

NATURAL BACKGROUND AS AN INDICATOR OF RADIATION-INDUCED CANCER*

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A recurrent theme in discussions about nuclear energy is the uncertainty regarding the effects of exposure to low levels of radiation. Statements on this subject are often misleading by implying a general level of knowledge approaching total ignorance. This paper attempts to place the problem in a probabilistic perspective.

Recent theoretical predictions on the effects of low-level ionizing radiation indicate induction rates as high as 8×10^{-3} cancers per man-rem. (1) Assuming this estimate is correct, then roughly half of all cancer incidence in the U.S.A. could be attributed to natural background radiation. Previous studies (2,3), however, indicate no correlation between cancer incidence and levels of background radiation.

Table 1 reviews some past estimates of radiation-induced cancer rates. These estimates pertain to effects of low-level radiation (sub MPC) whole body doses to large populations. The estimates shown were not all originally given in terms of cancers per man-rem. Some were calculated from doubling dose estimates, or were inferred from estimated effects of given population exposures. No judgment is made here as to the quality of these estimates or how they were derived. They are given to demonstrate their wide diversity.

Table 2 presents a summary of data on external background radiation and cancer incidence for the U.S.A. by state. The radiation values were taken from the USEPA (15), and were corrected for structural and body shielding according to the method suggested by the NCRP. (16) They are presented as corrected external background dose (CXBD) in mrem/yr. The cancer incidence values were taken from U.S. statistical abstracts. (17) For purposes of this analysis, a simplified but reasonable method was used to correct the raw data for age variation and other factors affecting the general state of health. The raw incidence data were normalized according to overall death rate, which itself is a function of the population age distribution and general state of health. The normalized cancer rate (NCR) was calculated by

$$NCR = \frac{\text{national death rate}}{\text{state death rate}} \times \text{state cancer rate.}$$

TABLE 1. Estimated radiation-induced cancer rates

Source	Date	Risk estimate (cancers/man-rem)	Source	Date	Risk estimate (cancers/man-rem)
ICRP: 8 (4)	1966	5.0×10^{-4}	Rasmussen (10)	1975	1.2×10^{-4}
Robison & Anspaugh (5)	1969	1.0×10^{-3}	NUREG-0216 (11)	1977	1.4×10^{-4}
Gofman & Tamplin (6)	1969	1.7×10^{-3}	Mancuso (12)	1977	6.8×10^{-3}
Otway (7)	1971	7.0×10^{-4}	Gofman (13)	1977	7.3×10^{-3}
Hull (8)	1971	1.0×10^{-4}	Tamplin & Cochran (1)	1977	8.0×10^{-3}
BEIR (9) Committee	"most likely"	Low	Morgan (14)	1978	6.0×10^{-4}
		High			

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TABLE 2. Background radiation and cancer incidence

STATE	NCR ^a	CXBD ^b	STATE	NCR	CXBD	STATE	NCR	CXBD
Alabama	150.9	81	Louisiana	161.3	57	Ohio	171.4	87
Alaska	112.2	79	Maine	175.1	93	Oklahoma	159.3	83
Arizona	164.5	92	Maryland	186.7	71	Oregon	165.9	83
Arkansas	167.9	84	Massachusetts	183.8	84	Pennsylvania	171.2	76
California	180.2	68	Michigan	183.8	83	Rhode Island	192.9	78
Colorado	155.8	175	Minnesota	168.9	94	South Carolina	144.0	81
Connecticut	198.8	74	Mississippi	147.4	78	South Dakota	158.5	137
Delaware	196.3	74	Missouri	162.	79	Tennessee	157.3	85
Florida	183.2	70	Montana	162.6	119	Texas	163.5	60
Georgia	144.5	74	Nebraska	163.6	103	Utah	142.1	129
Hawaii	198.0	65	Nevada	170.7	102	Vermont	168.3	74
Idaho	152.6	115	New Hampshire	185.4	82	Virginia	170.8	76
Illinois	170.3	82	New Jersey	190.8	74	Washington	180.9	83
Indiana	165.0	76	New Mexico	147.1	139	West Virginia	152.1	83
Iowa	170.4	83	New York	184.0	82	Wisconsin	174.0	80
Kansas	163.7	83	North Carolina	150	89	Wyoming	143.3	175
Kentucky	161.5	79	North Dakota	165.5	92			

^aNormalized cancer rate (yr⁻¹/10⁵ population).

^bCorrected external background radiation dose (mrem/yr).

Figure 1 presents this cancer and radiation data graphically. The data points present a picture similar to that previously shown by Frigerio (2), indicating a lack of correlation. Regression analysis of these data, assuming a linear relationship, indicates that the best-fit curve is described by the formula $NCR = 190 - 0.27 CXBD$, shown as a solid line in Fig. 1. The regression analysis reveals a somewhat negative correlation; however, the correlation coefficient, $r = 0.39$, indicates a very weak relationship.

Useful insight can nonetheless be derived by testing certain hypothetically assigned radiation-induced cancer rates against the

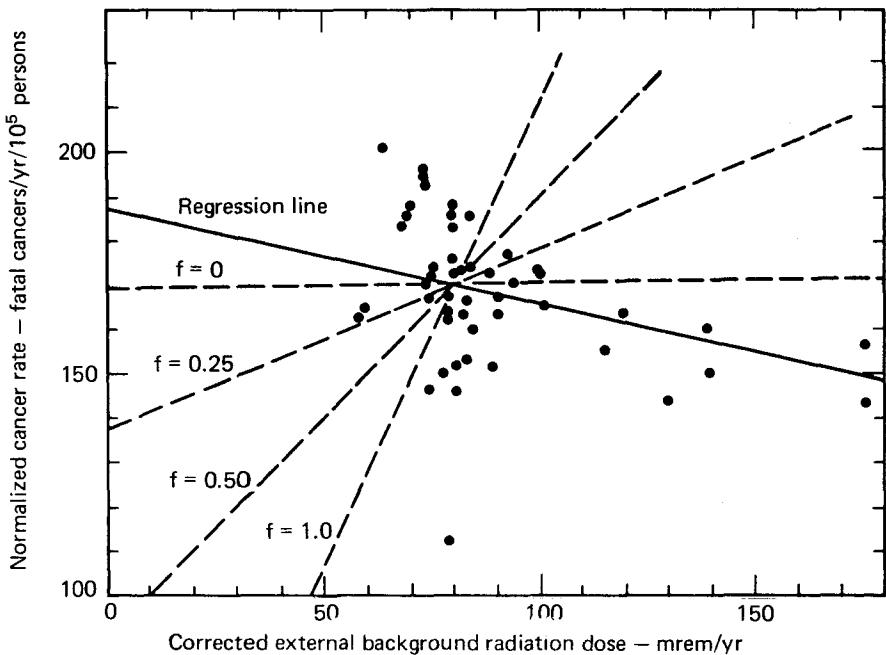


Fig. 1. Cancer incidence and background radiation.

data. This is done by determining mathematical relationships that (1) conform to the hypothesis and (2) best conserve the observed data. The hypotheses tested were:

1. The Fractional Hypothesis (a fraction, f , of all cancers are induced by exposure to external background radiation): $NCR = 167(1 - f) + 2.1 f CXBD$.
2. The Null Hypothesis (cancer and background radiation are unrelated): $NCR = 167$ (note: $f = 0$).
3. The Total Hypothesis (all cancers are induced by exposure to external background radiation and nothing else): $NCR = 2.1 CXBD$ (note: $f = 1.0$).

These hypothetical relationships are shown as the dotted lines in Fig.1. In testing these hypotheses, the question is asked: Given that the hypothesis is correct, what is the probability that the actual data could have been observed?

The statistical method used for the calculation was the "t" test described by F.S. Acton (18), where:

$$t_{(n-2)} = \frac{(b - \beta) \sqrt{n - 2} \sqrt{S_{xx}}}{\sqrt{SSR}}$$

Knowing "t" (at 48 d.f.), it is possible to determine the probability of a fractional cancer incidence (f) equal to or greater than that hypothesized. This relationship is given in Fig. 2.

To relate "f" to the radiation-induced cancer rate, assume all cancer incidence is caused by external background radiation, in which case, at steady state in the U.S.A.,

$$\frac{167 \text{ cancers/yr}}{10^5 \text{ people} \times 0.079 \text{ rem/yr}} = 2.1 \times 10^{-2} \text{ cancers/man-rem.}$$

If, for example, the induction rate value were in fact 8×10^{-3} cancers/man-rem, then $f = 0.38$. In light of the observed data, the probability of an induction rate of 8×10^{-3} or higher is approximately 7×10^{-5} , or about one chance in 14,000. From

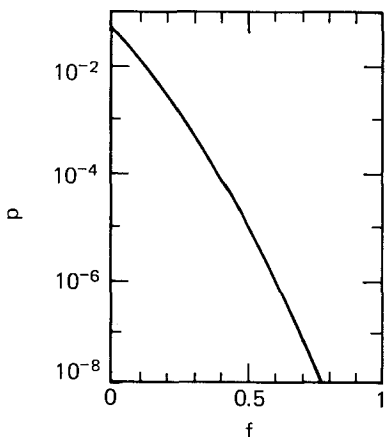


Fig. 2. Probabilistic assessment of radiation-induced cancer, where p is the probability that the indicated fraction or greater is valid, given observed data; and f is the hypothetical fraction of cancer incidence in U.S.A. attributable to background radiation.

this analysis it may be concluded that such high estimates of radiation-induced cancer rate, although not impossible, may certainly be considered highly improbable.

REFERENCES

1. Tamplin, A. and Cochran, T. (Dec. 1977): Uranium Impacts from Spent Fuel Reprocessing and Radioactive Waste, USNRC Hearing Docket No. Rm-50-3.
2. Frigerio, N.A., Echerman, K.E., and Stowe, R.S. (Sept. 1973): Carcinogenic and Genetic Hazard from Background Radiation, Environmental Statement Project, Argonne National Laboratory, Argonne, Ill., Rept. ANL/ES-26.
3. Jacobson, A.P., Plato, P.A., and Frigerio, N.A., (Jan. 1976): The Role of Natural Radiations in Human Leukemogenesis, Am. J. Pub. Health, 66.
4. International Commission on Radiological Protection (ICRP) (1966): The Evaluation Risks from Radiation, Publication No. 8.
5. Robinson, W.L. and Anspaugh, L.R. (1969): Assessment of Potential Biological Hazards from Project Rulison, Lawrence Livermore Laboratory, Livermore, Calif., Rept. UCRL-50791.
6. Gofman, J.W. and Tamplin, A.R. (Oct., 1969): Low Dose Radiation, Chromosomes, and Cancer, in Proc. of IEEE Nuclear Science Symp., San Francisco, Calif., GT-101-69.
7. Otway, H.O., Lohrding, R.K., and Battat, M.E. (Oct., 1971): A Risk Estimate for an Urban-Sited Reactor," Nuclear Technology.
8. Hull, A.P. (May 1971): Radiation in Perspective, Some Comparisons of the Environmental Risks of Nuclear and Fossil Fueled Power Plants, Nuclear Safety, 12(3), p. 185.
9. Report of the Advisory Committee on the Biological Effects of Ionizing Radiation (BIER) (Nov., 1972): The Effects on Populations of Exposure to Low Levels of Ionizing Radiation, Nat. Acad. of Sci., Nat. Res. Council.
10. Nuclear Regulatory Commission (1975): Reactor Safety Study, WASH-1400, Vol VI, App. G.
11. Nuclear Regulatory Commission Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle NUREG-0216 (March, 1977).
12. Mancuso, J., et al. (February, 1977): Radiation Exposures of Hanford Workers Dying from Various Causes, Health Physics.
13. Gofman, J. (December, 1977): Testimony in the Matter of Amendment of IOCFR, Part 51, Licensing of Production and Utilization Facilities, USNRC Docket No. RM 50-3.
14. Morgan, K.Z. (Sept., 1978): Cancer and Low-Level Radiation, The Bulletin.
15. U.S. Environmental Protection Agency (May 1976): Radiological Quality of the Environment, EPA-520/1-76 - 010.
16. National Council on Radiation Protection and Measurements (April 1975): Natural Background Radiation in the United States, NCRP Report No. 45.
17. U.S. Bureau of the Census (1975): Statistical Abstract of the United States: 1975 (96th edition), Washington, D.C.
18. Acton, F.S. (1959): Analysis of Straight-Line Data. John Wiley & Sons, Inc. - New York.