# Health Effects of Low-Level Radiation

**Position Statement**
**June 2001**

It is the position of the American Nuclear Society that there is insufficient scientific evidence to support the use of the Linear No Threshold Hypothesis (LNTH) in the projection of the health effects of low-level radiation.

Given this situation, an independent group of reputable scientists, medical experts and health researchers should be established to conduct an open scientific review of all data and analyses on the subject of LNTH. Based on the conclusions of this review group, a separate group composed of stakeholders should make recommendations on whether adjustments to current radiation protection guidelines should be made immediately to reflect current information.

In addition, it is the ANS position that new research on low-level radiation health effects, spanning several disciplines, should be initiated. Meritorious existing research within the disciplines should continue to receive funding.

While this research proceeds, the ANS concurs with the Position Statement on "Radiation Risk in Perspective" issued by the Health Physics Society in January 1996, which states as follows:

> "In accordance with the current knowledge of radiation health risks, the Health Physics Society recommends against quantitative estimation of health risks below an individual dose of 5 rem[1] in one year or a lifetime dose of 10 rem in addition to background radiation. Risk estimation in this dose range should be strictly qualitative accentuating a range of hypothetical health outcomes with an emphasis on the likely possibility of zero adverse health effects. The current philosophy of radiation protection is based on the assumption that any radiation dose, no matter how small, may result in human effects, such as cancer and hereditary genetic damage. There is substantial and convincing scientific evidence for health risks at high dose. Below 10 rem (which includes occupational and environmental exposures) risks of health effects are either too small to be observed or are non-existent."

[1] The rem is the unit of effective dose. In international units, 1 rem = 0.01 sievert (SV)

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## BACKGROUND

The Linear No Threshold Hypothesis (LNTH) is the current basis for regulation of low levels of radiation in the United States. Under this hypothesis, the effects of low-level radiation are assumed to be deleterious. This hypothesis presumes that detrimental health effects are linearly proportional to radiation dose down to zero dose. It assumes that any exposure, no matter how small, increases detrimental health effects. A corollary to the LNTH is the collective-dose theory, which assumes that small doses to large populations can be added up to predict a large number of statistical health effects.

Scientists and researchers, as described in the following paragraphs, are increasingly questioning the validity of the LNTH and the collective dose theory and their application in the regulation of the potential health effects of low-level radiation. If the LNTH is not valid, significant benefits can accrue to society by developing a valid science-based standard for assuring public health. These benefits include an increased public confidence in medical, industrial, food safety, and energy applications of nuclear science and technology and may include reduced societal costs in regulating and controlling radioactive material.

Since 1994, the ANS has sponsored numerous technical sessions on this topic at its national meetings with many distinguished internationally recognized panelists. The objective of these technical sessions was to establish a firm basis for re-evaluating the health effects of exposures to low-levels of radiation. There were two significant conclusions resulting from these sessions:

1. There does not appear to be good scientific evidence supporting a linear no threshold hypothesis (LNTH) at low-levels of radiation exposure; and

2. A complete review of past studies (both published and unpublished) and the conduct of new studies are needed to confirm or refute the LNTH hypothesis.

Congress has passed legislation authorizing the study by the Department of Energy, of health effects of low-level radiation. The overriding goal of this study must be to ensure that human health is adequately protected. In light of this activity, the ANS has developed a position and recommendation, as follows:

## ANS POSITION AND RECOMMENDATIONS

It is the position of the American Nuclear Society that there is insufficient scientific evidence to support the use of the Linear No Threshold Hypothesis (LNTH) in the projection of the health effects of low-level radiation. Given this situation, an independent group of reputable scientists, medical experts and health researchers should be established to conduct an open scientific review of all data and analyses on the subject of LNTH. The purpose of the review is to determine whether the reported conclusions on radiation health effects at low doses are supported by valid data. ANS recommends that this review be led by a nationally respected medical or health expert not previously connected with this issue. This review should, in a timely fashion, examine the existing data and analyses (published and unpublished). Based on the conclusions of this review group, a separate group composed of stakeholders should make recommendations on whether adjustments to current radiation protection guidelines should be made immediately to reflect current information.

In addition, it is the ANS position that new research on low-level radiation health effects, spanning several disciplines, should be initiated. Meritorious existing research within the disciplines should continue to receive funding. Such research includes epidemiology of exposed human populations, research involving protracted exposure in animals, cellular and molecular biology, dose assessments and measurements, and policy analysis relating to regulation in the presence of small risks.

The following question needs to be answered:

*Are there radiation doses or dose rates below which there is no significant biological change or below which the damage induced is effectively controlled, from a human health perspective, by normal cellular processes?*

In addition, the ANS recommends that the funding allocated for research on health effects of low-level radiation should be directed to accomplish the following activities:

1. Conduct follow-up research and analysis based on a review of the data discussed above, where warranted.

2. Attract researchers to the field to form multidisciplinary teams with individuals who have strong qualifications in their respective fields of expertise.

3. Conduct new research and continue meritorious existing research in a variety of disciplines. The research should be directed at:

    - Development of a scientifically based model that may be applied to determine the presence or absence of positive or adverse health effects due to low-level radiation exposure.

    - Improvement of the estimates of radiation risks and characterization of the uncertainties inherent in these estimates.

    - Finding appropriate regulatory approaches based on both the magnitude and shape of the dose effects curves and their uncertainties.

The review and research described above will develop a scientific basis for the health effects of low-level radiation on which most scientists agree. It is important to enlist stakeholders and policy makers in this process so that they will develop a good understanding of the underlying science and its implications and confidence in the results. Finally, communicating to the public is essential so that they also will have confidence that the underlying science of radiation protection policy is reasonable and appropriate.

**Original Statement - April 1999**
**Revised - June 2001**

# American Nuclear Society

**April 1999**

# Technical Brief for ANS Position Statement on the Health Effects of Low-Level Radiation

## BACKGROUND

Current radiation policy is based on two premises: First, the Linear No-Threshold Hypothesis (LNTH), which presumes that detrimental health effects of radiation are linearly proportional to the radiation dose, regardless of dose-rate, down to zero dose. Second, the idea of Collective Dose, which presumes that extremely small doses in an exposed population can be added up to predict a statistical number of deaths. Since no radiation level is considered small enough to be harmless, the requirement of ALARA (as low as reasonably achievable) naturally arises and is applied to ever-lower doses.

These basic premises have never been adequately justified scientifically, and contradictory evidence has been dismissed. NCRP-121, the National Council on Radiation Protection and Measurements' 106-page definitive report (NCRP 1995) on the use of LNT to calculate collective dose, justifies this position as follows:

> Few experimental studies, and essentially *no human data*, can be said to prove or *even to provide direct support* for the concept of collective dose with its implicit uncertainties of nonthreshold linearity and dose-rate independence with respect to risk. The *best* that can be said is that most studies do not provide quantitative data that, with statistical significance, contradict the concept of collective dose. Ultimately, confidence in the linear no-threshold dose-response relationship at low doses is based on our understanding of the basic mechanisms involved. …It is *conceptually possible*, but with a vanishingly small probability, that any of these effects *could* result from the passage of a single charged particle, causing damage to DNA that *could* be expressed as a mutation or small deletion. It is a result of this type of reasoning that a linear nonthreshold dose-response relationship *cannot be excluded*. [emphasis added]

If this is the best that can be said in defense of the LNTH, then research yielding contradictory evidence should be encouraged and given very careful attention.

## AMERICAN NUCLEAR SOCIETY SESSIONS

In 1994, the American Nuclear Society began exploring in detail the basis of the health effects of exposures to low level radiation. Special technical sessions were held at ANS national meetings beginning in November 1994 and they continue today. The objective of these sessions is to provide a forum for discussion of the basis for current models used to characterize health effects of low-level radiation. Internationally known experts in the field presented papers at these sessions. Attachment A to this background paper summarizes these sessions and provides relevant references to the work discussed. The information presented supports two important conclusions that are discussed below.

First, there does not appear to be good scientific evidence indicating deleterious health effects of radiation below a few tens of centiGrays, or rads, per year. Radiation, like some other physical assaults on the body, may tend at low levels to stimulate the body's defenses and prove beneficial.

Policy-makers do not appear to have drawn on this low-level radiation health effects data in formulating public policy. Some studies, which the government has funded initially, have for some reason been dropped or not published. These studies deserve careful peer review and should be subject to public scrutiny. Examples are the Oak Ridge mega-mouse studies, and the $10 million nuclear shipyard worker study that was completed in 1987.

The ANS is issuing a Policy Statement and this Technical Brief to lend support to statements by the Health Physics Society; the Wingspread Conference; the International Nuclear Societies Council; the French Academy of Science; the Advisory Committee on Nuclear Waste of the U.S. Nuclear Regulatory Commission, and others. Top priority should be given to conducting a full and open scientific review and evaluation of the scientific evidence, accompanied by the initiation of new research, with the aim of quickly bringing radiation policy into line with the best scientific data and theory.

## LOW-LEVEL NATURAL RADIATION BACKGROUND:

## VARIATIONS AND HEALTH EFFECTS

Natural radioactivity occurs ubiquitously in the environment. Natural radioactivity is also concentrated and released from burning coal, oil, gas and wood, from mining, plowing, and construction activities, from well-drilling (for water, oil, etc.), from geothermal energy, and other sources. Large geographic variations cause wide variations in natural radiation exposure (UNSCEAR 1993, NCRP 1987, Eisenbud 1997). Natural radioactivity discharged to the air, to groundwater, to surface water and the oceans, greatly exceeds artificially produced sources discharged to the environment (See UNSCEAR 1993, NCRP 1987). Populations in areas with high background radiation rates show no adverse health effects when compared to low-dose populations. Several studies of large populations with significant differences in doses indicate beneficial health effects, i.e., lower mortality and disease rates (Frigerio 1973, Sandquist 1997-US background; Cohen 1987, 1989, 1992, 1995, 1996; Bogen-1998; Jagger 1998-US radon; Kondo 1993-Misasa Spa, Japan; Wei 1997, Jaworowski 1995b-China; Luckey 1991-comprehensive).

Experiments that suppress background radiation in small organisms show that exposure below background causes a detriment in biological functions (Planel 1987; Luckey 1980, 1982, 1986, 1991; Jaworowski 1995a). No readily identifiable studies of suppressed background radiation show beneficial effects from such "radiation protection". Further studies are needed to confirm such detrimental effects in mammals.

## HEALTH EFFECTS FROM GREATER-THAN-NATURAL RADIATION: EPIDEMIOLOGY

Large human and animal populations have been exposed to radiation doses greater than the highest natural background radiation. Data are available on significant human exposures from medical and occupational sources, from the use of radium and radiology in the early 20th century, from the atomic bombs in Japan, and in public exposures in Russia from radioactivity releases from weapons plants and waste storage accidents.

From high radiation doses, such human populations exhibit some adverse health effects, primarily increases in cancer rates. For Japanese bomb survivors, there were no excess colon cancers below 100 centiGray, or 100 rad. (BEIR V 1990). Among the hundreds of US radium dial painters in the 1920s who received more than 1000 centiGray internal doses, there are about 65 cases of bone cancer. There were no excess cancers in the nearly 2000 measured cases with doses below 1000 centiGray (Rowland 1983, 1997, Maletskos 1994, Thomas 1994, 1995, Raabe 1994, 1995, White 1994).

With moderate dose, no adverse health effects and no deaths have been reported, while evidence of beneficial health effects has been documented (Yalow 1994; Shimizu 1988, 1990, 1992a,b; Kondo 1993; Mine 1990-in Japanese survivors; Miller 1989; Pollycove 1994-in fluoroscopy patients; Luckey 1981, 1982, 1991, 1995, 1997; Abbatt 1983; Matanoski 1991-in radiation workers; Jaworowski 1995a). Animal research data confirm the absence of adverse effects, and the presence of beneficial effects (Luckey 1980, 1982, 1986, 1991, 1994; Lorenz 1950, 1954; Henry 1961; Brown 1963, 1964; Spalding 1981, 1982; Caratero 1998). Animals that have been bred to be tumorigenic, with minimal immune function, have been inappropriately cited as evidence that mammals are not benefited by low-dose and low-dose-rate radiation exposure (Luckey 1991).

## BIOLOGY

Recent molecular and cellular biology and cancer research provides insights with respect to the hypothesis that radiation is harmful at low doses (Hattori 1996; Trosko 1995, 1996; Kondo 1993; Makinodan 1995; Wolff 1996; Feinendegen 1996; Liu 1997; Sakamoto 1996; Ohnishi 1995).

The LNTH was justified by arguing that a single nuclear ray or particle could damage DNA and lead to cancer and that the likelihood of cancer incidence was directly proportional to the number of such rays or particles intercepted by the body. DNA in each cell normally undergoes more than 100,000 alterations/day from oxidative metabolism and other normal bodily functions. Normal repair processes dramatically decrease the probability of harm as a result of this DNA damage. DNA damage from low-level radiation is insignificant compared with this normal damage rate. Some experts have concluded that radiation-induced DNA mutations at many times background levels do not contribute to an increase in normal cancer rates (Pollycove 1997, 1998; Bond 1994;

Weilopolski 1996; Feinendegen 1996; Billen 1990; Ward 1988).

Radiation tends to create a higher percentage of double strand breaks than other metabolic damage mechanisms in the DNA molecule. These double breaks are harder to repair. However, even after allowance for this fact, the total number of unrepaired or misrepaired DNA molecules from low-level radiation damage are insignificant compared with those from normal metabolism. Research and biological knowledge of molecular and cellular mechanisms confirm that cancer is a highly complex multi-step process. This makes unlikely the hypothesis that low-level radiation, or any contributor to DNA damage, can contribute linearly to cancer incidence (including linear-quadratic) (Pollycove 1997, 1998; Trosko 1996; Hattori 1996, 1997; Kondo 1993).

Further, many studies of the most significant biological repair mechanisms for both DNA and cell damage show that low-to-moderate radiation exposures stimulate these repair mechanisms. This is consistent with identified beneficial effects from supplemental radiation (Luckey 1980, 1982, 1986, 1991, 1996, 1997; UNSCEAR 1994; Feinendegen 1996; Jaworowski 1995a, 1995b; Hattori 1996, 1997; Liu 1997; Sakamoto 1996; Ohnishi 1995). In addition, theoretical models of molecular and cellular carcinogenesis processes are consistent with these data. For example, the evidence of reduced lung cancer in high-radon areas is consistent with biological models of damage-repair stimulatory effects (Pollycove 1994; Bogen 1998; Leonard 1996; Fleck 1997).

## Attachment A

ANS Sessions on Low Level Radiation Health Effects – 1994-1999

At the American Nuclear Society's **November 1994 Winter Meeting** in Washington DC, two special sessions were held on **Low-Level Radiation Health Effects: Current Data** and **Program**s covering actual dose-response data and applicable research programs with 10 papers and two panel presentations. (TRANSACTIONS of the American Nuclear Society, Vol.71)

Two sessions on **Low-Level Radiation Health Effects**, one on the above topics and one on **Policies and Cost/Benefits**, were held at the **June 1995 40th Annual ANS Meeting** in Philadelphia PA, with eight papers and two panel discussions. The ANS President-elect, Members representing the Health Physics Society (HPS), and the President and a Member of the National Council on Radiation Protection and Measurements (NCRP) made panel presentations at these sessions. (TRANSACTIONS of the American Nuclear Society, Vol.72)

At the **October-November 1995 ANS Winter Meeting** in San Francisco CA, four sessions on **Low-Level Radiation Health Effects** with 14 papers were held on the above topics, plus **Biology Research and Beneficial Effects** and a very large Panel on **Needs for Research, Organization and Communication, and Corrective Actions**. (TRANSACTIONS of the American Nuclear Society, Vol.73) The **ANS Wilhelm Roentgen Radiology Centennial Award and Lecture** was presented by Professor Emeritus Myron Pollycove, MD, U. Cal. San Francisco, Radiology and Clinical Medicine, retired Head of Nuclear Medicine at San Francisco Medical Center, and NRC Visiting Medical Fellow.

In conjunction with the **November 1996 ANS Winter Meeting** in Washington DC, an **Embedded Topical Meeting on Low-Level Radiation Health Effects** was held. The Embedded Topical Meeting included six sessions and 28 papers on **Biological Research Confirming Beneficial Effects, Biological and Epidemiological Data and the LNT Model, Human Data from Radium and Radon Exposures, Applying Science and Data to Setting Standards and Costs versus Human Benefits of Radiation Protection**. In addition, a large Panel discussed **Research Work and Policy Initiatives Needed to Effect Change.** (TRANSACTIONS of the American Nuclear Society, Vol.75)

At the June **1997 ANS Annual Meeting** in Orlando FL the **Low-Level Radiation Health Effects** sessions were one Panel session on **Programs and Progress** and the ANS President's Special Session on **Applying Science to Change the Rules**. (TRANSACTIONS of the American Nuclear Society, Vol.76)

At the November **1997 ANS Winter Meeting** in Albuquerque NM there was one General session on **Low-Level Radiation Health Effects** (TRANSACTIONS of the American Nuclear Society, Vol.77) At the **June 1999 ANS Annual Meeting** in Boston MA, three paper sessions and two Panel sessions with 15 papers are scheduled on **Low-Level Radiation Health Effects**.

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