review). The most recent estimates for Savannah River are upwards of 2 PBq (60,000 curies) of ^{131}I (CDC, 1999). Among these sites, Oak Ridge is the only location for which there has been a partial attempt to account for the total exposure due to releases from the local facilities and to regional fallout occurring from atmospheric testing in Nevada; the additional impact from the Marshall Islands and former Soviet Union remains to be assessed.

Table 4 presents summary information showing the doses, risks, and probability of causation for individuals born in January, 1952, who consumed locally produced commercial milk from several locations in the general region around Oak Ridge. Table 4 shows that Nevada Test Site fallout is a substantial contributing source of exposure for all nearby residents; however, at locations more distant from Oak Ridge, Nevada Test Site fallout is the dominant source of ^{131}I

exposure. In all cases, the average estimate of lifetime risk of thyroid cancer exceeds 1 chance in 10,000 for a female born in early 1952 consuming only modest amounts of milk. For someone consuming goat s milk produced near the most distant location considered (Wartburg, Tennessee) and who consumed only one 8-ounce glass per day, the thyroid dose ranges from about 7 to 200 cGy (95% confidence interval), the excess lifetime risk of thyroid would range from 1 to about 60 chances per 1,000, and the probability of causation (if this person were to have a diagnosed thyroid cancer or other neoplasm) would range from 20% to over 90%. Thus, if this person had a diagnosed thyroid cancer or other neoplasm, exposure to fallout could be interpreted as a substantial contributing factor to (if not the predominant cause of) the presence of that disease. Individuals born in different years than 1952 would have different results because both the thyroid dose and excess risk decrease with increasing age at time of exposure.

Table 4 clearly shows that in all cases the upper bound of a 95% confidence range of the probability of causation exceeds an estimate of probability of causation of 50%. This would be significant if the same rules currently used to establish eligibility for compensation and medical care of radiation workers and atomic veterans (White House, 2000) were to be extended to members of the public (i.e., the upper 99^{th} percentile of the probability of causation must exceed a value of 50%). For more distant locations, where only exposure to Nevada Test Site fallout ^{131}I occurs, the upper bound of confidence of the probability of causation estimates still exceeds 50% for someone exposed in childhood who consumed only modest amounts of fresh dairy milk (Table 3). The significance of these high values of probability of causations has not been widely publicized and perhaps is being presented in this paper for the first time.

We acknowledge at this point that some members of the public are highly frustrated with a system that attempts to answer their concerns with paper studies that are supposedly the result of decades of detailed investigations but whose results are inconclusive (ACERER, 1998). They believe that more than enough paper has been produced. They are aware that many so-called negative findings in epidemiological studies are simply the result of insufficient statistical power (Connor, 1997). The trust in the content of these studies is low because they perceive these reports to have been subjected to an extensive amount of policy spin to downplay the significance of past exposures and to reduce the potential for public alarm (NRC, 2000). These individuals demand that proper health care be immediately provided to those exposed and harmed without informed consent (HHES, 2001). They have expressed a need for clinics to be established to treat those affected with diseases brought about from their exposure (ACERER, 1998; SCA/ACERER, 2000). Some of these same individuals, and others, are asking in addition for a full Presidential apology (Thomas, 2001).

Conclusions.

T*he full story on public exposure to fallout has not been told.*

In concluding this paper, we would like to emphasize that the total impact from exposure to multiple sources of contamination in weapons testing and production has not yet been fully evaluated in a public document. If this were to occur, it is obvious that the estimates of dose, risk, and probability of causation given in this paper would only get larger. The numbers presented in this paper, with the exception of those from Oak Ridge, reflect only exposures to ^{131}I released from the Nevada Test Site.

The Nevada Test Site released about 6 Ebq (150 million curies). Thermonuclear testing in the Marshall Islands and the former Soviet Union released far more than this (although much of the ^{131}I was injected into the stratosphere where it decayed). The Marshall Islands tests from 1946 through 1958 released almost 240 Ebq (8 billion curies) of ^{131}I, and it is estimated that during the final years of weapons testing from 1961 to 1962 that the former Soviet Union and U.S. testing in the Pacific released upwards of 430 Ebq (12 billion curies) of ^{131}I (UNSCEAR, 2000; Beck, 2001). The total health risk from combined exposures to ^{131}I and with other major radioisotopes in all major sources of fallout is yet to be investigated at a scale in which individual dose and risk estimates can be obtained, or at least at which dose and risk estimates can be obtained for representative individuals residing in various parts of this country and in locations beyond the borders of the U.S. Telling the complete story about fallout will indeed require further investigation. On the other hand, time is running out for those who were in childhood during the 1950s.

Are there any conclusions that can be drawn without waiting for the complete story to be told?

What we can clearly say is that if the present criteria for compensating exposed and sick radiation workers and atomic veterans were to be applied to the public, then people throughout the U.S. who have thyroid cancer or a non-cancer neoplasm would be eligible for medical care and compensation if they were children when exposed to Cold War Era ^{131}I and if their diets were composed of fresh milk from either cows or goats. The present criteria for establishing eligibility for compensating sick radiation workers and atomic veterans currently state that the upper 99th percentile of the estimate of probability of causation must exceed the value of probability of causation of 50% (White House, 2000). This criterion is met throughout the U.S. for those who were in childhood during the 1950s whose diet included fresh milk. This situation would become more pronounced if one were to take into account those who were exposed to multiple sources of fallout and if exposure to all Cold War Era contaminants were to be included.

What remains to be done?

We are of the firm belief that the highest priority in any action to follow up on the public health legacy of nuclear weapons testing and production is that of fully addressing the public s right to know. This must be accomplished in such a manner as to regain lost trust (Thomas, 2001; Connor, 1997; ACERER, 1998). This entails providing the public and workers with complete and credible information on their personal exposure and risk from all major sources of Cold War Era contaminants. This entails inclusion of the full range of health consequences potentially caused by these exposures (including exposures to persons residing at locations both inside and beyond the borders of the U.S.). Risk estimates should include cancer and non-cancer disease endpoints. This action requires a major effort to archive data on what was actually measured during the 1950s and 1960s. We are told that the original milk data maintained by the U.S. Public Health Service, and then EPA, cannot be located at present. Other datasets are disappearing with the retirement and deaths of scientists who were in the peak of their careers during the time of atmospheric weapons testing.

The evaluation of the exposure and health consequences of fallout should be conducted with real opportunities for public involvement, scrutiny and notification, without compromising rigorous and independent technical peer review. It is essential, in addition to allowance for public involvement and scrutiny, that scientific accuracy and technical integrity be maintained at the highest level.

Finally, we believe it is imperative that the time required to complete remaining investigations should neither delay or distract from a prompt and more direct consideration of a national public health and social justice response. There is a need for a governmental focal point to be established that addresses and responds to public and worker health and social justice concerns from involuntary exposures. The resolution on this matter by the HHS Advisory Committee on Energy-Related Epidemiologic Research in September of 1998 remains a compelling and reasonable articulation of the basis upon which the government should be addressing research and public health activities related to nuclear weapons test fallout.

> ACERER Resolution, Finding No. 2: The Difficulties In Identifying Specific Fallout Injuries Do Not Absolve The Federal Government Of Its Responsibility To Shape A Meaningful Public Health Response.
>
> Given the widespread nature of fallout and the limitations of epidemiology when it comes to identifying specific cases of low-dose radiation injuries, there are inherent and formidable difficulties in locating the people whose cancers or other health problems are attributable to fallout exposures. Still, the difficulties in identifying individuals whose

injuries are caused by fallout exposures does not absolve the federal government of its civil and moral responsibility to aid the injured. The general obligation of the Government to attend to the well-being of its citizens is, in this instance, profoundly enhanced by the facts that the Government is responsible for the exposures and for failing to give people the information necessary to avoid or minimize the risks imposed upon them.

It is not the role of this committee to make recommendations on the delivery of health care. Based on the above principle, however, we encourage the Secretary to work with the President and the Congress to:

a) Improve the nation s capability to better identify the people who ve either been injured by radioactive fallout or who are at substantially greater risk for injury due to their exposures. And,

b) Take reasonable and prudent steps to enhance the diagnostic and other health care services available to those who ve been affected or who are at appreciably greater risk for injuries due to their exposures (ACERER, 1998).

The cost for a government response to the public information, health and social justice issues of exposures received from the production and testing of nuclear weapons should not be a major issue given the $5.5 trillion dollar cost (Schwartz, 1998) of the entire nuclear weapons program since 1940 through 1996. Moreover, a nearly unanimous recommendation for the formation of a presidential commission on appropriate public health or social justice responses due to public and worker exposures to Cold War Era contaminants (with an 18-month deadline) was made during the February 7, 2001, roundtable discussion with the Assistant Secretary of Planning and Evaluation to Secretary of Health and Human Services, Dr. William Raub (DHHS, 2001b).

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Table 1. Thyroid Dose (cGy or Rad) for an Individual Born on January 1, 1952 (based on IOM/NRC, 1999).

Dietary source of Iodine-131	Average diet with retail commercial milk.				Average diet with milk from a back-yard cow				Average diet and milk from a backyard goat				Average diet without milk			
	(95% Uncertainty Range)[a]				**(95% Uncertainty Range)**				**(95% Uncertainty Range)**				**(95% Uncertainty Range)**			
Location (County)	**2.5 %-tile**	Geo. Mean	GSD	**97.5 %-tile**	**2.5 %-tile**	Geo. Mean	GSD	**97.5 %-tile**	**2.5 %-tile**	Geo. Mean	GSD	**97.5 %-tile**	**2.5 %-tile**	Geo. Mean	GSD	**97.5 %-tile**
(units)	**(cGy)**	(cGy)		**(cGy)**	**(cGy)**	(cGy)		**(cGy)**	**(cGy)**	(cGy)		**(cGy)**	**(cGy)**	(cGy)		**(cGy)**
Pacific Coast																
Los Angeles, CA	**0.02**	0.19	3.1	**1.7**	**0.2**	0.7	1.9	**2**	**0.9**	6.4	2.8	**48**	**0.001**	0.013	4.6	**0.26**
Alameda, CA	**0.2**	1.4	2.6	**9.1**	**0.4**	2.9	2.6	**19**	**3.0**	21	2.7	**147**	**0.01**	0.048	2.8	**0.36**
Coos, OR	**0.4**	2.0	2.2	**9.4**	**1.0**	4.0	2.0	**16**	**4.0**	22	2.4	**122**	**0.01**	0.081	4.1	**1.3**
Western States																
Navajo, AZ	**0.3**	2.8	2.9	**23**	**4.9**	21	2.1	**169**	**20**	120	2.5	**723**	**0.09**	0.48	2.4	**2.7**
Clark, NV	**0.4**	5.5	3.6	**68**	**2.9**	16	2.4	**197**	**3.5**	38	3.4	**418**	**0.04**	0.82	4.4	**15**
Washington, UT	**2.5**	23	3.1	**211**	**9.2**	51	2.4	**468**	**13**	210	4.1	**3336**	**0.3**	3.2	3.2	**31**
Mountain States																
Boise, ID	**1.4**	19	3.8	**260**	**3.4**	31	3.1	**424**	**15**	180	3.5	**2097**	**0.05**	1.5	5.8	**47**
Meagher, MT	**2.5**	43	4.3	**750**	**3.8**	55	3.9	**959**	**20**	330	4.2	**5496**	**0.11**	0.91	2.9	**7.3**
Denver, CO	**4.2**	12	1.7	**34**	**11.5**	29	1.6	**82**	**34**	120	1.9	**422**	**0.04**	0.52	3.5	**6.1**
Central States																
Scott, MN	**2.7**	15	2.4	**83**	**4.5**	23	2.3	**128**	**18**	120	2.6	**781**	**0.11**	0.61	2.4	**3.4**
Milwaukee, WI	**2.2**	8.4	2.0	**33**	**2.8**	13	2.2	**51**	**20**	79	2.0	**307**	**0.08**	0.31	2.0	**1.2**
St. Louis, MO	**2.3**	13	2.4	**72**	**5.4**	30	2.4	**167**	**23**	130	2.4	**723**	**0.20**	0.69	1.9	**2.4**
Franklin, KS	**3.3**	14	2.1	**60**	**6.9**	27	2.0	**116**	**29**	150	2.3	**767**	**0.24**	0.75	1.8	**2.4**
Southeast States																
Orange, FL	**0.3**	1.8	2.4	**10**	**3.3**	14	2.1	**78**	**9.4**	61	2.6	**397**	**0.10**	0.25	1.6	**0.6**
Anderson, TN	**1.8**	6.5	1.9	**23**	**4.3**	15	1.9	**53**	**34**	120	1.9	**422**	**0.18**	0.46	1.6	**1.2**
Washington, DC	**1.2**	5.0	2.1	**21**	**1.2**	5.0	2.1	**21**	**13**	70	2.4	**389**	**0.02**	0.20	3.5	**2.3**
Northeast States																
Albany, NY	**1.1**	9.7	3	**84**	**2.2**	23.0	3.3	**198**	**12**	100	2.9	**806**	**0.05**	0.43	2.9	**3.5**
Columbiana, OH	**0.18**	4.1	4.9	**92**	**0.23**	5.5	5.0	**124**	**1.1**	32	5.7	**970**	**0.02**	0.31	4.1	**4.9**
Hartford, CT	**1.5**	11	2.8	**83**	**3.4**	19	2.4	**143**	**14**	110	2.9	**887**	**0.07**	0.35	2.3	**1.8**
York, ME	**1.5**	7.7	2.3	**39**	**3.3**	13	2	**67**	**13**	75	2.4	**417**	**0.10**	0.31	1.8	**1.0**

[a] NOTE: The original NCI Website (http:www2.nci.nih.gov/fallout/html) gives only the geometric mean and the geometric standard deviation. The 95% uncertainty range is calculated as 97.5%tile = GM*(GSD$^{1.96}$); 2.5%tile = GM/GSD$^{1.96}$).

Table 2. Number of thyroid cancers[a] estimated to occur in the entire United States from exposure to ^{131}I from NTS fallout.

Age group	No. of individuals in the 1952 cohort	Estimated thyroid doses (cGy)		Radiation induced cancers expected over the lifetime of the cohort			Expected total number of cancers from all causes over the lifetime of the cohort		
				95% uncertainty range			95% uncertainty range		
FEMALES		GM[b]	GSD[b]	lower limit	central value	upper limit	lower limit	central value	upper limit
0	1,698,600	10.3	1.4	720	5,500	43,000	11,000	16,000	53,000
1-4	6,931,200	6.7	1.4	1,800	15,000	112,000	43,000	56,000	153,000
5-9	6,929,430	4.5	1.4	1,000	6,400	44,000	42,000	48,000	85,000
10-14	6,023,970	2.8	1.4	320	2,300	15,000	36,000	38,000	50,000
15-19	5,715,114	1.8	1.4	80	860	7,800	31,000	32,000	39,000
TOTAL (females)	**27,298,314**			**8,200**	**36,000**	**159,000**	**167,000**	**195,000**	**318,000**
MALES	°	°	°	°	°	°	°	°	°
0	1,757,800	10.3	1.4	280	2,100	17,000	4,200	6,000	21,000
1-4	7,171,000	6.7	1.4	690	5,700	43,000	17,000	22,000	59,000
5-9	7,174,043	4.5	1.4	400	2,500	17,000	16,000	18,000	33,000
10-14	6,236,357	2.8	1.4	120	900	5,900	14,000	15,000	20,000
15-19	5,916,664	1.8	1.4	30	350	3,200	13,000	13,000	16,000
TOTAL (males)	**28,255,864**			**3,200**	**14,000**	**62,000**	**65,000**	**76,000**	**124,000**
TOTAL (both genders)	**55,554,178**			**11,000**	**50,000**	**221,000**	**233,000**	**272,000**	**442,000**

[a] Calculated using the NCI s ^{131}I thyroid doses reported in IOM/NRC (1999), the excess relative risk per unit dose for thyroid cancer from pooled epidemiological studies on external radiation (Land et al. 2000), the dose and dose-rate reduction factor proposed by Land et al. (2000) for chronic exposures, and the thyroid cancer incidence rates reported by Surveillance, Epidemiology, and End Results (SEER) program of the National Cancer Institute (NCI 1999). The exposed cohort is defined as individuals 0-19 years old in 1952 across the entire United States.

[b] GM (cGy) = geometric mean; GSD = geometric standard deviation (unitless).

Table 3. Thyroid doses and probabilities of causation for representative individuals from selected locations in the continental United States who have a diagnosed thyroid cancer or non-cancerous thyroid neoplasm, who were born on January 1, 1952, and who consumed an average diet composed of average amounts of fresh milk from commercial sources.

	Alameda, CA (95% C.I.)			**Denver, CO** (95% C.I.)			**St. Louis, MO** (95% C.I.)			**Washington, D.C.** (95% C.I.)			**Albany, NY** (95% C.I.)		
Main Test Series	2.5	50	97.5	2.5	50	97.5	2.5	50	97.5	2.5	50	97.5	2.5	50	97.5
Dose (cGy) [a]															
Tumbler-Snapper (4/52 — 6/52)	0.11	0.83	6.2	0.94	4.8	24	0.44	4.8	52	0.27	1.6	9.6	0.36	3.9	43
Upshot-Knothole (3/53 — 6/53)	0.01	0.11	1.0	0.24	1.3	7.2	0.17	1.7	17	0.20	0.92	4.3	0.08	1.8	38
Teapot (2/55 — 5/55)	0.01	0.13	3.1	0.26	1.3	6.6	0.12	0.84	5.8	0.12	0.56	2.6	0.12	0.97	7.8
Plumbbob (5/57 — 10/57)	0.002	0.02	0.26	0.49	2.1	8.9	0.34	2.5	19	0.04	0.67	11	0.08	1.1	16
Total Dose (cGy)[b]	**0.13**	**1.1**	**11**	**1.9**	**9.5**	**47**	**1.1**	**9.8**	**94**	**0.63**	**3.8**	**27**	**0.64**	**7.8**	**104**
Excess Lifetime Risk[c]															
Females	0.15	3.7	85	2.0	30	460	1.3	33	740	0.63	12	240	0.83	26	740
Males	0.049	1.3	35	0.73	12	180	0.46	12	300	0.23	4.6	87	0.29	10	300
Probability of Causation (%)[d]	**1**	**8**	**51**	**8**	**39**	**83**	**8**	**43**	**87**	**3**	**22**	**67**	**7**	**41**	**90**

[a] Thyroid doses were estimated using the NCI individual dose calculator (http://rex.nci.nih.gov/INTRFCE_GIFS/WHTNEW_INTR_DOC.htm)

[b] The total doses reported in this table are different from doses seen in Table 1. The doses in Table 1 are produced assuming that the total dose is a log-normal distribution, while the doses in this table were summed with a Monte Carlo simulation (1,000 iterations using midpoint LHS) to total across individual test series.

[c] Excess Lifetime Risk expressed as chances in 10,000.

[d] Probabilities of Causation were estimated using the Interactive RadioEpidemiological Program (IREP) which is an update to the 1985 Radioepidemiological Tables (Land et al., 2000).

Table 4. The thyroid dose, risk and probability of causation from combined exposure to I-131 in releases from the X-10 facility near Oak Ridge, TN (1944 to 1956) and I-131 in Nevada Test Site fallout (1952 to 1957).

Exposure scenario: A female born on January 1, 1952, consuming 2 eight-oz. glasses of milk produced from a local commercial dairy.

Location, county, and state	Thyroid dose (cGy) (95% uncertainty range)	Excess lifetime risk of thyroid cancer (95% uncertainty range)	Probability of causation for a diagnosed neoplasm (95% uncertainty range)	Relative importance to total dose and risk
Bradbury, Roane, TN	2.9 to 41	4.9×10^{-4} to 1.8×10^{-2}	11 to 81%	NTS (34%) X-10 (66%)
Solway, Knox, TN	1.6 to 25	2.7×10^{-4} to 1.1×10^{-2}	7.2 to 71%	NTS (39%) X-10 (61%)
Farragut, Knox, TN	1.4 to 19	2.1×10^{-4} to 8.1×10^{-3}	5.8 to 64%	NTS (51%) X-10 (49%)
Oak Ridge, Anderson, TN[(a)]	1.1 to 17	1.8×10^{-4} to 6.4×10^{-3}	4.8 to 60%	NTS (75%) X-10 (25%)
Knoxville, Knox, TN[(a)]	1.0 to 13	1.5×10^{-4} to 4.9×10^{-3}	3.9 to 55%	NTS (70%) X-10 (30%)
Maryville, Blount, TN	1.0 to 15	1.3×10^{-4} to 5.7×10^{-3}	3.6 to 57%	NTS (85%) X-10 (15%)
Sweetwater, Monroe, TN	1.0 to 16	1.6×10^{-4} to 5.9×10^{-3}	3.9 to 60%	NTS (83%) X-10 (17%)
Wartburg, Morgan, TN	0.7 to 16	1.1×10^{-4} to 6.2×10^{-3}	3.2 to 59%	NTS (92%) X-10 (8%)

(a) Residents of the cities of Oak Ridge and Knoxville, Tennessee, obtained mostly commercial milk from regional dairies.

Figure 1. Per capita thyroid doses per county from Nevada Test Site fallout from exposure to I-131.

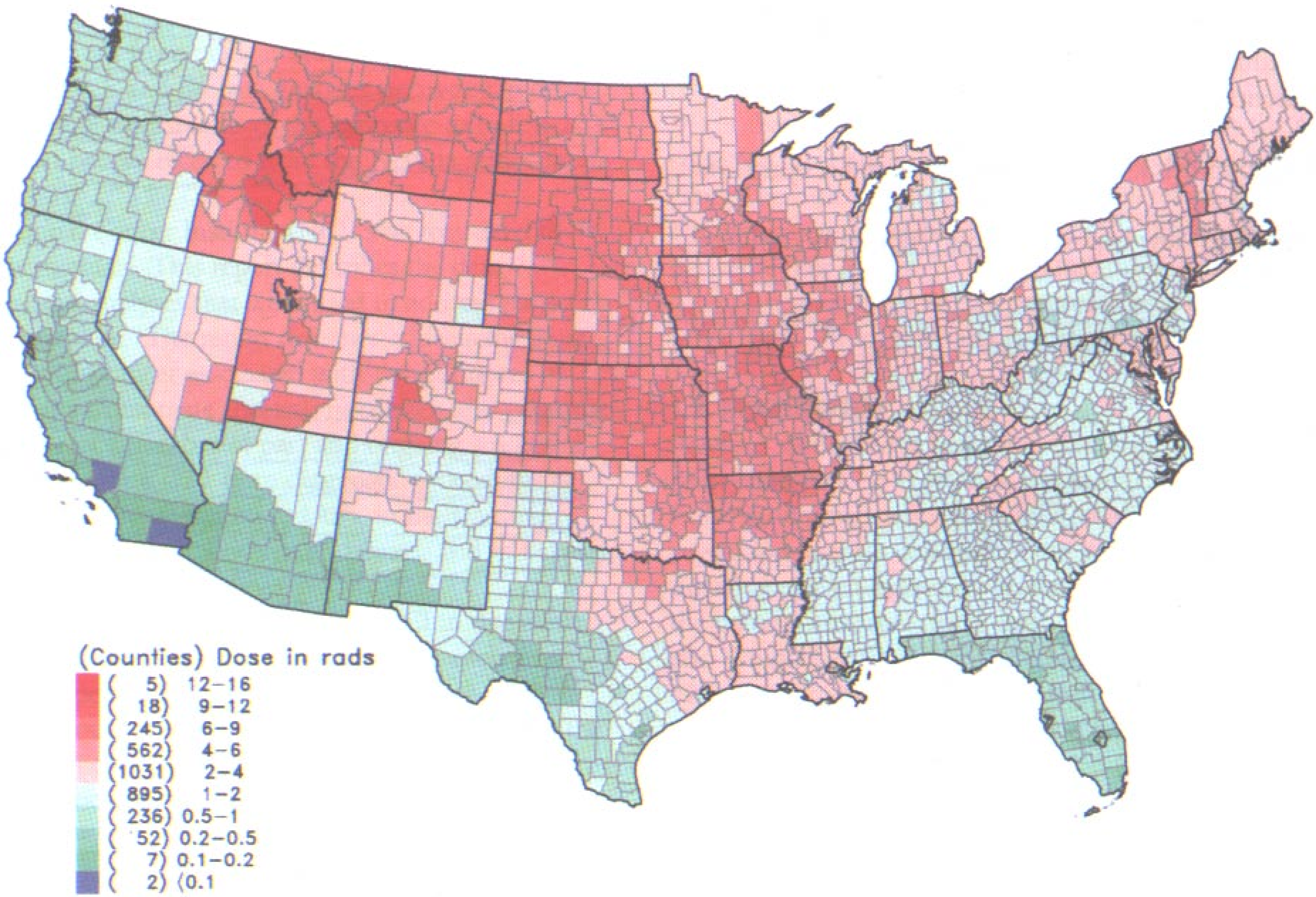

Figure 2. Per capita thyroid dose per county for persons born on January 1, 1952, with an average diet but higher than average milk consumption.