RADIATION AND MAN

Presentation of U.S.A. National Academy of Sciences
Report on The Effects on Populations of Exposure to Low Levels of
Ionizing Radiation (BEIR Report)

1. General Review and Implications

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Abstract

This paper toegther with that of Dr. James F. Crow on Genetic Effects and of Dr. Arthur C. Upton on Somatic Effects is an expository review of the report of the Advisory Committee on the Biological Effects of Ionizing Radiations of the National Academy of Sciences - National Research Council which was prepared by about 50 members of the Committee and its Subcommittees and completed in late 1972. It deals with the scientific basis for establishment of radiation protection standards encompassing a review and re-evaluation of existing scientific knowledge concerning radiation exposure of human populations.

Data, assumptions, and numerical risk estimates are presented for the genetic and somatic effects of low levels of exposure. It is calculated that exposure of the entire U.S. population to 170 mrem/year would cause at equilibrium (after many generations) between 1100 and 27,000 incidences per year of serious genetic disabilities. In the opinion of the Committee, the same exposure could cause from roughly 3000 to 15,000 cancer deaths annually based on the assumptions used including linearity and with no correction for dose-rate. The uncertainties and bases for these estimates are stressed in the papers of Drs. Crow and Upton. Interpretations are presented in regard to effects on growth and development and on the environment (on organisms other than man).

Future major contributions to radiation exposure of the population will continue to be natural background and medical applications. Medical radiation exposure can and should be reduced considerably without any deprivation of benefits. Radiation exposure to the U.S. population from the developing nuclear power industry can be kept at about 1% of natural background and the exposure of any individual kept to a small fraction of background provided that the technology operates as planned. Engineering and technical uncertainties in regard to nuclear power were not assessed by the Committee.

It is suggested that radiation protection standards not be set on an arbitrary basis such as related to background levels, (even though all agree that such levels will not produce observable effects), but rather should be established in terms of minimal exposures required to fill society's needs. Hopefully, it will be possible to make meaningful risk-benefit assessments, then to make cost-effectiveness assessments so that logical decisions can be made as to the worth of any given effort to reduce the risk, and finally to choose among the alternate options taking into account a comparison of the biological and environmental costs.

Ultimately, these techniques for dealing with radiation protection (actually estimating the risks and the worth of reducing them) may provide guidance for other pollutants, since the time is coming when priority decisions will have to be made in allocation of limited resources for the maintenance and improvement of the quality of life.

I. Introduction

In late 1972 the Advisory Committee on the Biological Effects of Ionizing Radiation of the U.S.A. National Academy of Sciences - National Research Council completed its Report on The Effects on Populations of Exposure to Low Levels of Ionizing Radiation (BEIR Report). This paper, the first of three, is a personal interpretation of the approach, general findings and implications of the BEIR Report. It will be followed by detailed discussions of Genetic Effects by Dr. James F. Crow and of Somatic Effects by Dr. Arthur C. Upton. Appreciation is expressed to the Program Committee of the International Radiation Protection Association for the opportunity of presenting these papers and the generous time allotment.

II. Background

Understanding of the objectives and frame of reference of the BEIR Report can be gained by remembering the "BEAR" Reports (on Biological Effects of Atomic Radiation) of an earlier committee of the National Academy that was established in 1955 to respond to public anxiety about the possible effects of nuclear weapons testing on the human population. The BEAR reports did so respond, were accepted by the public, and served mainly to: (a) place in perspective the extent of harm expected from fallout, (b) introduce the concept of regulation of average population doses on the basis of genetic risks, and (c) emphasize the significance of medical-dental radiation exposure.

In the late 1960's public concern again became aroused because of potential exposures from a developing nuclear power industry. Numerical genetic and somatic risk estimates were being used, and harmful effects were widely described as if it were planned that the total U.S. population were to be exposed to levels equivalent to present radiation protection guideline (namely 170 mrem/year). In February of 1970 the Federal Radiation Council (FRC) asked an existing NAS-NRC Advisory Committee to undertake a complete review of the matter. Thereafter the FRC was subsumed into the Environmental Protection Agency, the Advisory Committee was expanded into the BEIR Committee, and the review was undertaken.

Over the years, somewhat similar responsibilities in regard to radiation protection have fulfilled by other organizations including; the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), The International Commission on Radiological Protection (ICRP), and the National Council on Radiation Protection and Measurements (NCRP). Their reports have been most useful to members of the BEIR Committee and their personnel most cooperative.

It must be remembered that reports of various bodies may differ because of the charge, scope and composition of the committee involved, as well as the state of knowledge and public atmosphere existing at the time of the writing of a given report. In general the main differences between the BEIR Report and previous official documentation arise not so much from the inclusion of new data or new interpretations, but rather from a philosophic approach to radiation protection generated by changing conditions and public attitudes.

The BEIR report differs from the other reports in one or more of the following ways: (a) efforts are made to present the conclusions in such a way as to be useful to those who must take into account technological, economic, and sociological considerations in the development of regulatory programs in the United States; (b) numerical risk estimates for human populations exposed to low levels of ionizing radiation are presented together with the assumptions and compilations of data on which they are based; (c) it is suggested that radiation protection standards should not be set on an arbitrary basis, such as in relation to background levels (even though all investigators agree that such levels will not produce observable effects), but rather that they should be established in terms of minimal exposures required to fill society's needs: (d) implications of possible effects of radiation on the environment - on organisms other than man - are considered; (e) it is proposed that medical-dental radiation exposure can and should be reduced considerably without impairing medical benefits; (f) emphasis is placed on the desirability of making meaningful risk-benefit assessments and then cost-effectiveness assessments so that logical decisions can be made as to the worth of any given effort to reduce the risk - choices could then be possible among alternate options involving radiation and non-radiation processes by comparison of biological and environmental costs.

Obviously the BEIR Committee and its subcommittees even though expanded to a membership of about fifty could not deal definitively with the broad non-scientific, sociological or economic issues. Yet it was felt that such issues must be brought forward. For example, in regard to the possibilities of catastrophic reactor accidents; it was not within our competence to render opinions on probabilities, effects, overall risks, financial expenditures justified, or rational of public acceptance. Nevertheless, we did call attention to this matter prominently in the summary statement.

III. Risk Estimates

There is always the question as to whether numerical risk estimates should be included in official documentation. It is realized that no matter how carefully the estimates are qualified, the numbers will be used and quoted by others out of context. The decision to include numerical values was based largely on the fact that such estimates were already being widely used in public discussion and were having a significant emotional impact on decision-making. It was felt necessary first to assure that the most reliable numbers be used, but perhaps more important, to bring about the understanding that it may be a public disservice to misuse risk estimates, that is to make decisions on the basis of risk estimates for only one of the necessary options, or to spend large amounts of resources to reduce small risks even further while larger risks go unattended.

The philosophy in radiation protection to-date has been to state the matter in qualitative terms. For example, NCRP 39* contains the following statement:

> "In particular, it is believed that while exposures of workers and the general population should be kept to the lowest practicable level at all times, the presently permitted exposures (170 mrem/yr for the population) represent a level of risk so small compared with other hazards of life, and so well offset by perceptible benefits, that such approbation (public acceptance) will be achieved when the informed public review process is completed."

*Basis Radiation Protection Criteria, National Council on Radiation Protection and Measurements, January 15, 1971, NCRP Report No. 39. Material in brackets added.

However, it appears now that public knowledge and public demand requires further detail.

The risk estimates of the BEIR Report are presented in greatly simplifield form in Tables 1 and 2. In round figures it is stated that exposure of a population of 200 million to 170 mrem/yr could cause about 10,000 deaths or serious disabilities per year of somatic and genetic origin in the first generation. This can be expressed as a risk per year of 1 in 20,000. Given the numerical estimates for genetic and somatic risk the question arises as to how this information can be used as a basis for radiation protection guidance. Logically, the guidance or standards should be related to risk. Whether we regard a risk as acceptable or not depends on how avoidable it is. Obviously no risk, no matter how small, should be accepted if it is indeed readily avoidable. To the extent not avoidable, acceptability depends upon how the risk compares with those of alternative options and those normally accepted by society.

It is not difficult to compare the risks from radiation with those normally accepted by society - recognizing that any such comparison is not meant as a justification for acceptance of any unnecessary risk. As indicated in Table 3, there seem to be two natural boundary conditions. The high risk boundary of 1 in 100 is the statistical risk of deaths from all causes. The lower boundary of 1 in 1,000,000 appears to be the risk of deaths from external catastrophes such as floods, earthquakes, lightning, snake bites, etc. Thus, one can establish a rough scale of risk, as shown in Table 4.

Traditionally, society has treated low and negligible risks as acts of God and has focused attention on the high risk category. It is interesting to note that in the high risk range we find such voluntary activities as auto travel, plane travel, hunting, and skiing.

It is important to realize that public response will probably never be completely logical. For example, the public abhorrence of specific catastrophes may result in relatively large investments to avoid them, regardless of the quantitative importance. There may be other philosophic biases related to risk that are just not subject to rational agreement.

There are two main aspects of the analysis. First, it is necessary to assess risk-benefit relationships since a man-made risk can be regarded as avoidable unless we need the associated benefit. As indicated, we feel that the risk estimates for radiation are comparatively well established, but the question of benefit requires much more consideration. The BEIR Committee has now been specifically charged to undertake the study of benefits, the difficulty of which should not be underestimated. As an example, one benefit of radiation exposure from the nuclear power industry is, obviously, the avoidance of health effects from the combustion of fossil fuels, which immediately necessitates comparing the biological costs of the alternative options.

The second aspect concerns what might be called "cost-effectiveness analysis," which governs just how avoidable the risk is. It is obvious that any risk can be decreased at an increased financial cost. In a resource limited society (and believe me, we are becoming more so all the time) the allocations must be made where they will do the most good. It is a misuse of resources and a disservice to society to add costs for the purpose of decreasing the risks of any one system greatly below acceptable levels, when other societal activities with unacceptable risks are being ignored. Some examples of choices that could be made are: a national program to persuade people to use seat belts is estimated to cost less than $100 for each death averted; a program of early cancer detection and treatment is estimated to cost up to about $40,000 for each death averted. At the height of fallout it was calculated that the removal of ^{90}Sr from milk at a cost of 2 to 3 cents per quart would cost about 20 million dollars for each case of cancer averted. It has been estimated that money spent on improved collimation of X-ray machines would be 1000 to 10,000 times more effective in reducing radiation dosages than money spent on improving present reactor waste systems.

By way of summarizing risk considerations, certain points appear to be important. Our best estimates of risk from radiation exposure, even when expressed in numerical terms support previous views (implied by NCRP documentation) that such risks are indeed small when compared with the probable benefits from necessary activities. The public should somehow be educated to this truth and all attempts should be made to reduce any philosophic biases. As part of this process, regulatory procedures should assure that societies' needs are being met with the lowest possible risks. The interpretation of the words, "lowest possible," should rest upon development of cost-effectiveness analyses. It should be made clear that even when the benefits clearly exceed the risks, the risks should still be reduced to the lowest level compatible with cost-effectiveness considerations.

IV. Summary of BEIR Report Recommendations

The BEIR Report made ten major points which are paraphrased in abbreviated form:

a. No exposure to ionizing radiation should be permitted without the expectation of a commensurate benefit.

b. Public protection from radiation must not result in a substitution of worse hazards for the radiation avoided. Small risks should not be reduced below the point of cost-effectiveness.

c. The upper limit of non-medical radiation exposure for individuals in the general population should produce risks that are small relative to those normally accepted.

d. The above upper limit for individuals should be considerably lowered if the general population is to be exposed. This limits the total amount of harm that could be caused as well as the probability of harm to any individual.

e. Medical radiation exposures can and should be reduced considerably without impairing medical benefits.

f. Guidance for the nuclear power industry should be based on risk-benefit and cost-effectiveness analysis taking into account the alternate options.

g. Extraordinary efforts to minimize the risk from catastrophic accidents in the nuclear power industry are called for.

h. Occupational and emergency exposure limits should be based on numerical risk estimates to the individual.

i. Populations of other living organs will most likely not be perceptibly harmed if the radiation protection guidelines acceptable for man are adhered to. Nevertheless, there are good reasons for strengthening ecological studies.

j. Every effort should be made to assure accurate estimates and predictions of radiation equivalent dosages from all existing and planned sources.

V. A Broader View

Society is becoming increasingly sensitive to health problems from contamination and pollution. Whenever a potential hazard is identified, becomes measurable, and is publicly recognized there is pressure for zero or near zero guidelines. Usually there is little or no information about low-level population effects and decisions may well be made that overall cause a lowering of the quality of life. Radiation is the one agent for which tremendous amounts of data are available. Now that we have risk estimates, fraught with uncertainty though they may be, the way we use, neglect, or misuse them for the public good may set an example for the course we are to follow with the great variety of potential harmful agents that modern man exposes himself to. In a real sense then, radiation workers have societal responsibilities that go far beyond the effects of ionizing radiation.

Table 1

Simplified Summary of Radiation Effects

170 mrem/yr to U.S. population (200 x 10^6)

would cause an upper limit of 3600 genetic disabilities/year in 1'st generation

could cause as a most likely estimate 6000 cancer deaths/year

Table 2

Radiation Effects Expressed as Risk per year

170 mrem/yr could cause

$\sim$ 10,000 cases of harm in 200 x 10^6 per year

or 1 case in 20,000 per year

Table 3

Comparative Population Risks in the U.S.

Sources	Risk of Death per Year
From all causes	
Under 1 year	1 in 46
1 year old	1 in 735
10 years old	1 in 3600
35 years old	1 in 470
55 years old	1 in 85
Average population	1 in 100
From 170 mrem/year	1 in 20,000
From natural disasters	1 in 1,000,000
From 1 mrem/year	1 in 3,400,000

Table 4

Arbitrary Categories of Risks

Scale	Risk of Death per Year
High	1 in 100 to 1 in 1,000
Medium	1 in 1,000 to 1 in 100,000
Negligible	1 in 100,000 to 1 in 10,000,000