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NATURAL RADIOACTIVITY AND RADIOACTIVE FALLOUT

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FILE BARCODE
00131449

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I. COMPARISON OF FISSION PRODUCTS BY WEAPONS TESTING AND POWER REACTORS

The problem of the disposal of radioactive wastes exists not only in the field of weapons testing but also to a crucial degree in the power reactor program. In the latter case, more control can be exercised over the immediate fate of the fission products, but disposal must eventually be made. If disposal is to be simple enough so that nuclear power can be economically competitive, then advantage will have to be taken of natural dispersing systems. The possibility exists that ultimately the reactor-produced activities may enter the food cycle and man. The basic problem of permissible exposure and many of the distribution mechanisms in the biosphere are, therefore, the same for bombs and for reactors.

For comparison of the potential magnitudes of the two problems, it can be noted that a 100-megawatt (heat) reactor will in the course of one year's operation produce the same quantity of long-lived fission products as the detonation of a 1-megaton fission bomb. One reactor of the type contemplated for the nuclear propulsion of aircraft would operate at a power level of about 300 megawatts, equivalent to 3 megatons of bombs per year. The British estimate their production of power with nuclear reactors at about 6,000 megawatts by 1965. At 10% efficiency this is 60,000 megawatts of heat, equivalent to 600 megatons of fission per year. The estimate of United States nuclear power production by 1975 is 20,000 to 40,000 megawatts (electrical).

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II. ESTABLISHED PERMISSIBLE EXPOSURE LEVELS

Because the scarcity of adequate biological data makes estimates of the minimum amount of radiation necessary to produce damage only approximate, the International Commission on Radiological Protection has adopted the philosophy of setting permissible exposure levels for the general population in terms of the inevitable natural radiation to which man is exposed. The natural radiation levels vary several fold, depending on geographic location. Even conservative geneticists (such as Müller) agree that man has evolved amid this radiation without apparent damage. Since Sr^{90} cannot constitute a genetic hazard, the limiting factors with regard to long-term fallout are effects such as cancer or leukemia. While some authorities feel that the natural levels could be increased by a factor of ten without detectable effects of this sort, the most conservative will admit only an absolute safety limit of twice natural background. This is by no means guesswork but depends on a large amount of experimental work by geneticists and biologists. To quote from the Report of the Committee on Genetic Effects of Atomic Radiation, Summary Report page 6: "There is a considerable margin of uncertainty about much of this, and as a result, there are naturally some differences of opinion among geneticists themselves as to exact numerical values, <u>although no disagreement as to fundamental conclusions</u>" (Italics in original).

The principle has been adopted, therefore, by the International Commission on Radiological Protection that an <u>additional</u> amount of radiation equal to that

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normally received from natural sources is permissible, even for entire populations -- men, women, and children.* In other words, it is the opinion of geneticists that we can safely double the radiation dose the human race is receiving.

The average natural background radiation is made up as shown in the following table.

THE AVERAGE NATURAL BACKGROUND RADIATION

Source	Dose Rate (mr/yr)
Local gamma rays (from Ra, U, etc.)	50
Cosmic rays	30
Potassium in body	20
Radiocarbon in body	1
	100 mr/yr (whole-body irradiation)
Radium in bones	60 (bone only)
Total dose rate to bone	160

The local gamma dose alone has been measured to be as high as 170 mr/yr in some Swedish houses (alum shale concrete) and 100 mr/yr in Scottish buildings (granite).

* The actual recommendation of the NAS-NRC Committee on the Genetic Effects of Radiation, Summary Report, page 29, is less restrictive: "....members of our general population shall not receive...(from all sources)....an average of more than 10 roentgens, in addition to background, of ionizing radiation as a total accumulated dose to the reproductive cells from conception to age 30". Ten roentgens is 10,000 mr, and distributed over 30 years is a rate of 330 mr/yr. This is an additional dose of twice the average background irradiation. The above is the permitted national average dose; individuals are permitted up to 50 roentgens by age 30, or an average of 1600 mr/yr. We have used the more rigorous limit suggested by the ICRP, since exposures resulting from world-wide fallout should be judged against the most conservative international standards. It should be clear, however, that we are using the most conservative values and that large safety factors are inherent in these numbers.

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The cosmic ray dose is about doubled at the altitudes of Denver and Los Alamos (5,000 to 7,000 feet). It is clear that various human populations live under wide ranges of irradiation without detectable differences in their health, cancer incidence, longevity, etc. A comparison of Sweden with Denmark is particularly interesting in this respect, since both countries have exceptionally accurate vital statistics available over the past century and since the exposure levels are quite different. Further study of these records is certainly desirable, but up to now no significant differences ascribable to radiation are known.

The maximum permissible life-time burden of 0.1 μc of Sr^{90} in the human body (for the general population) has been established by the Committee on Pathological Effects of Atomic Radiation (Summary Reports, page 39). This amount of activity, if maintained at a constant level, would irradiate the bones to the extent of 260 mr/yr. Since formation of the skeleton is complete by age 20 and no further significant incorporation of Sr^{90} occurs after this age, the assumption of an invariant level of Sr^{90} in the body is unrealistic. The maximum amount of Sr^{90} will be found in the skeleton of persons of approximately 20 years of age. Beyond this age, the Sr^{90} level will decline by radioactive decay. Assuming a maximum burden of 0.1 μc at age 20 and allowing for radioactive decay, the average dose rate to the bones during a life-time is 120 mr/yr (Eisenbud) or just about the average natural radiation dose.

Since much of the conservatism in permissible levels is engendered by genetic arguments and since Sr^{90} irradiates only bone and therefore cannot possibly cause genetic damage, the proposed level of 0.1 μc is certainly safe probably by a considerable margin.

Permissible levels for persons working with radioactivity are a factor of ten higher than the numbers given above for large populations.

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III. PRESENT Sr^{90}

The maximum present level of Sr^{90} in the bones of the population of the United States is reported by Libby to be 0.001 μc, or 1/100th of the new International Commission on Radiological Protection's permissible level for large populations.* The United States probably has the highest Sr^{90} level in the world because of the fallout from the Nevada Test Site. The dose rate to the bone from 0.001 μc Sr^{90} is 2.6 mr/yr, compared with the 160 mr/yr average from natural sources.

IV. PREDICTED FUTURE Sr^{90} LEVEL

If weapons testing were halted now, the Sr^{90} level would continue to rise for a time, due to the accumulation in the stratosphere of radioactivity from weapons already detonated. From observations, it has been estimated that this radioactivity is falling out of the stratosphere with a half-time of 5 to 10 years and that a Sr^{90} activity equivalent to about 24 megatons of fission may still be in the stratosphere. It is extremely difficult to estimate the exact level to which Sr^{90} concentrations may rise as a result of the subsequent fallout of this activity. However, reasonable estimates can be made and upper limits established with some degree of confidence.

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* Libby's "Sunshine" or "MPC" unit is based on the official United States National Bureau of Standards' permissible level for workers of 1 μc and in terms of this unit, the present Sr^{90} level is 1/1000th of permissible. The recent NRC-NAS Committee on the Biological Effects of Radiation recommended the ICRP value for large populations.

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Libby's prediction, on the basis of currently available data, is that the amount of Sr^{90} in people may eventually rise to 0.004 to 0.010 μc, by say 1970. Eisenbud has reached a similar conclusion. He reports that if all factors are given their most pessimistic values, the maximum upper limit which could possibly result is 0.026 μc, and that this limit may be as low as 0.002 μc.

V. Cs^{137} AND OTHER FISSION PRODUCTS

Sr^{90} is accompanied by other fission products, most of which have such short lives that they do not persist long enough to constitute a hazard. One of these fission products, Cs^{137}, has an abundance and a radioactive half-life comparable to Sr^{90} (about 30 years). It seems very improbable, however, that Cs^{137} can be a significant hazard because of the short time which it remains inside the human body. It is not accumulated as is Sr^{90}, but is eliminated within a few months. Therefore, while Cs^{137} is now present in the human body (at a level of about 1/20th of the natural potassium radioactivity), no increase in this level will result from stratospheric storage.

Los Alamos has devoted considerable effort to the study of Cs^{137} because, while it is harmless, it is much easier to measure than is Sr^{90}. These measurements are extremely useful in increasing our understanding of the meteorological factors influencing the Sr^{90} calculations. Our results have been reported at the meeting of the American Nuclear Society in Chicago on June 6-8, 1956, and at the Conference on the Measurement of Body Radioactivity in Leeds, England, on April 16-17, 1956 (to be published in the December 1956 issue of The British Journal of Radiology). A complete account of results to date is being prepared for publication in Science.

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VI. CONCLUSIONS

On the basis of these data, which are reported in the unclassified scientific literature (reprints of which are attached), it is concluded that there is no cause for alarm in the present Sr^{90} level nor in levels likely to be reached as a result of weapons so far tested. There are numerous basic documents on this general subject which are still classified because they contain specific weapons data. The unclassified documents contain all the pertinent information, and there is certainly no reason to feel that damaging facts are being withheld. It is obvious that a full-scale nuclear war may produce catastrophic levels of fallout and that indiscriminate testing of weapons by many nations could, after a period of time, cause the permissible levels to be exceeded.

This is also the view expressed in the Summary Reports on "Biological Effects of Atomic Radiation", of the National Academy of Sciences-National Research Council, page 60: "At present the amount of Sr^{90} in the stratosphere from nuclear weapons tests is far too small to approach maximum permissible concentration even if it were all to be deposited now. However, if the testing programs of the several countries producing thermonuclear weapons were to intensify, stratosphere storage time may become a critical item in terms of hazard to mankind. For this reason, a continuing program to investigate this phenomenon is needed".

A grave and responsible concern with the long-term implications of weapons testing must be maintained to insure that the responsibiliti , of Project Sunshine are not neglected; but the concern must be based on a reasoned consideration of the scientific evidence available and not on emotional exaggerations.

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Actually, the present situation provides an extremely useful "tracer experiment"; it not only can but must be studied with care and thoughtfulness if we are to enter the era of atomic power protected by knowledge. If due attention is given to this problem, then in the course of the next few years the continued studies by Project Sunshine can provide data permitting an accurate extrapolation of the expected maximum level which Sr^{90} can reach. Sufficient advance warning of the rise in Sr^{90} levels will be available to prevent the permissible levels being exceeded inadvertently.

The present disagreement among the experts on the proper maximum permissible levels for large populations and the degree of hazard implied by a given exposure is a result of the deficiencies and uncertainties in the basic biological data. If sufficient long-term biological experimentation is supported to supply the missing information, the disagreements can be resolved and permissible levels established in which the public can have confidence.

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