SESSION XI

LUNCHEON MEETING

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CHAIRMAN: D. W. Moeller

SOME PERSPECTIVES ON RADIATION PROTECTION Dr. Warren K. Sinclair

OPENING REMARKS OF SESSION CHAIRMAN:

The year, 1978, marks the 50th anniversary of the founding of the National Council on Radiation Protection and Measurements. Today we are honored to have with us as our luncheon speaker, the President of the Council, Dr. Warren K. Sinclair.

Dr. Sinclair is a native of New Zealand who came to the United States about twenty-five years ago and has been a citizen for the past twenty years. He received his bachelors degree and masters degree in physics from the University of New Zealand. Thereafter, he completed the doctorate at the University of London where he studied under Professor W. V. Mayneord, a pioneer in radiation protection.

During the early years of his career, Dr. Sinclair showed an interest in the academic profession and has been closely associated with it ever since. From 1945-47, he served as Lecturer in Physics and Radiological Physics, University of New Zealand; from 1947-54, he was Assistant Physicist, Royal Cancer Hospital, and Lecturer, University of London; and from 1954-60, he was Head, Physics Department, M.D. Anderson Hospital and Professor of Physics, University of Texas. Subsequently, Dr. Sinclair became Professor of Biophysics at the University of California in Berkeley, and in 1970, he became Director, Division of Biological and Medical Research, Argonne National Laboratory. In 1974, he was appointed Associate Laboratory Director, a position which he continues to hold today. In addition to these many duties, Dr. Sinclair also serves as Professor of Radiation Biology, Department of Radiology, University of Chicago and as President of the Radiation Research Society. He is also a past president of the American Association of Physicists in Medicine and currently serves as a member of the International Commission on Radiation Units and Measurements, the International Commission on Radiological Protection, and the U. S. Scientific Delegation, UNSCEAR. He was elected to the Presidency of the NCRP in 1977. In short, he is a very busy man and it is a delight to have him with us today. Dr. Sinclair will speak to us on the subject of "Some Perspectives on Radiation Protection."

SOME PERSPECTIVES ON RADIATION PROTECTION

Warren K. Sinclair, President
National Council on Radiation Protection and Measurements

I am pleased to have this opportunity to address you on the subject of protection from ionizing radiation and especially to describe to you some of the work of the National Council on Radiation Protection and Measurements (NCRP) of which I am the President, and of the International Commission on Radiological Protection (ICRP) of which I am a recently elected member.

Both of these bodies have almost exactly half a century of history - and indeed the ICRP celebrated its 50th anniversary in Stockholm recently. It was in Stockholm in 1928 that the Second International Congress of Radiology established the International Commission on Radiological Protection, and Lauriston Taylor, of the USA, was one of its founding members. He also organized, that same year, the Advisory Committee on X-ray and Radium Protection which became the forerunner of first, the National Committee on Radiation Protection, and in 1964, the National Council on Radiation Protection and Measurements chartered by the Congress of the United States as a non-profit corporation "...to collect, analyze, develop, and disseminate in the public interest, information and recommendations about (a) protection against radiation and (b) radiation measurements, quantities, and units, particularly those concerned with radiation protection."

The Council has a membership of some 75 scientists, physicians and engineers, elected for six-year terms (from the nominations of its members and its more than 30 collaborating organizations) drawn from the fields of radiation physics, biology, nuclear medicine, radiology, public health, nuclear engineering, environmental science, biophysics, genetics, microwave and ultrasound studies, dentistry, veterinary medicine, epidemiology and many other branches of science. In addition, its scientific committees and study groups include more than 300 additional scientists selected for their expert knowledge in the given subject area of the committees' work.

NCRP reports are produced by establishing, in a specific subject area, a scientific committee or study group of six to ten persons who draft a report which is then submitted to the entire Council for review. All substantive comments from the Council, and sometimes from other additional reviewers, are accounted for before the report is published as a report of the NCRP. The preparation and reviewing process takes time and NCRP reports reach the press often, regrettably, only slowly; but the process is one of careful deliberation and the detailed review process has certainly been responsible for the maintenance of high quality in the technical accuracy of the reports and in the quality of their guidance and recommendations. All work by Council and committee members is voluntary, which also contributes to the length of the process but ensures an independence of viewpoint and judgment generally not possible by other means. The true role of the NCRP is to provide this deliberate, expert opinion as free as possible of special interests or groups, and keeping always the public interest and the national good, as perceived by this expert body, in mind. The scope of the NCRP program is as broad as the impact of radiation on our lives and environment. The NCRP therefore seeks to render useful information and advice about all matters pertaining to radiations and protection against them.

The NCRP has a total of about 60 scientific committees and study groups of which more than 35 are currently active. The NCRP presently has two important committees dealing with non-ionizing radiation, but for purposes of discussion here, we shall limit our attention to committees concerned with ionizing radiation only.

For purposes of explanation and clarification, the work of these committees and groups can be divided into three principal categories:

1. Scientific Committees and Study Groups concerned with basic radiation protection criteria:
   - SC-1 Basic Radiation Protection Criteria
   - SC-40 Biological Aspects of Radiation Protection Criteria
   - SC-57 Internal Emitter Standards
   - \- Study Group on Human Exposure Experience
   - \- Study Group on Comparative Risk
2. Scientific Committees concerned with the assessment of dose to members of the general public:
   - SC-28 Radiation Exposure from Consumer Products
   - SC-41 Radiation Resulting from Nuclear Power Generation
   - SC-43 Natural Background Radiation
   - SC-44 Radiation Associated with Medical Examinations
   - SC-45 Radiation Received by Radiation Employees
   - SC-48 Apportionment of Radiation Exposure
3. Scientific Committees concerned with matters of guidance. For example:
   - SC-46 Operational Radiation Safety
   - SC-51 Radiation Protection in Pediatric Radiology
   - SC-15 Radiation Protection in Teaching Institutions
   - SC-16 Dental X-ray Protection
   - SC-17 Radiation Protection in Veterinary Medicine

   Or Scientific Committees concerned with information on selected topics of importance. For example:
   - SC-38 Waste Disposal-Krypton-85 in the Atmosphere
   - SC-36 Tritium Measurement Techniques
   - SC-35 Environmental Radiation Measurements
   - SC-24 Radionuclide and Labeled Organic Compounds Incorporated in Genetic Material

By way of explanation of the NCRP program, I will make just a few comments on each of these three, starting with the third category and working back.

A task group of SC-38 on Waste Disposal, in 1975, produced NCRP Report No. 44, Krypton-85 in the Atmosphere - Accumulation, Biological Significance and Control Technology[1], which may be of some particular interest to air quality engineering experts.

The report describes the properties of ^{85}Kr, and makes estimates of future power requirements and ^{85}Kr releases to the year 2000; it describes the fate of ^{85}Kr, the dosimetry, the projected exposure of the population from ^{85}Kr, the biological significance of the absorbed dose due to ^{85}Kr, and the status of control technology procedures. The final discussion and summary indicates that, depending on nuclear power assumptions in the year 2000, which may now be modified due to changes in policy on reprocessing, the atmospheric inventory of ^{85}Kr and the doses to skin from diffused ^{85}Kr ($T_{\frac{1}{2}}$ 10.7 yr., β, 0.51 MeV), and the whole body dose will rise from 1970 to the year 2000, as shown in the table:

	1970	2000
Inventory of ^{85}Krypton	55 megacuries	3600-6200 megacuries
Dose to Skin	0.02 mrem/yr.	2-3 mrem/yr.
Dose to Whole Body	2×10^{-4} mrem/yr.	0.02 mrem/yr.

While the dose to whole body is negligible, the dose to the skin may become a factor to be considered. The report indicates that various control technologies are available which could remove ^{85}Kr from waste gases, including fluorocarbon extraction, precipitation as a clathrate, selective membranes or cryogenic distillation or absorption.

Another report of potential interest to this audience is NCRP Report No. 50, Environmental Radiation Measurements[2]. I would like to draw your attention to the major headings in the Table of Contents as follows:

Introduction
Natural and Manmade Environmental Radioactivity and Radiation Fields
Requirements for Measurement and Surveillance Programs
In Situ Radiation Measurements
Collection and Preparation of Samples for Laboratory Analysis
Laboratory Measurements
Conclusions: Trends and Problem Areas.

Among the second category of committees, i.e. those addressing population exposure, two have already produced reports; one, Report No. 45, Natural Background in the United States[3], is a definitive report on this subject for the USA.

This report evaluates the contributions to human exposure of external cosmic radiation and cosmic ray-induced radioactivity, external terrestrial radiation, inhaled radioactivity, and internally deposited radionuclides. It concludes that the average exposure to an individual in the USA is as shown below:

Average for the U.S.	∿ 80 mrem/year
Maximum (Denver)	∿125 mrem/year
Minimum (Atlantic Coast)	∿ 65 mrem/year

These numbers are often rounded off to ∿100 ± 25 mrem/year.

The report also deals with contributions to the dose from fall-out and from air travel. Some of you might be interested in the latter because many of you probably travel quite a lot. I have added a few small calculations to the material in Report No. 45 in the slide that follows:

Dose from Air Travel (NCRP Report No. 45) *

Mid-latitude flights ~5 hours = 2.5 mrem

High latitude (polar) flights ~ 10 hours = 10 mrem.

Frequent Traveler at Mid-Latitudes

100,000 miles per year at 500 mph = 200 hours (or about 2% of total available time!)

Dose = $\frac{200}{5}$ x 2.5 mrem = 100 mrem (or a doubling of natural background.)

Pilot and Crew

100 hours per month maximum - (Actual 60-65 hours)

$\frac{100}{5}$ x 2.5 x 12 = 600 mrem/year

(Note: This is well below occupational levels, 5000 mrem/year.)

Contribution of Air Travel to Population Dose (NCRP Report No. 45)

~1 mrem/year

This shows that a very frequent traveler may double his exposure to natural background and that pilots and crew may get substantial exposure if they fly up to the maximum amount. These exposures are, however, considerably below those currently allowed for occupational workers.

Another very recent report in this category is NCRP Report No. 56, Radiation Exposure from Consumer Products and Miscellaneous Sources (1977)[4]. This report considers thirty or more sources of exposure to segments of the public from consumer products. These include electronic products such as television receivers, x-ray devices such as airport inspection systems, sources such as incorporated radionuclides in building materials, or (more bizzarre) uranium in dental porcelain, or sources such as luminous materials in watches, clocks or instrument dials. A few of the estimated average exposures to the population from representative sources are as follows:

Source	Tissue	No. of People Exposed	Average Annual Population Dose
Television Receivers	Gonads	100,000,000	0.5 mrem
Airport Inspection Systems	Gonads	10,000,000	1 μrem
Luminous Wristwatches			
Radium	Gonads	10,000,000	150 μrem
Tritium	Whole body	16,000,000	50 μrem
Combustible Fuels (Coal)	Lungs	50,000,000	0.5 - 1 mrem
Building Materials	Whole body	100,000,000	3.5 mrem

The overall exposure to the public from all such sources is less than 5 mrem/year, and most of this (70%) comes from building materials, primarily U, Th and ^{40}K in masonry (as opposed to frame construction). Note, this includes office exposure for many people as well as private housing (100,000,000 people receiving 7 mrem/yr is equivalent to a dose of 3.5 mrem/yr to the entire US population of 200,000,000).

At this point I thought it might also be of interest to you to know about some important sources of exposure and the average doses to which the average member of the public is estimated to be exposed.

Estimated "Average" Annual Exposure to Members of U.S. Population

A.	Natural Background	100 mrem
B.	Air Travel	1 mrem
C.	Radioactive Fallout	
	Whole Body	$\sim$0.5 mrem
	Bone	2 mrem
	(Alaskan Eskimos (max.)	50 mrem)
D.	Occupational	$\sim$0.8 mrem
E.	Consumer Products	$<$ 5 mrem
F.	Nuclear Power	$<$ 1 mrem
	Waste Management	$<$ 0.001 mrem
G.	Medical	55-75 mrem

The two kinds of committees I have discussed so far, namely those concerned with guidance or information, and doses to the public, are of interest and considerable value. However, the most important function of the NCRP (and the ICRP) is contained in my first grouping; namely the work of committees concerned with Basic Radiation Protection Criteria. In the NCRP, in the past, a single committee established the basic radiation protection criteria for external exposure, and the basic report here is that known as NBS Handbook 59 (NCRP Report No. 17) published in 1954[5], after an extended period of examination and close cooperation with the ICRP. It set levels of permissible occupational exposure (weekly 0.3 rem= 15 rem/yr) which, in 1957, were effectively lowered when age proration was introduced. The new basic occupational level then became 5(N-18) rem/yr, where N is the age in years. These occupational levels have been widely adopted by government agencies in rule-making, and by industry and many others for guidance.

These levels were essentially repeated in the NCRP Report No.39 Basic Radiation Protection Criteria, issued in 1971[6]. At that time, the NCRP, following the philosophy of absence of harm, saw no reason to alter the levels. These are the levels the NCRP recommends at the present time and are summarized as follows:

Emergency	Life Saving (>age 45)	$\not>$ 100 rems
	Non-life Saving	$\not>$ 25 rems
Occupational	Whole Body (N=age in years)	$\not>$ 5 (N-18) rems
	Extremities higher	
Public	Individual	$\not>$ 0.5 rem in 1 yr.
	Average	$\not>$ 0.17 rem av./yr.
	(i.e. 170 mrem or $\sim$ 2 x natural background).	

Nevertheless, the process of examining levels and their suitability both for external radiation and for internal emitters released in the air and water is a continuing one. The primary responsibility for this rests with NCRP's SC-1, but in 1971 a new committee was set up, SC-40, on Biological Aspects of Radiation Protection Criteria, to aid Committee 1 in the evaluation and analysis of important radiobiological information which would enable better extrapolation of data obtained at high doses to the low doses of protection level interest. This Committee has been examining the important matter of dose-rate effects and their influence on the dose response curve at low doses. It will also examine the important matters of the relative effectiveness of high-LET radiation at low levels. These examinations will result in estimates of risk being supplied to Committee 1 for radiation exposure circumstances relevant to radiation protection.

At the same time a new Study Group on Human Exposure Experience will be examining all sources of human exposure taking into account not only the excellent surveys of Japanese data from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)[7], but considering, also, the validity of recent studies such as those reported by Mancuso et al.[8], exposures at the Portsmouth naval shipyard, military exposures during bomb tests, and other sources of potential value in establishing levels at which harm exists. Many other sources in the medical field such as the induction of thyroid tumors in persons given x-ray therapy to the head and neck region may also yield important information. Medical studies tend to receive less publicity than studies on workers, but they may yield more information ultimately.

The NCRP also has a Study Group on Comparative Risk which seeks to examine the hazards from other agents to which the public and occupational workers may be exposed, and to place radiation hazards in context with them. In all of these cases, while the principle of "as low as practicable (ALAP)," or "as low as reasonably achievable (ALARA)" is the basic operating tenet, when limits above which exposure is unacceptable must be defined, they should be based on similar considerations no matter what the exact source of the hazard may be, if the effects on the individual and/or the population are comparable. The basis should, perhaps, be acceptable risk, and I might point out that the NCRP has another group examining this question specifically in relation to waste disposal procedures.

SC-57 on Internal Emitter Standards is examining the maximum permissible levels of radionuclides in air and water, and is studying the metabolism of nuclides introduced to the body by these routes and, therefore, causing exposures in workers and others at levels controlled by the recommendations of SC-1. SC-1 and SC-57 work closely on these matters and are heavily engaged on their programs at the present time and I expect both committees to come out with highly significant reports within the next two years.

Now let me turn briefly to the ICRP. The ICRP comprises a Chairman and 12 members of the main commission elected as individuals for four-year terms. Currently these members are drawn from nine countries, and many other countries are represented among the individuals serving on the four main committees of the ICRP and on their task groups. The ICRP program also includes the study of the fundamental principles upon which radiation protection measures are based as well as general guidance on matters of radiation protection. More specific guidance tends to be left appropriately to the national groups of each country. Also, the United National Scientific Committee on the Effects of Atomic Radiation[7] provides much of the radiobiological assessment, population exposure information, and worldwide impact of sources that ICRP can use, and therefore does not need to generate independently. In recent years, ICRP has been very active in developing the basic principles of radiation protection and in 1977 produced ICRP Publication 26[9]. In this connection, it is interesting to note that the ICRP initiated publication of its Annals in 1977, and the reports of the ICRP are now readily available by subscription to these Annals.

The principal features of ICRP Publication 26 are as follows:

The report

- discusses risk in detail
  - total stochastic risk, 10^{-2} Sv^{-1}*
  - total genetic risk, 4×10^{-3} Sv^{-1}
- limits occupational exposures for adults irradiated whole body to 50 mSv/year (5 rems/year), i.e. somatic risk has a maximum value of 5×10^{-4}/year
- does not allow for age proration, i.e. the occupational limit is ≯5 rems/year even if exposure has been much lower in previous years
- permits higher exposure of individual organs when body is irradiated non-uniformly (see below)
- suggests that exposure of individual members of the public be limited to 5 mSv, in which case the average exposure should not exceed 0.5 mSv, corresponding to a risk of 10^{-6}/year, which is deemed to be acceptable when compared with other risks
- promotes principles of optimization of protection procedures to keep exposures well below these limits (i.e. ALARA).
- emphasizes that the upper limit (5 rem/year) is rarely received by workers, that 10-15% of this level is an average, and this average exposure of radiation workers is comparable with the hazards of other safe industries.

*1 Sievert (Sv) = 100 rems.

The weighting factors for non-uniform radiation are as explained in the following two paragraphs quoted from ICRP Publication 26:

(104) For stochastic effects the Commission's recommended dose limitation is based on the principle that the risk should be equal whether the whole body is irradiated uniformly or whether there is non-uniform irradiation. This condition will be met if

$$\sum_T w_T H_T \leq H_{wb,L}$$

where, w_T is a weighting factor representing the proportion of the stochastic risk resulting from tissue (T) to the total risk, when the whole body is irradiated uniformly, H_T is the annual dose equivalent in tissue (T), $H_{wb,L}$ is the recommended annual dose-equivalent limit for uniform irradiation of the whole body, namely 50 mSv (5 rem).

(105) The values of w_T recommended by the Commission are shown below:

Tissue	w_T
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder	0.30

The value of w_T for the remaining tissues requires further clarification. For the reasons stated in paragraphs 58 and 59 the Commission recommends that a value of $w_T = 0.06$ is applicable to each of the five organs or tissues of the remainder receiving the highest dose equivalents, and that the exposure of all other remaining tissues can be neglected. (When the gastro-intestinal tract is irradiated, the stomach, small intestine, upper large intestine and lower large intestine are treated as four separate organs.)

The ICRP has also been revising the permissible levels for internal emitters and a report of its Committee 2 on the first 22 elements, some 200 radionuclides considered to be of primary importance, will go to press this fall. It is not yet available for general distribution, but its approach is to develop dose equivalent limits for internal exposure which are equated with those of ICRP 26 for external exposure. These will define a Committed Dose Equivalent, H50, the dose caused by the intake of a nuclide over 50 years, which must not deliver an annual dose greater than 5 rem/year (weighted for organs if necessary). Secondary levels which will conform to these dose limits are expressed as Annual Limits of Intake (ALI's) either by ingestion or inhalation. In the case of inhalation, a Derived Air Concentration is defined such that the ALI is divided by the volume of air inhaled by Reference Man in a working year. Total ingestion includes liquids and solids and is controlled by the ALI for ingestion. No separate value for water will be given. This new approach by ICRP in the internal emitter area is yet to be tested in practical application and working experience on the part of health physicists is needed.

Another area in which the ICRP has made a significant contribution, recently, is in the issuance of its Publication 27, Problems Involved in Developing an Index of Harm[10]. This report is not intended to be a definitive report but rather tries to develop a method for equating risks from very different sources. For example, the industrial accidents or injuries. This effort is well worth further study and refinement. One general conclusion to be derived from this report is that radiation exposure at the average level of occupational workers (10-15% of the upper limits themselves) is comparable with the hazards of "safe" industries. If exposures are actually at the upper limit however, the risks, estimated on the basis of the linear hypothesis, are more comparable with the relatively dangerous industries like construction and mining.

In view of the trend toward greater and greater safety in all fields leading presumably to further reductions in accident rates, and as the approaches to comparative risks from different sources of hazard become better appreciated, it will be increasingly necessary to re-examine the philosophy of radiation protection. Hopefully, in time, more definitive quantitative information on the risks at low levels may become available, possibly demonstrating the extent to which the assumed linear hypothesis over-estimates the hazard. An important aspect of this is that we must keep analyzing actual data from all sources of radiation exposure of human beings as it accumulates. Positive information will enable future estimates of risk to be more accurate than they are now and thus recommendations for limits for occupational workers and for the public can be put on a steadily sounder foundation.

* More recent estimates involving a more extensive direct survey (R.W. Wallace and G.A. Sondhaus, Aviat. Space and Environ. Med. 49 (4): 610-613, 1978) indicate appreciably lower values for the average exposures due to air travel.

References

1. NCRP Report No. 44. KRYPTON-85 IN THE ATMOSPHERE--Accumulation, Biological Significance, and Control Technology. July 1975.

2. NCRP Report No. 50. Environmental Radiation Measurements. December 1976.

3. NCRP Report No. 45. Natural Background Radiation in the United States. November 1975.

4. NCRP Report No. 56. Radiation Exposure from Consumer Products and Miscellaneous Sources. November 1977.

5. National Bureau of Standards Handbook 59 (NCRP Report No. 17). Permissible Dose from External Sources of Ionizing Radiation. September 1954.

6. NCRP Report No. 39. Basic Radiation Protection Criteria. January 1971.

7. UNSCEAR Report, "Sources and Effects of Ionizing Radiation." United Nations, New York, 1977.

8. Mancuso, T. F., A. Stewart, and G. Kneale. "Radiation Exposures of Hanford Workers Dying from Cancer and Other Causes." Health Physics, Vol. 33, No. 5, pp. 369-385, 1977.

9. ICRP Publication 26. "Recommendations of the International Commission on Radiological Protection." Annals of the ICRP, Vol. 1, No. 3, 1977.

10. ICRP Publication 27. "Problems Involved in Developing an Index of Harm." Annals of the ICRP, Vol. 1, No. 4, 1977.