Note

NATURAL BACKGROUND RADIATION AND CANCER DEATH IN ROCKY MOUNTAIN STATES AND GULF COAST STATES

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Abstract—**Calculations based on data from NCRP reports show that the average level of natural background radiation (NBR) in Rocky Mountain states is 3.2 times that in Gulf Coast states. However, data from the American Cancer Society show that age-adjusted overall cancer death in Gulf Coast states is actually 1.26 times higher than in Rocky Mountain states. The difference from proportionality is a factor of 4.0. This is a clear negative correlation of NBR with overall cancer death. It is also shown that, comparing 3 Rocky Mountain states and 3 Gulf Coast states, there is a strong negative correlation of estimated lung cancer mortality with natural radon levels (factors of 5.7 to 7.5).**

Health Phys. 75(4):428–430; 1998

Key words: cancer; hormesis; radon; radiation, background

INTRODUCTION

DATA AVAILABLE in the literature permit calculation of natural background radiation (NBR) in individual states of the United States. Yet such calculations seem not to have been made. Using only published data from the National Council on Radiation Protection and Measurements (NCRP), I estimate that the NBR effective dose equivalent in Rocky Mountain states is over three times that in Gulf Coast states.

One may also compare cancer death rates in various states using data from the American Cancer Society. These comparisons also seem not to have been done, although there have been a number of comparisons of lung cancer and natural radon levels, notably by Cohen (1995, 1997). The present note compares cancer death rates in three Gulf Coast states (Louisiana, Mississippi, and Alabama) and three Rocky Mountain states (Idaho, Colorado, and New Mexico) and shows that there is a negative correlation of NBR with both reported overall cancer death rates and estimated lung and bronchus cancer death rates in these two groups of states.

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(*Manuscript received* 12 *September* 1997; *revised manuscript received* 20 *February* 1998; *accepted* 8 *June* 1998)

0017-9078/98/$3.00/0

NATURAL BACKGROUND LEVELS

Table 1 shows NBR annual effective dose equivalents from 1987 reports of the NCRP. For terrestrial radiation, the reported levels differ considerably between NCRP Reports No. 93 (1987a) and No. 94 (1987b), so an average is taken: 195 μSv y^{-1} for Gulf Coast states and 765 μSv y^{-1} for Rocky Mountain states. Both cosmic and terrestrial radiation levels are seen to be much higher in Rocky Mountain states than in Gulf Coast states.

Radon is more difficult to determine. The national average is given by NCRP Report No. 93 (1987a) as 2,000 μSv per annum. One may make the reasonable assumption that radon levels are proportional to terrestrial gamma-ray levels. [Although ^{40}K provides the major component of terrestrial radiation, uranium and thorium and their decay products, which include radon, produce a quite constant fraction of the total emission (Table 4.3, NCRP Report No. 94).] This assumption provides an estimate (Table 1) of 1,400 μSv for Gulf Coast states and 5,500 μSv for Rocky Mountain states or a ratio of radon in Rocky Mountain states to that in Gulf Coast states of 3.9.

For comparison, Table 6.1 in NCRP Report No. 94 (1987b) shows direct measurements of mean radon exposure in Colorado Springs is 44 Bq m^{-3}, while the median in Houston is 8 Bq m^{-3}, a ratio of 5.5. Furthermore, the data of Cohen et al. (1994) show (Table 2) an average radon level *in living areas of homes* of about 0.5 pCi L^{-1} (18.5 Bq m^{-3}) in Gulf Coast states and about 2.6 pCi L^{-1} (96 Bq m^{-3}) in Rocky Mountain states, giving a ratio of home radon in the two areas of 5.2. Thus, the ratio 3.9 in Table 1 is conservative, especially in terms of human exposure to radon.

Table 1 shows that the average total level of NBR in Rocky Mountain states is 3.2 times that in Gulf Coast states.

CANCER DEATH RATES

In Table 2, the three states of Idaho, Colorado, and New Mexico were chosen to represent the Rocky Mountain states because they showed the highest levels of NBR, both statewide and county-by-county, while the three chosen to represent Gulf Coast states showed very low levels of NBR (Cohen et al. 1994). One might question the choice of Idaho, since it is not on the eastern

Table 1. Natural background radiation (NBR) in Gulf Coast states and Rocky Mountain states. All figures are annual effective dose equivalents in μSv. Figures in parentheses are derived.

Source	Gulf Coast	Rocky Mts.	National average[a]
Internal[b]	390	390	390
Cosmic[c]	260	500	270
Terrestrial[c]	160	630	
	195	765	280
Terrestrial[d]	230	900	
Radon[e]	(1,400)	(5,500) (R=3.9)	2,000
Sum	2,250	7,160	3,000
Ratio	3.2		

[a] NCRP Report No. 93 (1987a). Table 2.4.
[b] Assumed equal to the national average.
[c] NCRP Report No. 93 (1987a), pp. 11, 12. For cosmic radiation, numbers refer to sea level and 1,600 m (1 mile). For terrestrial radiation, numbers refer to Gulf coastal plain and eastern slopes of the Rocky Mountains.
[d] NCRP Report No. 94 (1987b). Fig. 5.4.
[e] For Gulf Coast and Rockies, this is calculated. NCRP (1987a) gives a national average of 2,000 μSv for radon. Assuming that radon concentration is proportional to terrestrial gamma rays, the Gulf Coast radon level would be 195/280 × 2,000 = 1,400 μSv, and the Rocky Mountain radon level would be 765/280 × 2,000 = 5,500 μSv.

slopes of the Rockies (Table 1, footnote c), but the data in Table 2 (last column) show that the high radon levels in Idaho imply a high level of terrestrial radiation characteristic of the eastern slopes of the Rockies.

The American Cancer Society (1998) data show (Table 2) that the overall reported age-adjusted annual cancer death rate in the period 1990–1994 in the three Rocky Mountain states averages 147 per 100,000, while in the three Gulf Coast states it averages 185 per 100,000 population. Thus, overall cancer death in the Gulf Coast states was 1.26 times that in the Rocky Mountain states, a ratio that appears to be significant. Yet the Rocky Mountain states have 3.2 times the level of NBR (Table 1). It is therefore clear that NBR shows a negative correlation with overall cancer death. The difference from the expectation that cancer death might be directly proportional to NBR is a factor of 4.0 (3.2 × 1.26) for these two regions.

It is generally accepted that radon induces lung cancer in uranium miners, who receive moderately high exposures. The exposure response for miners is generally linear (e.g., see Lubin et al. 1995), leading to a common assumption that NBR levels of radon will also induce lung cancer. Yet the estimated annual lung and bronchus cancer death rate in the three Rocky Mountain states in 1990–1994 averages 47 per 100,000 population, while in the Gulf Coast states it averages 68 per 100,000 (Table 2). Thus, while the Rocky Mountain states have at least 3.9 times (Table 1) the natural radon level of the Gulf Coast states (and probably 5.2 times inside homes—see above), they have a lung and bronchus cancer death rate only about two-thirds (1/1.45) that of the Gulf Coast states. The difference from expectation is a factor of 5.7 (3.9 × 1.45). This is a clear negative correlation.

DISCUSSION AND CONCLUSION

Calculations based on data from NCRP reports show (Table 1) that the average level of all natural background radiation (NBR) in Rocky Mountain states is 3.2 times that in Gulf Coast states.

In spite of the much higher NBR in Rocky Mountain states, data from the American Cancer Society (Table 2) show that age-adjusted overall cancer death rate in three Gulf Coast states are individually all higher than in three Rocky Mountain states, averaging 1.26 times higher. The difference from the expectation that the cancer death might be proportional to NBR is a factor of 4.0 (3.2 × 1.26). It is therefore clear that, comparing Rocky Mountain and Gulf Coast states, there is a negative correlation of NBR with overall cancer death.

Table 2. Cancer mortality—1998.[a]

State	Pop.[b] ($\times 10^{-5}$)	Overall cancer death rate per 100,000[c]	Lung and bronchus cancer: Est. number of deaths	Deaths/100,000[d]	Radon[e]
					r_0
Idaho	10.1	148	500	50	2.4
Colo.	33.1	147	1,500	45	2.8
N. Mex.	15.2	146	700	46	2.5
Aver.		147		47	2.6
Lou.	42.4	194	2,900	68	0.5
Miss.	25.9	181	1,700	66	0.5
Ala.	40.6	179	2,800	69	0.5
Aver.		185		68	0.5
Ratio of averages		1.26		1.45	5.2

[a] From Table 4 of American Cancer Society (1998).
[b] *1998 Rand McNally Road Atlas* (1990 census).
[c] Average reported annual mortality rate for 1990–1994, age-adjusted to the 1970 U.S. standard population. National Center for Health Statistics. (Am. Cancer Soc. 1998).
[d] Calculated from estimated number of deaths in 1998 and population of the state (e.g., 500/10.1 = 50).
[e] Average home radon level across state. Derived from county-by-county data of Cohen et al (1994). r_0 is in units of pCi L^{-1}. 1 pCi L^{-1} = 37 Bq m^{-3}.

Again comparing Rocky Mountain and Gulf Coast states (Table 2), it is shown that there is a strong negative correlation of estimated lung and bronchus cancer mortality with natural radon levels by a factor of 7.5 (5.2 × 1.45).

It is possible that confounding factors, such as smoking, poverty, or environmental pollution, contribute to the differences in cancer mortality between Rocky Mountain and Gulf Coast states. However, the factor of disproportion is so great (4.0 to 7.5) that it strains credulity to assume that such confounding factors could reverse this negative correlation. For example, Cohen (1997) has found that corrections made for smoking prevalence vs. average home radon levels in U.S. counties with a wide variety of socioeconomic characteristics did not basically alter the negative correlation that he found. It is to be noted (Table 2) that *all three* of the Rocky Mountain states greatly exceed *all three* of the Gulf Coast states in radon levels, yet both the reported age-adjusted cancer death rate and the estimated lung and bronchus cancer death rate are significantly lower in *all three* Rocky Mountain states.

The most reasonable conclusion from these findings is that the levels of NBR in the United States are either too low to be a significant cause of cancer mortality, or that, at the low doses of NBR, there is a nonlinearity of the dose-effect curve, or even hormesis. This is consistent with the negative correlations of lung cancer mortality with home radon levels shown by Cohen (1995, 1997).

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