REPORT OF THE UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION

GENERAL ASSEMBLY

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NOTE

Throughout the present report, references to the annexes are indicated by a letter immediately followed by a number: the letter denotes the relevant annex and the number the paragraph therein. Within each annex, references to its scientific bibliography are indicated by numbers.

Symbols of United Nations documents are composed of capital letters combined with figures. Mention of such a symbol indicates a reference to a United Nations document.

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ABBREVIATIONS

ABCC	Atomic Bomb Casualty Commission
FAO	Food and Agriculture Organization of the United Nations
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiological Units and Measurements
WHO	World Health Organization
WMO	World Meteorological Organization

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CNS	Central nervous system
DNA	Deoxyribonucleic acid
ERG	Electroretinogram
ESR	Electron spin resonance
GI	Gastro-intestinal
LET	Linear energy transfer
MPC	Maximum permissible concentration
MPRE	Minimum pure radium equivalent
OR	Observed ratio
RBE	Relative biological effectiveness
RES	Reticulo-endothelial system
RNA	Ribonucleic acid
TBR	Total body radiation
TNT	Trinitrotoluene
UV	Ultra violet

CHAPTER I

INTRODUCTION

Constitution and terms of reference of the Committee

1. The United Nations Scientific Committee on the Effects of Atomic Radiation was established by the General Assembly at its tenth session on 3 December 1955, under resolution 913 (X), as a result of debates held in the First Committee from 31 October to 10 November 1955. The terms of reference of the Committee were set out in paragraph 2 of the above-mentioned resolution by which the General Assembly requested the Committee:

"(*a*) To receive and assemble in an appropriate and useful form the following radiological information furnished by States Members of the United Nations or members of the specialized agencies:

"(i) Reports on observed levels of ionizing radiation and radio-activity in the environment;

"(ii) Reports on scientific observations and experiments relevant to the effects of ionizing radiation upon man and his environment already under way or later undertaken by national scientific bodies or by authorities of national Governments;

"(*b*) To recommend uniform standards with respect to procedures for sample collection and instrumentation, and radiation counting procedures to be used in analyses of samples;

"(*c*) To compile and assemble in an integrated manner the various reports, referred to in sub-paragraph (*a*) (i) above, on observed radiological levels;

"(*d*) To review and collate national reports, referred to in sub-paragraph (*a*) (ii) above, evaluating each report to determine its usefulness for the purposes of the Committee;

"(*e*) To make yearly progress reports and to develop by 1 July 1958, or earlier if the assembled facts warrant, a summary of the reports received on radiation levels and radiation effects on man and his environment together with the evaluations provided for in sub-paragraph (*d*) above and indications of research projects which might require further study;

"(*f*) To transmit from time to time, as it deems appropriate, the documents and evaluations referred to above to the Secretary-General for publication and dissemination to States Members of the United Nations or members of the specialized agencies."

2. The Committee consists of Argentina, Australia, Belgium, Brazil, Canada, Czechoslovakia, France, India, Japan, Mexico, Sweden, the Union of Soviet Socialist Republics, the United Arab Republic, the United Kingdom of Great Britain and Northern Ireland and the United States of America.

Activities of the Committee

3. Since its establishment, the Committee has held fourteen sessions. Its activities during the first eleven sessions were surveyed in the introduction to the comprehensive reports that the Committee submitted to the thirteenth and seventeenth sessions of the General Assembly in 1958[1] and 1962,[2] respectively. The 1962 comprehensive report of the Committee was noted by the General Assembly during its seventeenth session in resolution 1764 (XVII) of 21 November 1962. By that resolution, the General Assembly:

(1) Commended the United Nations Scientific Committee on the Effects of Atomic Radiation for its work and for the valuable report it had presented;

(2) Expressed its appreciation to the International Atomic Energy Agency, to the specialized agencies, to the international non-governmental and the national scientific organizations and to the individual scientists who had assisted the Scientific Committee in its work;

(3) Called particular attention to the Scientific Committee's finding that the exposure of mankind to radiation from increasing numbers of artificial sources, including the world-wide contamination of the environment with short- and long-lived radio-nuclides from weapons tests, called for the closest attention, particularly because the effects of any increase in radiation exposure might not be fully manifested for several decades in the case of somatic disease, and for many generations in the case of genetic damage;

(4) Urged all concerned to take note of the suggestions made and the views expressed in the report of the Scientific Committee;

(5) Requested the Scientific Committee to continue its assessment of radiation risks as well as its review of those studies and further investigations that should be undertaken in the interests of increasing man's knowledge of the effects of radiation, and to report to the General Assembly at the eighteenth session on its progress and on its future programme of work;

(6) Called upon the International Atomic Energy Agency, the specialized agencies, the international non-governmental and the national scientific organizations, individual scientists and the Governments of Member States to continue to co-operate fully with the Scientific Committee in carrying out its further important responsibilities;

(7) Recommended the Governments of Member States to prepare and carry out according to their means large-scale information programmes on the effects of atomic radiation;

(8) Requested the Secretary-General to continue to provide the Scientific Committee with the assistance necessary for the conduct of its work.

[1] *Official Records of the General Assembly, Thirteenth Session, Supplement No. 17* (A/3838).

[2] *Ibid., Seventeenth Session, Supplement No. 16* (A/5216).

4. As requested in that resolution, the Committee discussed its programme of work at its twelfth session, which was held at the European Office, Geneva, from 21 January to 30 January 1963, and outlined the programme in a report to the General Assembly.[3]

5. In that report, it was noted that the request of the General Assembly that the Committee continue the assessment of radiation risks involved reviewing, on the one hand, the dose contributions from different sources of radiation and, on the other, the results of biological and medical studies which would lead to a better knowledge of the genetic and somatic effects of radiation and of the way in which the frequency of their occurrence depended upon radiation dose. Any significant change in estimates of the doses received by human tissues or in the evaluation of quantitative relationships between dose and effects might require revision of the estimates of radiation risks.

6. The Committee also expressed the view that the General Assembly might be effectively kept informed of the results of the Committee's continuing deliberations if the Committee submitted, at relatively frequent but not necessarily yearly intervals, short or specialized reports on any conclusions significantly affecting the estimates of radiation risks. The Committee left open the possibility of preparing a new general review of the whole field of study encompassed by its terms of reference at a time when scientific progress would, in its opinion, so require.

7. The report was considered by the General Assembly at its eighteenth session. Following debate in the Special Political Committee, the General Assembly adopted, on 12 November 1963, resolution 1896 (XVIII) by which the Scientific Committee was requested to continue its programme and its co-ordinating activities to increase the knowledge of the levels and effects of atomic radiation from all sources.

8. In response to that request, the Committee at its thirteenth session reviewed the information on environmental contamination and on induction of malignancies as a preliminary to the present report, which was completed and adopted on 10 July 1964 during the fourteenth session of the Committee.

9. At its fourteenth session, the Committee also discussed how it should continue its work of assessment of radiation risks from all sources and asked that arrangements be made to hold one session in 1965. The Committee expressed the hope that it would find it possible to submit a further substantive report to the General Assembly in 1966.

Sources of information

10. The reports received by the Committee between 10 March 1962 and 3 July 1964, inclusive, from States Members of the United Nations and members of the specialized agencies and of the International Atomic Energy Agency, as well as from these agencies themselves, are listed in annex C. Reports submitted prior to 10 March 1962 were listed in the 1958 and 1962 reports of the Committee. These reports were supplemented by a number of other publications available in the scientific literature and also by unpublished personal communications from individual scientists.

[3] *Ibid., Eighteenth Session, Annexes,* agenda item 31, document A/5406.

Organization of the work of the Committee

11. Discussion and evaluation of the information received by the Committee, as in the past, took place in the course of informal meetings among groups of specialists set up by the Committee, their general conclusions being subsequently reviewed by the full Committee. According to the Committee's established practice, no detailed record of its technical discussions was taken.

12. Mr. D. J. Beninson of Argentina and Mr. M. E. A. El-Kharadly of the United Arab Republic served as Chairman and Vice-Chairman, respectively, during the twelfth and thirteenth sessions of the Committee. At the thirteenth session, Mr. D. J. Stevens of Australia and Mr. A. R. Gopal-Ayengar of India were elected Chairman and Vice-Chairman, respectively, to serve during the fourteenth and fifteenth sessions. The names of scientists who have attended sessions of the Committee from the twelfth to the fourteenth sessions, inclusive, as members of national delegations, are listed in appendix I.

Scientific assistance

13. As in the past, the Committee was assisted by a small scientific staff and by consultants appointed by the Secretary-General. Scientific staff and consultants were responsible for preliminary review and evaluation of the scientific information received by the Committee or published in the technical literature.

14. While the responsibility for the report rests entirely with the Committee, the Committee wishes to acknowledge the help and advice received from those scientists whose names are listed in appendix II. The Committee owes much to their co-operation and goodwill.

Relations with United Nations agencies and other organizations

15. The Committee has been gratified by the assistance that it has received during its sessions from the International Labour Organisation (ILO), the Food and Agriculture Organization of the United Nations (FAO), the World Health Organization (WHO), the World Meteorological Organization (WMO) among the specialized agencies of the United Nations and from the International Atomic Energy Agency (IAEA), as well as from the International Commission on Radiological Protection (ICRP) and the International Commission on Radiological Units and Measurements (ICRU) among the non-governmental organizations.

16. In response to a request of the Committee, FAO assembled data on the contamination of the food chain that were used in the preparation of the present report, and WMO assisted in the evaluation of problems of transport and distribution of radio-active debris by convening a group of leading meteorologists who took part in the discussions on atmospheric contamination that were held during the thirteenth session of the Committee.

17. As noted in the 1962 report, at its eleventh session the Committee had given consideration, at the request of the Secretary-General of WMO, to a draft plan proposed by that Organization for the implementation of section II of General Assembly resolution 1629 (XVI). In response to a further request of the Secretary-General of WMO, the Committee considered at its

twelfth session a revised plan prepared by that Organization following the recommendations previously made by the Committee. As a result of its deliberations, the Committee adopted a statement that was transmitted to the Secretary-General of WMO and which contained a number of recommendations on those aspects of the plan which fell within the terms of reference of the Committee.

Scope and purpose of the report

18. The present report makes no attempt to cover the whole field of radiation effects as did the 1958 and 1962 reports of the Committee. Rather, the report confines itself to two subjects only: the contamination of the environment by nuclear explosions and the possibility of quantitatively assessing the risk of induction of malignancies by radiation in man.

19. Regarding the former subject, the Committee felt it appropriate to make a detailed review of the information available as at June 1964, which would complete the survey made in the Committee's 1962 report. After the adoption of that report, atmospheric contamination from nuclear explosions had continued on a large scale until the end of 1962, thus calling for a revision of the estimates of doses and risks from radio-active debris. Besides, the results of a number of new studies had been published since March 1962 which had to some extent clarified many of the problems left unsolved in the 1962 report. In making estimates of risks from environmental contamination, the present report will therefore take into account not only the amount of radio-active material that is now present in the environment but also the new knowledge of mechanisms of distribution in the environment and of uptake in the food chains and eventually in body tissues. Since only those aspects of the subject that have been significantly altered by new advances since 1962 are reviewed in the present document, the reader is referred to the 1962 report for the necessary background information.

20. With regard to the induction of malignancies, though no radical change in our knowledge has taken place since 1962, recent information makes it possible to give a sounder basis to certain risk estimates that the Committee had already obtained in the past, to confirm some that had been adumbrated and to propose new ones. In the case of the induction of malignancies also, the reader is referred to the 1962 report for a discussion of many details of radiation carcinogenesis that will not be dwelt upon in the present report.

21. As in earlier reports of the Committee, the main text of this report is accompanied by technical annexes in which the scientific information available to the Committee is discussed in some detail. The Committee wishes to emphasize, as it did in the past, that its conclusions, being based on the scientific evidence presently available, cannot be considered as final and will require revision as scientific knowledge progresses.

CHAPTER II

RADIO-ACTIVE CONTAMINATION OF THE ENVIRONMENT BY NUCLEAR TESTS

1. The nuclear explosions carried out between September 1961 and December 1962 sharply increased the radio-active contamination of the environment and consequently the doses of radiation that human populations will receive. However, the Committee notes that after the cessation of nuclear test explosions in the atmosphere, in outer space and under water, and in view of the propitious circumstances prevailing, further contribution from these sources to the radio-active contamination of the environment has ceased. Information on the amounts of various radio-nuclides and on the rates at which they deposit on the earth's surface and enter the food chain is necessary in order to compute the doses to human tissues. Since the cessation of atmospheric tests in December 1962, the Committee has been able to collect sufficient information to enable it to up-date adequately the estimates of the resulting radiation doses.

2. Almost all of the fission products from the 1961-1962 explosions have been introduced into the stratosphere. The strontium-90 from these tests increased the stratospheric inventory at the end of 1962 by about 5 megacuries over the level in mid-1961 (A32-34).[4]

3. The rate of transfer from the stratosphere to ground level depends upon the altitude to which the products rise in the atmosphere and the latitude at which the explosions occur. For example, the mean residence time of material in the stratosphere above 100 km exceeds five years while in the lower stratosphere it is less than one year (A16-19). Assessment of the experimental data has led the Committee to adopt an over-all mean residence time for the composite stratospheric fission products of two years (A20). While this time is shorter than that used in the 1962 report, the predicted deposition of strontium-90 and caesium-137 is not appreciably altered by the change in the mean residence time.

4. The fall-out rate of long-lived radio-activity in 1962 was three times that for the period 1960-1961 and during the year 1963 the fall-out exceeded that in any previous year (A36-38). The Committee envisages that in 1964 the fall-out rate may be some two-thirds of that during 1963 and will continue to decrease progressively in future years.

5. Short-lived fission products have decayed to negligible levels during 1963 so that no further dose will be incurred from them after 1964 (A56-59).

6. Radio-active materials which have been deposited on the surface of the earth constitute sources of both external and internal radiation to the population. Whereas their contribution to the external dose depends on the gamma radiation which they emit, the magnitude of the internal dose is determined mainly by the extent to which different nuclides are transferred through food chains to man.

7. Strontium-90 and caesium-137 are the most important fission products from nuclear explosions that contaminate man's diet. The mechanisms which control the transfer of strontium-90 through food chains into man's diet were discussed extensively in the 1962 report.[5] Information which has been obtained since that time does not necessitate the modification of the basis for assessment. During 1962 dietary contamination in the northern hemisphere was somewhat greater than in 1959, which, up to that time, had been the year when highest levels were observed. In 1963, dietary levels in the northern hemisphere were at least twice those in 1962 (A80). In the southern hemisphere, dietary contamination increased in 1962 and 1963, though to a smaller extent, and the levels remained considerably lower than those in the northern hemisphere (A81).

8. Recent evidence on the transfer of caesium-137 through food chains has led to an improved basis for evaluating radiation doses from caesium-137 within the human body (A134, 135, 178-180). It is now apparent that doses from caesium-137 were somewhat over-estimated in the 1962 report. Between 1961 and 1963, the changes in levels of caesium-137 in diet were broadly similar to those in levels of strontium-90 (A117).

9. It has been found that, under certain local ecological conditions, the transfer of caesium-137 to man is enhanced, leading to the highest body contents yet measured. Thus, in arctic regions, the levels of caesium-137 in the flesh of reindeer and caribou are high on account of the accumulation of this nuclide in the vegetation on which the animals graze (A118). The body content of caesium-137 in small groups of local inhabitants who live almost exclusively on the meat of reindeer and caribou has on occasions exceeded the world average by a factor of more than 100 (A128).

10. Short-lived radio-nuclides have been measured in the environment, in food and in the human body more consistently since the end of 1961 than during earlier series of tests. As a consequence, doses delivered by those nuclides are now more accurately known. Iodine-131 has received particular attention (A136-146) because its absorption by infants from fresh milk leads to the irradiation of their thyroid glands. Adults receive much lower doses owing to the larger size of their thyroid glands, and their lower consumption of fresh milk.

11. In most areas of the temperate zone in the northern hemisphere, the average dose to the thyroid glands of children who were brought up on fresh milk was about 0.1 rad in 1961 (A, table XXX); similar doses were received in 1962, whereas in 1963 the doses were negligible (A182, 183). In the southern hemisphere, doses were considerably lower. In 1962, the concentration of iodine-131 in milk produced in some limited areas within a few hundred kilometres of testing grounds were

[4] Throughout the present report, references to the annexes are indicated by a letter immediately followed by a number. Thus A32-34 refers to paragraphs 32 to 34 of annex A.

[5] *Official Records of the General Assembly, Seventeenth Session, Supplement No. 16* (A/5216), chapter V, paragraphs 60-69.

ten times higher than the average; doses to the thyroid were correspondingly higher (A138).

12. The Committee has again reviewed the problem of the doses due to carbon-14, a radio-nuclide with a half-life of about 5,700 years, which is formed from atmospheric nitrogen both naturally, by the continuous interaction of cosmic rays, and artificially, by neutrons released from nuclear explosions. The atmospheric content of artificial carbon-14 has been increased about threefold by testing in 1961-1962. By July 1963, the artificial carbon-14 concentration in ground level air rose to 90 per cent of the natural carbon-14 concentration in the northern hemisphere (A, table XV). With time, artificial carbon-14 will tend to become uniform throughout the atmosphere and to be progressively absorbed by the oceans. Thus, by the year 2000, the artificial carbon-14 concentration in the atmosphere will fall to some 3 per cent of the natural carbon-14 concentration (A71).

13. As in its 1962 report,[6] the Committee has based its evaluation of comparative risks due to past nuclear explosions on dose commitments to the gonads, to the cells lining bone surfaces and to the bone marrow—those tissues whose irradiation may give rise to hereditary defects, bone tumours and leukaemias, respectively. The dose commitment is the total dose that will be delivered, as an average for the world population, to the relevant tissues during the complete decay of radio-active material introduced into the environment. Doses included in the dose commitments may be delivered over a very long period of time. The dose commitments due to all tests before January 1963 are summarized in table I.

[6] A/5216, chapter VI.

14. In the present report dose commitments are expressed in rads.[7] For radiations resulting from nuclear explosions, rads, as used here, and rems, as defined in the 1962 report,[8] are numerically equivalent. In this report, doses from natural radiation also are expressed in rads and therefore are numerically slightly smaller than in the 1962 report where they were expressed in rems. They are 99, 96 and 95 millirads per year to gonads, cells lining bone surfaces and bone marrow, respectively.

15. Comparative risk estimates can be made by reference to doses from natural sources of radiation. One inherent difficulty in such comparisons arises from the arbitrary period over which the natural radiation dose must be integrated. In principle, several alternatives are possible:

(1) The dose commitment could be compared with the natural radiation dose delivered over a period of time equal to that over which a substantial part of the dose commitment is delivered. This comparison could be misleading in the sense that exposures from future nuclear tests might overlap this period.

[7] The rad is the unit of absorbed dose; A/5216, chapter II, paragraph 23.

[8] A/5216, chapter II, paragraph 26; the rem has recently been given a new definition by the International Commission on Radiological Units and Measurements.

TABLE I. DOSE COMMITMENTS FROM NUCLEAR EXPLOSIONS [a]

Tissue	*Source of radiation*	*Dose commitments (mrad)*		*Paragraph of annex A*
		For period of testing 1954–1960 (estimates from 1962 report)	*For period of testing 1954–1962 (new estimates)*	
Gonads	External, short-lived [b]	11	21	163
	Cs^{137}	16	29	165
	Internal, Cs^{137} [b]	8	13	179
	C^{14}	5[c]	13[c]	187
	TOTAL	40	76	
Cells lining bone surfaces	External, short-lived [b]	11	21	163
	Cs^{137}	16	29	165
	Internal, Sr^{90}	67	174	173
	Cs^{137} [b]	14	13	179
	C^{14}	8[c]	20[c]	187
	Sr^{89}	0.15	0.30	176
	TOTAL	116	257	
Bone marrow	External, short-lived [b]	11	21	163
	Cs^{137}	16	29	165
	Internal, Sr^{90}	33	87	174
	Cs^{137} [b]	10	13	179
	C^{14}	5[c]	13[c]	187
	Sr^{89}	0.07	0.15	176
	TOTAL	75	163	

[a] In the 1962 report, these doses were reported in mrems. As explained in paragraph 191 of annex A, the doses in the present report are all given in mrads.

[b] The dose commitments from short-lived nuclides and from internal Cs^{137} have been calculated on a slightly different basis in this report (paragraphs 162, 178 of annex A) as compared to the 1962 report.

[c] For C^{14} it seems to be appropriate to include only the dose which is accumulated up to the year 2000, at which time the doses from the other nuclides will have essentially been delivered in full. The *total* dose commitments from C^{14} from tests up to 1960 for the gonads, cells lining bone surfaces and bone marrow are 48, 80 and 48 mrads, respectively. For all tests up to the end of 1962, the dose commitments from C^{14} are 180, 290 and 180 mrads, respectively.

(2) As in the 1962 report,[9] a comparison could also be made with the natural radiation dose delivered during the period of testing, with the justification that it is the commitment incurred during this period which is relevant, irrespective of the radiation source. However, the latter comparison may also be considered unsatisfactory because the period is not easy to define.

(3) A direct comparison between dose commitments (millirads) and annual dose rates from natural radiation (millirad/year) is hardly justified.

(4) An alternative approach that was also used in the 1962 report[10] and is followed here is to express the dose commitments in terms of the period of time during which natural radiation would have to be doubled to give a dose increase equal to the dose commitment.

16. For all tests carried out before January 1963, these periods amount to approximately 9 months for the gonads, 32 months for cells lining bone surfaces and 20 months for the bone marrow. These periods are not directly comparable with the periods given in the 1962 report because they only take into account that part of the dose commitment from carbon-14 which is delivered before the year A.D. 2000. In addition, the periods given in the 1962 report related to tests during the years 1954-1961 and involved an assumption of testing practice for the year 1961.

[9] A/5216, chapter VI.
[10] A/5216, chapter VI, paragraph 17.

CHAPTER III

RADIATION CARCINOGENESIS IN MAN

1. Among the major problems discussed in the 1958 and 1962 reports was that of obtaining estimates of absolute risk of induction of a number of effects by irradiation at doses and dose rates such as those delivered by natural sources and by fall-out from nuclear testing. In the 1958 report, the estimates of absolute risks that were presented in terms of expected frequencies of given effects per unit dose were tentative and largely hypothetical, and in many cases involved hardly justifiable assumptions in applying the observed results of high doses and dose rates to low doses and dose rates and to different conditions of exposure. For these reasons, in the 1962 report the Committee confined itself to estimating comparative risks. Having again reviewed the available information relating radiation to cancer induction in man, the Committee sees no possibility of changing this procedure at the present time.

2. Data published since 1962 have, however, led the Committee to believe that it is possible, for a few tissues only and mainly in the high dose range, to make estimates of risk (B20)[11] (expressed for example as number of cases per year per rad per million exposed individuals) that are valid within the observed range of doses and the given conditions of irradiation. Furthermore, and especially when the doses studied lie within the range over which the frequency of the effect increases rapidly with rising dose, it is unlikely that the risk per unit dose at very low doses will be any greater than that at high doses and it is likely to be much less. Thus, the estimated risk per unit dose will in most cases represent an upper limit for effects at very low doses (B18, 19).

3. New possibilities of analysing the increased incidence of leukaemias as a function of dose among the survivors of the explosions at Hiroshima and Nagasaki have been offered by a study of a sample of survivors who had been divided in groups according to the estimated doses that they had received. The estimate was made according to distance from the hypocentre and extent of shielding from radiation (B25-30). The accuracy of the dose estimates is difficult to assess, as they might well be affected by some systematic error, in particular that due to our limited knowledge of the relative importance of neutrons and gamma rays delivered during the explosions. The estimates of the doses are, however, almost certainly not in error by a factor greater than two or three.

4. Taking the dose estimates at face value, the average yearly incidence of radiation-induced leukaemia, as determined over a period of nine years, from 1950 to 1958, shows approximate proportionality with the dose in the range from about 100 rads to 900 rads. The rate of increase with dose is between 1 and 2 cases per year per rad per million exposed individuals (B30). It is not known for how long a period of time the increased incidence of leukaemia among survivors will last. There is some indication that the excess has been slightly subsiding during the 1960's.

5. This estimate of absolute risk can only be applied with caution to the population at large. The surviving population has been heavily selected by the lethal effect of the irradiation itself so that the survivors may not necessarily be representative of the irradiated population with respect to sensitivity to radiation carcinogenesis.

6. The estimate obtained from the A-bomb survivors is consistent with that determined, between 300 and 1,500 rads, from a completely different survey of subjects irradiated therapeutically for ankylosing spondylitis (B40-55). In this survey doses were fractionated and are known with greater accuracy, but the number of cases of leukaemia that were observed is very small. Besides, there is no way of knowing to what extent the disease itself for which the patients had been treated, or other means of therapy to which they had been exposed, might have been responsible for the increased incidence of leukaemia. An estimate obtained from this survey alone would therefore only apply to spondylitic patients.

7. The 1962 report dealt briefly with data on induction of malignancies in children irradiated *in utero*. The data were at that time considered as controversial. More recent reports have confirmed a higher incidence of malignancies, including leukaemias, in children irradiated *in utero* (diagnostic irradiation, sometimes repeated) (B62-73). Though precise dose estimates are not available, there is reason to believe that the doses were of the order of a few rads. Risk estimates based on this assumption suggest that the risk of leukaemia per unit dose might be several times higher in children irradiated *in utero* than in adults (B72). These surveys have provided the important suggestion that under certain conditions low radiation doses, of the order of a few rads, can induce malignancy. As in the case of ankylosing spondylitis, there is the possibility that the sample of irradiated children may not be representative of the whole population of children (B73).

8. The 1962 report also discussed data from the Hiroshima tumour registry on the relationship between distance from the hypocentre and over-all incidence of tumours. Further data from the Hiroshima and also from the Nagasaki tumour registry have now been reviewed by the Committee. While these data still indicate a diminishing incidence with distance from the hypocentre, this relationship is now less clear-cut than that derived from earlier reports and does not lend itself to quantitative analysis. Another recent study among Japanese survivors, based on a restricted but more precisely defined population sample, though showing the increased mortality from leukaemia, gave no clear evidence that radiation affected mortality from any other cause of death between 5 and 14 years after the irradiation, though

[11] Throughout the present report, references to the annexes are indicated by a letter immediately followed by a number. Thus B20 refers to paragraph 20 of annex B.

there was some indication of an increased incidence of other malignancies (B175-180).

9. The Committee has reviewed recent surveys on the induction of thyroid carcinoma as a result of irradiation of the thyroid region for therapeutic purposes during childhood (B105-119). The irradiation was often fractionated. As in all instances of therapeutic irradiation, it is not possible to distinguish between the effect of the irradiation and the effect of the conditions for which radiation was administered. The accuracy of the estimates of doses of radiation to the thyroid is not high, but is sufficient to allow some conclusions to be drawn about the relationship between dose and incidence of thyroid carcinoma.

10. As in the case of leukaemia, the incidence of thyroid cancer shows approximate proportionality in a range of doses between 100 and 300 rads, and leads to a risk estimate of about one case per year per rad per million exposed individuals, averaged over a period of approximately sixteen years following irradiation (B117). The period of risk may, however, be somewhat longer. Higher incidence of thyroid tumours has also been reported among adult survivors of atomic explosions (B90-100). The incidence is related to distance from the hypocentre but information is not adequate to provide quantitative assessments of risk.

11. The Committee has reviewed evidence bearing on risk estimates for certain other malignancies; namely, bone tumours in persons contaminated with radium (B130-145), liver tumours in persons who had received thorium compounds for diagnostic purposes (B146-151), skin cancer from external irradiation (B126-129), and lung tumours in miners exposed to radio-active dusts (B152-174). Inadequacies of sampling and dosimetry, longer latent periods and possibly lower likelihood of induction, make unreliable the quantitative assessments based on the information now available. However, the Committee considers that for some tumours, besides leukaemias and thyroid tumours, it might be possible in time to collect enough information to make additional estimates of risk practicable, and that investigations aimed at recording significant quantitative relationships between doses and observed incidence of any specific malignancy in man should be strongly encouraged and supported.

12. It is not to be expected, however, that such estimates will become available for all, or even for many, types of human tissue. The only data suitable for determination of over-all risks of radiation-induced malignancy are those derived from whole body exposure with substantial doses, as in Hiroshima and Nagasaki. The continuation of the latter studies is therefore of great importance. It is still too soon after the exposure of these populations for all possible malignancies to have developed, but present data suggest that leukaemia may well be the predominant type of malignancy produced and that the over-all risk of all malignancies is unlikely to exceed by any large factor that given above for leukaemia (B179, 180).

13. It is important that no opportunity should be lost of exploring the possibilities for undertaking significant studies in exposed human population groups and of pursuing such studies when sound epidemiological techniques can be applied. On the other hand, the usefulness of such data in estimating the effects of very low doses must depend on progress in our understanding of the fundamental mechanisms of carcinogenesis, the mode of action of radiation, and its interaction with other carcinogenic agents in the environment.

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