NATURAL BACKGROUND RADIATION AS A BASIS FOR COMPARISON WITH NUCLEAR EFFLUENTS

John H. Harley, Director
Environmental Measurements Laboratory
U.S. Department of Energy
New York, New York 10014

Before we can use natural background radiation as a basis for comparison with other exposures we must attempt to get the best available data on what the background actually is. There are many unsupported statements made that are entirely erroneous and in fact there are some published reports where serious errors were made and have not been corrected. For our purposes we will use the data from the NCRP Report #45 (NCRP 1975) entitled "Natural Background Radiation in the United States". The most recent U. N. Scientific Committee report (1977) gives data that are very comparable and I believe that we can use this information to describe the average natural background exposure. Table I is a simplified version of a summary table from the NCRP report which gives the average exposure for the United States.

It is apparent that there are three components of whole body exposure which are approximately equal plus a lung exposure from inhalation of radon daughter products that gives a considerably higher dose equivalent rate. In this paper I will try to indicate the range of variation in these components and to examine some of the fallacies that have appeared in previous comparisons of natural background with exposures to man-made sources.

VARIABILITY OF NATURAL BACKGROUND

Cosmic Radiation

Cosmic radiation varies by a few percent with latitude but the major changes occur with altitude. The mean value for whole body dose equivalent in our table is 28 mrem/y and the comparable values at various heights would be

Sea Level	- 25 mrem/y
1 km	36
2 km	58
3 km	108

TABLE I

Summary of Average Dose Equivalent Rates (mrem/y) from Various Sources of Natural Background Radiation in the United States

Source	Gonads	Lung	Bone Surface
Cosmic Radiation[a]	28	28	28
Cosmogenic Radionuclides	0.7	0.7	0.8
External Terrestrial[b]	26	26	26
Inhaled Radionuclides[c]	---	100[d]	---
Radionuclides in the Body[e]	27	24	60
Rounded Totals	80	180	120

[a] "Cosmic Radiation" includes 10% reduction to account for structural shielding.

[b] "External Terrestrial" includes 20% reduction for shielding by housing and 20% reduction for shielding by the body.

[c] Doses to organs other than lung included in "Radionuclides in the Body".

[d] Local dose equivalent rate to segmental bronchi is 450 mrem/y.

[e] Excluding the cosmogenic contribution.

thus living at 2 km above sea level would increase your total whole body exposure from about 80 mrem/y to 110. I am merely trying to point out that the cosmic ray dose rate may double but this merely increases the total dose rate by about 30%.

Terrestrial Radiation

The average whole body dose equivalent from external terrestrial gamma radiation is about 26 mrem/y in the United States. In the NCRP report, the major radiation regions of the country included the Atlantic and Gulf Coast with 15 mrem/y and a limited area in the Rocky Mountains receiving 57 mrem/y. The rest of the country averaged out at 29 mrem/y. Once again it is possible to change this component of radiation by a factor of 2 from the mean but the change in total dose rate would only be from about 70 to 110 mrem/y.

Probably the most detailed study of terrestrial radiation was carried out in West Germany, with about 25,000 outdoor measurements and 30,000 indoors (BMI 1978). Their mean values were 50 mrem/y indoors and 37 mrem/y outdoors. The total spread was considerable, but less than 1% of the population was above 100 mrem/y indoors and 80 mrem/y outdoors. Conversely, less than 1% of the population was below 17 mrem/y indoors or 12 mrem/y outdoors. Once again, values greater than twice the mean are rare, while at the lower exposure end the difference is a factor of 3 from the mean.

Radioactivity in the Body

There is very little variability in the radiation received from internal radioactivity. The majority of the exposure comes from potassium-40 where the concentration is under homeostatic control in the body and does not vary significantly. The major difference results from the greater lean body mass of the male with consequent higher potassium concentration and dose. The bone doses are higher than for the whole body due to accumulation of heavy metals including radium and radioactive lead and polonium. The concentrations are largely a function of dietary exposure and are generally within a factor of 2 of the mean even for small groups with specialized diets.

Lung Dose

The value shown in the NCRP tabulation might now be modified by two factors. The first is that the ICRP has changed the RBE for alpha particles once again to 20, and the second that we would now base our radon daughter exposure on the levels indoors. These are about a factor of 2 higher than outdoors so the overall dose equivalent is probably about four times the tabulated value.

The variability again is of the order of a factor of 2 for sizeable population groups although individuals can show a greater range. Smoking is definitely a contributor, but the full significance of the exposure is not yet clear.

FALLACIES IN NATURAL BACKGROUND COMPARISONS

I have heard a large number of mistatements concerning natural background which have been used to justify man-made exposure including nuclear effluents. I think that such comparisons can be useful but that exaggerating the natural background situation is not productive in the long run. I have just listed a few of these as a matter of interest.

1. Background is 130 mrem/y for the whole body or gonads. This was adopted from a report which misused the cosmic ray exposures in particular. It is widely dispersed in the literature but the NCRP and UNSCEAR values are closer to the truth.

2. The background in Denver is 3 times normal. This of course comes from looking at single components of the radiation field. My best estimate for total exposure in Denver is about 125 mrem/y including both increased cosmic and terrestrial components.

3. It's more dangerous to be in Grand Central Station than near a reactor. Grand Central Station in New York City is a massive granite building that many thousands of people pass through every day. We have made external radiation measurements in the Station and found levels of 60 mrem/y in the hall area, 150 mrem/y up against a wall and 270 mrem/y in a corner. This sequence of course, merely shows that the more source is exposed to a detector, the higher the reading. The values might be compared however with perhaps 40 mrem/y for the city in general - outdoors. The statement was made at the time that Grand Central Station could never get a license. This is not really relevant but it should be realized the present climate could lead to regulations against the future use of such building materials. There would be an outcry against the regulation of "natural"

materials, since "natural" is often related to "harmless". A quick reply to this equivalence is that water is "natural", but that more than 6000 people are drowned every year in this country.

4. All soil is radioactive so contamination doesn't matter. Actually a general value for radioactivity in soil might be 1 pCi/g each for uranium and thorium and 10 pCi/g for potassium. This is what produces the terrestrial radiation field. If we consider that the airborne dust level may be as high as 100 $\mu g/m^3$ it is obvious that we may inhale a couple of milligrams of soil per day. Most of this is not retained, so that the body burden or lung burden measured as a result of inhaling soil is not significant. Airborne radioactive effluents on the other hand can be a problem locally, at least, because of their difference aerodynamic, chemical and physical properties. They cannot be brushed off easily by comparison with natural background but the exposures must be evaluated realistically for each case.

5. The range of natural background is so great that contamination doesn't matter. At the start of nuclear testing there was a very common thought that if we only doubled the natural background radiation that this would be acceptable. Fortunately the average dose equivalent from the 1945-1962 nuclear testing was only about 100 mrem for the whole body and about twice that for bone surfaces. This was considerably less than the natural dose equivalent received in the same period so the question of doubling did not really come up. Since that time, of course, reference values such as 10 mrem/y or 25 mrem/y for exposure in the vicinity of a nuclear plant or as total exposure from the nuclear fuel cycle have been used. This is the case where many think that a valid comparison seems possible and justified. It would seem that if sizeable populations are exposed to double the mean from natural sources, a comparable exposure from nuclear effluents might be justified. I have called this a fallacy only in that serious consideration is now being given to whether the high natural exposures should be modified. This is exactly the reverse of the desired effect, but it is certainly something to think about.

In closing it seems worth while to look at where there is an exact comparison between effluents and natural activity and where I believe that insufficient attention has been given to the significance of this comparison. Quite a few articles have appeared discussing the radon released from mill tailings piles.

A number of these have calculated radon concentrations, used reasonable dosimetry to estimate the lung dose equivalent and have continued on with the BEIR risk estimates (BEIR 1972) to come up with a number of lung cancer deaths that would be caused by the radon releases (for example, Comey 1975). These have been also multiplied by the length of time that the releases would continue (in some cases more than 100,000 years) to produce some rather alarming numbers of casualties.

It is equally valid to use the natural radon concentrations that exist in the environment and to apply the same dosimetry and the same BEIR risk estimates to see what the expected lung cancer incidence from natural radon would be. This exercise gives us a number which is a sizeable fraction of the present lung cancer incidence. This seems reasonable but, if we look back to 1930 when our diagnostic information was probably reasonable and when the radon exposures were certainly the same as they are now, the calculated lung cancer incidence is higher than the actual values (Harley 1976).

These calculations would merely indicate that one of the factors used is off by a considerable margin. The radon concentrations seem to be valid and the dosimetry is at least physically sound so the most likely error comes in the risk estimates. In any case, I believe that the alarm over radon releases would not seem to be justified as a global hazard.

SUMMARY

The average dose equivalent rate to the whole body from natural background radiation in the United States is about 80 mrem/y. The lung dose from inhaled radon daughters is about 400 mrem/y in addition, with the local dose to specific cells being 5 times as great.

The variability of the terrestrial component of natural background seems to be about a factor of two in either direction from the mean. The same is true for the lung dose, but the cosmic-ray exposure can only be increased. In most cases, a change in location or living habits will only modify one of the components and the overall range of total dose for population groups should be less than a factor of two.

Natural background radiation and its variability may be useful as a basis of comparison with nuclear effluents. As in all other arguments, it is necessary first to get the facts straight and to be sure that the comparison is relevant.

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