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RADIOACTIVE FALLOUT MEASUREMENTS IN AIR AND PEOPLE

RADIOBIOLOGY LABORATORY

COLLEGE OF MEDICINE, UNIVERSITY OF UTAH

U.S. ATOMIC ENERGY COMMISSION CONTRACT AT(11-1)-119

The following measurements of radioactive fallout made at the Radiobiology Laboratory, University of Utah, are assembled under a single cover. None of this material is or has been classified. This material has previously been presented as follows:

1) Air Sampling During Time of Pacific Tests (1956), D.R. Atherton, Radiobiology Semi-Annual Report, pg. 59, (Sept. 1956).

2) Potassium 40 and Cesium 137 in Humans, C.W. Mays, D.H. Taysum, and B.W. Glad, Radiobiology Laboratory Annual Report, COO-215, pp. 147-157, (March 1958).

3) Fallout Cesium 137 in Utah Residents: 1958, C.W. Mays, Summary of a talk given before the Biomedical Directors of the Atomic Energy Commission, Cincinnati, Ohio (October 23, 1958).

Compiled for Dr. T.P. Dougherty, Director

by ______________________

C.W. Mays, Ph.D.

AIR SAMPLING DURING TIME OF PACIFIC TESTS (1956)

D.R. Atherton

Pursuant to the request of Gordon Dunning, this laboratory participated in an air monitoring program during the months of April through August 1956.

With an air sampling device having a filter paper area of 63 square inches, 107 daily samples were taken. This device was located by an air intake 20 ft. above ground level in a 5-story building 1 mile east of Salt Lake City. The samples along with pertinent data were forwarded for further analysis to Mr. Joe B. Sanders, Chief, Las Vegas Branch USAEC, Las Vegas, Nevada.

Prior to sending the samples away, a circular area one inch in diameter was counted with a G. M. tube. Most of the filter papers were counted within a day or two after sampling. The counting efficiency of this G. M. tube varied from about 5% for weak beta emiters such as Ca^{45} to about 15% for energetic beta emiters such as Y^{90}. The ratios of net beta counting rates on this 0.785 square inch area to instrument background were calculated and normalized to 1,000 ft^3 of air passing through the air sampling device. Background was about 20 counts per minute. The distribution of the normalized net beta counts to background counts was as follows:

PERCENT OF SAMPLES	NET/BACKGROUND
54	0 --> 1.9
31	2 --> 4.9
5	5 --> 6.9
10	7 --> 14.2

The values from 7 --> 14.2 occurred for samples collected on the following dates: April 17-18; 19-20; 23-24; 24-25; May 10-11; 15-16; 23-24; 31-June 1; June 12-13; August 2-3.

Post script (1959) - Air samples were also taken during the spring and summer of 1957. These filter papers were not counted in Salt Lake, but forwarded directly to Dr. Oliver B. Placak, Off-Site Rad. Safe Office, Nevada Test Organization, USAEC, P.O. Box 2088, Las Vegas, Nevada.

POTASSIUM 40 AND CESIUM 137 IN HUMANS

C.W. Mays, D.H. Taysum, and D.W. Glad

Abstract:

Whole-body gamma measurements have been made on 38 persons. The amount of potassium in a person is approximately proportional to body weight and tends to be greater in men than in women. The average Cesium content measured in people living in Salt Lake City, Utah, is greater than average values reported for people living in other parts of the United States. This difference may be due to the proximity of Salt Lake City to the atomic bomb test site in Nevada. About 70% of the people in the Radiobiology Laboratory have been measured. So far, there is no evidence of contamination with the radioelements with which we work.

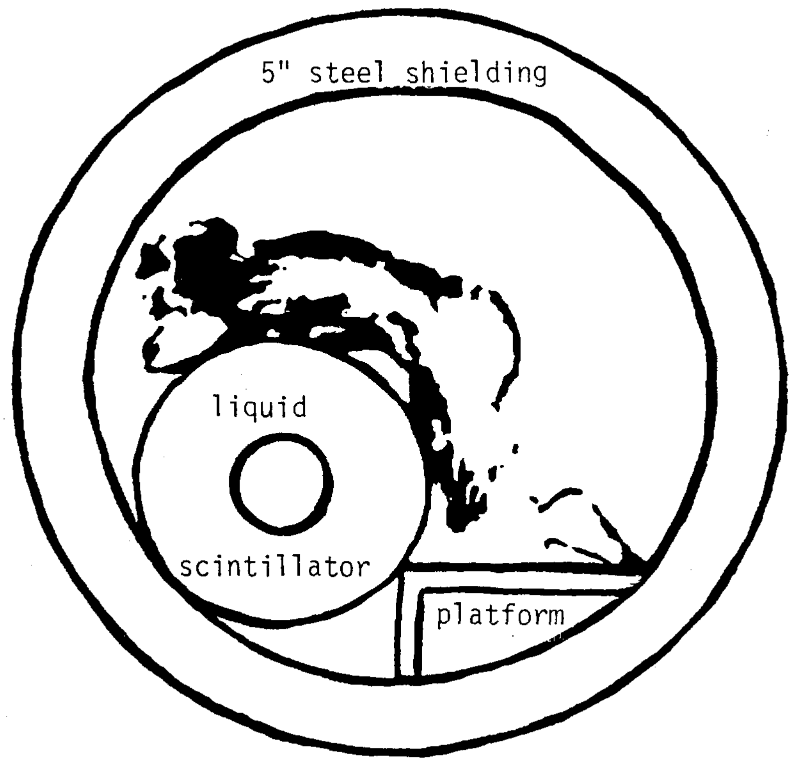
INTRODUCTION:

It has been estimated(1) that during the winter of 1957-1958, over 95% of the gamma activity in people was due to the disintegration of Potassium 40 and Cesium 137. Potassium 40 is a naturally occurring radioelement which has existed in living systems for millions of years. Cesium 137 results from nuclear fission. It was first detected in humans by Miller and Marinelli(2) in the spring of 1955. These measurements have been pursued extensively at the Argonne National Laboratory using a large NaI(Tl) crystal detector and at the Los Alamos Scientific Laboratory using a large whole body liquid scintillation detector(3).

Whole body measurements on personnel at the Radiobiology Laboratory were made to (a) monitor for possible contamination with the gamma emitting radioelements with which we work, and (b) to determine Cs^{137} burdens in persons from the Salt Lake City area.

Positioning of Humans:

Human measurements were made with our whole body gamma counter, K-9 Bark II(4). Positioning was as shown on the following page.



HUMAN POSITIONING FOR GAMMA COUNTING

This position was found to give the highest counting rate outside the tunnel. Individuals were counted for four minutes. To avoid radioactive contamination in counting, a plastic suit was worn by the subject.

A Potassium standard* and a Cesium 137 standard** were placed in turn in the human position. The standards were imbedded in a masonite phantom of variable thickness so as to closely approximate the effects of self-absorption and radioelement distribution in the human.

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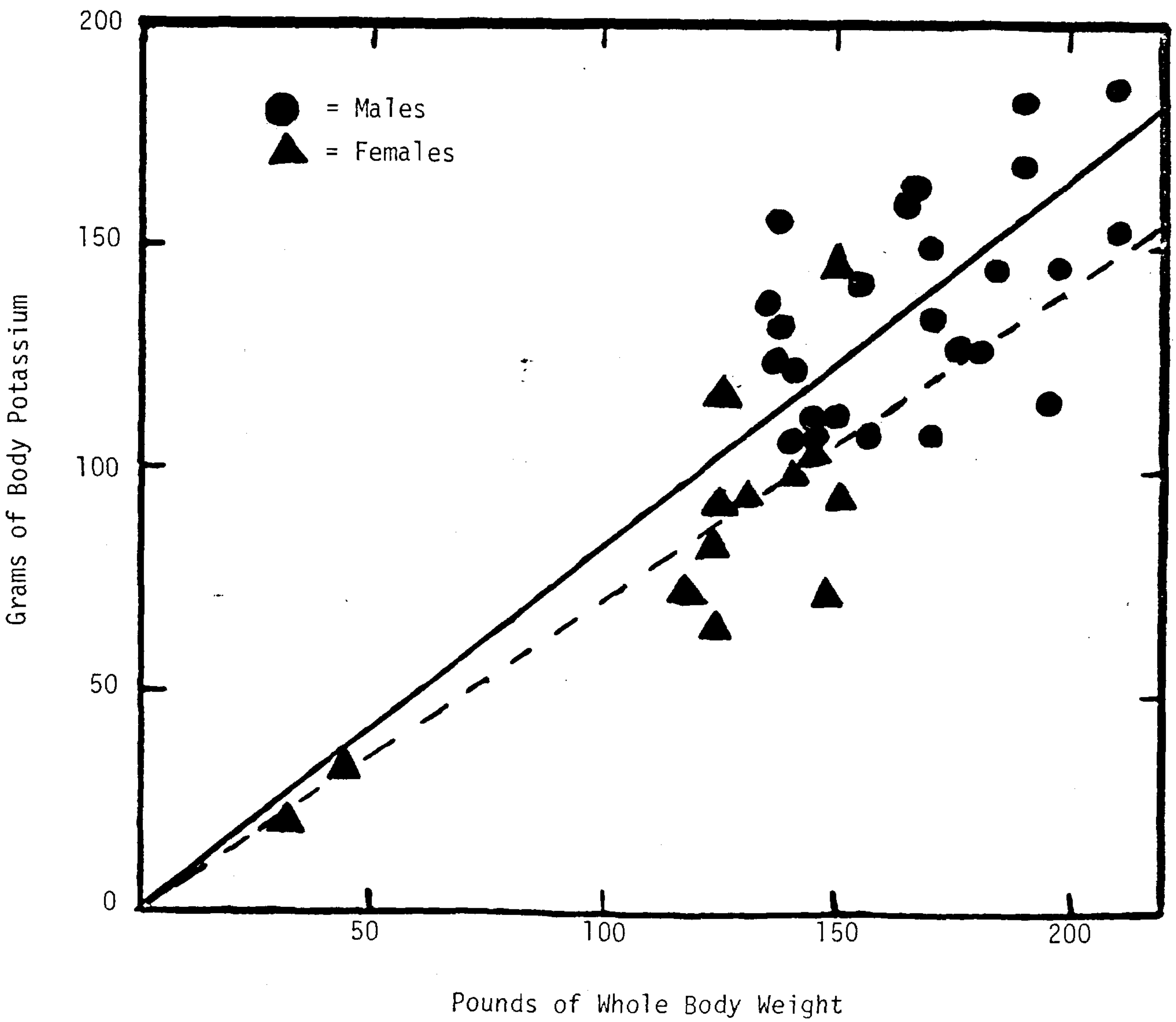
*The Potassium standard was 1 kilogram of KCL.

**The Cesium standard was calibrated against a Cs^{137} standard at the Argonne National Laboratory with the assistance of O.J. Steingraber and J.B. Corcoran.

Pulses were simultaneously counted in a high energy channel (about 0.8 to 1.6 Mev) and a low energy channel (about 0.4 to 0.8 Mev). The Potassium and Cesium in the subject were calculated by comparisons which are described in the Appendix. A basic assumption is that the only gamma activity in the human body is one for K^{40} (1.46 Mev) and Cs^{137} (0.66 Mev). Since our measurements were made between November 1957 and March 1958, when the short lived components of atomic fallout were small, we believe that this assumption is justified. A similar assumption is made for measurements in the Los Alamos human counter(5).

Potassium

Grams of potassium are plotted versus total body weight.

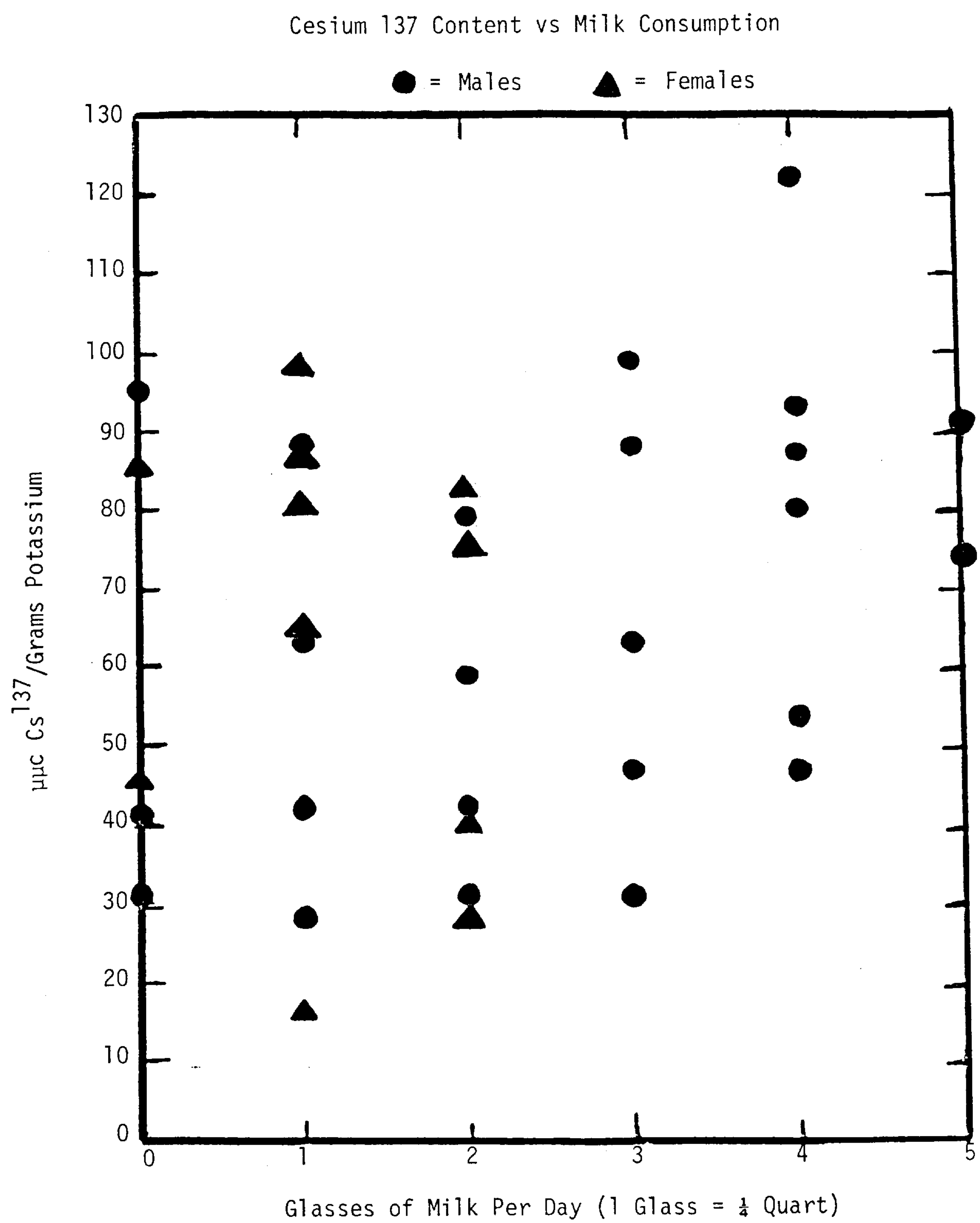


Potassium contents tends to be proportional to body weight. In the man measured, the average Potassium content is 0.183% of body weight; whereas a slightly lower value of 0.157% was measured for women. This compares closely with average Potassium values of 0.188% of body weight for men and 0.154% for women as measured with a NaI(Tl) crystal counter by Miller and Marinelli[2]. Anderson, et at,[5] report that the Potassium content of the adult male is 0.19% of gross body weight as measured in the Los Alamos Human Counter.

Cesium

It has been stated[5] that about 50% of the Cesium 137 in people comes from milk. An attempt was made to correlate our Cesium measurements with milk consumption. Plotted values show that although there is a trend for Cesium content to increase with milk consumption, this accounts for only a small fraction of the observed individual differences. Several reasons are postulated for these individual differences:

1. Milk consumption was an estimated and not a measured quantity.
2. No account was taken of the consumption of cheese and other dairy products.
3. The milk supply in Salt Lake City comes from widely scattered areas which may differ appreciably in fallout contaminations.
4. Individual differences may exist in the ability to assimilate and retain Cesium.
5. The standard deviation, 13 μμc Cs^{137}/gram K, of an individual measurement amounts to about 20% of the average Cesium to Potassium ratio. This contributes to scatter in Cs/K values but accounts for only part of the observed variation.


Cesium 137 Content vs Milk Consumption
= Males
= Females
130
120
110
100
90
80
70
60
50
40
30
20
10
0
μμc Cs137/Grams Potassium
0
1
2
3
4
5
Glasses of Milk Per Day (1 Glass = ¼ Quart)

It is of interest that the highest milk drinker (not plotted) who drank 12 glasses of milk per day, had only 64 μμc Cs^{137}/gram K. We postulate that heavy milk drinkers get less Potassium and Cesium from other (non-milk) sources, than do low milk drinkers. Hence, the correlation between total body Cesium and milk consumption is only moderate.

The average Cesium to Potassium ratio measured in adults living in Salt Lake City is 67 μμc Cs^{137}/gram K. Anderson(5) has reported an average value of 44 μμc Cs^{137}/gram Potassium for persons in the United States. Miller(6) reports an average value of 34 μμc Cs^{137}/gram K for 13 persons from the Chicago area, 32 μμc Cs^{137}/gram K for 5 Europeans, and 14.6 μμc Cs^{137}/gram K for 11 persons from Central and South America. It is apparent that the average Cesium value measured in people living in Salt Lake City, Utah, is greater than the average of the rest of the United States. The Strontium concentrations of 34.6 μμc Sr^{90}/gram Ca in the soil in Salt Lake City is about double the average Strontium concentration of 14.7 μμc Sr^{90}/gram Ca for the United States(7). The proximity of Salt Lake City to the Nevada atomic bomb test area may be responsible for the higher concentrations of these fallout radioelements.

Accuracy of Measurement

To evaluate the statistical accuracy of our measurements, three subjects (D.H.T., B.W.G., and C.W.M.) were each measured six times and their computed values of Potassium and Cesium are as follows:

Man	Grams Potassium DHT	BWG	CWM	$\mu\mu c$ Cs^{137}/gram Potassium DHT	BWG	CWM
1	127	84	125	87	85	106
2	104	115	108	95	101	104
3	141	107	134	96	106	66
4	124	122	136	85	84	93
5	128	109	132	65	110	89
6	112	115	138	98	111	77
Average	123	109	129	88	100	89
S.D.**	±13	±13	±6	±12	±12	±16

*Computed for average values of 0.006 μc Cs^{137} and 133 grams Potassium per person.

**For a single measurement.

From these measurements the standard deviation of a single measurement for Potassium in adult humans is ±11 grams. The standard deviation in the Cesium/Potassium ratio is ±13 μμc Cs^{137}/gram K. Part of the error is Potassium measurement is due to difference in positioning, while this error tends to cancel in the Cesium/Potassium ratio. Compton degradiation of 1.46 Mev Potassium gamma rays into the lower energy (Cesium) channel increase the error in the Cesium/Potassium ratio.

To check the absolute accuracy of our measurements, two subjects, (D.H.T. and G.D.W.) were counted both in the Los Alamos Human Counter by E.C. Anderson and in K-9 Bark II at the Radiobiology Laboratory.

Subject	Where Measured	Grams K	μμc Cs^{137}/grams K
D.H.T.	Los Alamos	113	94
D.H.T.	K-9 Bark II	123	87
G.D.W.	Los Alamos	167	45
G.D.W.	K-9 Bark II	154	47

The agreement between measured values is excellent.

Lack of Radioelement Poisoning

The effect of Ra^{226}, Ra^{228}, or Th^{228} in a person's body is to increase both the apparent Cesium and Potassium burdens when measured by our counter. Contamination is best detected in our method by comparing computed Potassium levels with the average value expected for the person's weight and sex; or better yet, with a previous uncontaminated value of the person's Potassium. The large difference of Cesium in uncontaminated persons limits the usefulness of abnormally high Cesium values as an index of radioelement contamination.

The maximum permissible body burden of Radium 226, 0.1 μc, increases the apparent Potassium content by 160 grams (assuming 30% Radon retention). In no person measured was there an indication that their computed value of Potassium was excessively high. Hence, in the persons thus measured there is no evidence of contamination with the gamma emitters with which we work.

Summary

1. Our whole body gamma counter has been used effectively to measure humans.

2. Potassium content is approximately proportional to body weight and is slightly greater in men than women.

3. The average Cesium content measured in people living in Salt Lake City, Utah, is higher than the average for people in other parts of the United States.

4. No evidence of radioelement poisoning has been detected in personnel at the Radiobiology Laboratory.

Addendum:

On April 5, 1958, it was possible to measure four adult male residents of St. George, Utah. This area is close to the Nevada Test Site and received appreciable fallout from atomic tests in 1953. Measured values are as follows:

Subject	Glasses of Milk	μμc Cs^{137}/grams K
C.G.	0	58
S.B.	2	69
L.G.	2	54
C.T.	2.5	56
AVERAGE	1.6	59

It is of interest that the average Cesium content of these persons is greater than average Cesium content for persons in the United States, but slightly less than the average value of 67 μμc Cs^{137}/grams K measured in adults from Salt Lake City, Utah.

APPENDIX

SIMULTANEOUS DETERMINATION OF A NUMBER OF RADIOELEMENTS

If a specimen is known to contain several different radioelements, these individual activities may be determined simultaneously when (a) the radiation from each radioelement can be detected and (b) the comparative efficiencies of detection among the radioelements are different under various conditions. It is unnecessary to have a detector which selectively detects only one of the radioelements. The specimen and a standard for each of the N radioelements contained are each counted under N different conditions.

Let: x = the fraction of radioelement (a) in the specimen
y = the fraction of radioelement (b) in the specimen
z = the fraction of radioelement (c) in the specimen

A = the count rate of a standard of radioelement (a)
B = the count rate of a standard of radioelement (b)
C = the count rate of a standard of radioelement (c)

K = the count rate of the specimen

In the specimen, the sum of individual count rates = the total count rate.

$$A_1x + B_1y = C_1z + \dots = K_1 \qquad \text{(at condition 1)}$$
$$A_2x + B_2y + C_2z + \dots = K_2 \qquad \text{(at condition 2)}$$
$$A_3x + B_3y + C_3z + \dots = K_3 \qquad \text{(at condition 3)}$$

The solution to these simultaneous equations gives the fraction of the activity of each standard which is present in the specimen.

FOR ONLY ONE RADIOELEMENT (x)

$$x = \frac{K_1}{A_1}$$

FOR TWO RADIOELEMENTS (x and y)

$$x = \frac{K_1B_2 - K_2B_1}{A_1B_2 - A_2B_1}$$

$$y = \frac{K_1A_2 - K_2A_1}{B_1A_2 - B_2A_1}$$

FOR THREE RADIOELEMENTS (x, y, and z)

$$x = \frac{K_1(B_2C_3 - B_3C_2) + K_2\ (B_3C_1 - B_1C_3) + K_3\ (B_1C_2 - B_2C_1)}{A_1(B_2C_3 - B_3C_2) + A_2\ (B_3C_1 - B_1C_3) + A_3\ (B_1C_2 - B_2C_1)}$$

$$y = \frac{K_1(A_2C_3 - A_3C_2) + K_2\ (A_3C_1 - A_1C_3) + K_3\ (A_1C_2 - A_2C_1)}{B_1(A_2C_3 - A_3C_2) + B_2\ (A_3C_1 - A_1C_3) + B_3\ (A_1C_2 - A_2C_1)}$$

$$z = \frac{K_1(A_2B_3 - A_3B_2) + K_2\ (A_3B_1 - A_1B_3) + K_3\ (A_1B_2 - A_2B_1)}{C_1(A_2B_3 - A_3B_2) + C_2\ (A_3B_1 - A_1B_3) + C_3\ (A_1B_2 - A_2B_1)}$$

These equations are well adapted for evaluation by digital computers. There is no theoretical limit to the number of radioelements which may be simultaneously evaluated in this manner. The trick is in knowing beforehand which radioelements are present in the specimen.

References:

(1) C.E. Miller, Personal communication, February 1958.

(2) C.E. Miller and L.D. Marinelli, Gamma ray activity in contemporary man, Science, Vol. 124, No. 3212, pp. 122-123, July 20, 1956.

(3) E.C. Anderson, R.L. Schuch, J.D. Perrings, and W.H. Langham, The Los Alamos Human Counter, Nucleonics, 14, No. 1, pp. 26-29, January 1956.

(4) D.H. Taysum et al, K-9, Bark II, an improved live dog gamma counter, Semi-Annual Report, Radiobiology Laboratory, September 1957.

(5) E.C. Anderson, R.L. Schuch, W.R. Fisher, and W.H. Langham, Radioactivity of people and foods, Science, 125; pp. 1273-1278, 1957.

(6) C.E. Miller, The Human Spectrometer, Argonne National Laboratory Semi-Annual Report, Radiological Physics Division, ANL 5755, pp. 47-61, January - June 1957.

(7) M. Eisenbud, Measurement of Strontium 90 in geophysical materials, Congressional hearings on the nature of radioactive fallout and its effects on man, pp. 557-573, May 27 and June 3, 1957.

FALLOUT CESIUM 137 IN UTAH RESIDENTS: 1958

C.W. Mays

Concern has been expressed[1] relating to the radioactive fallout burdens carried by people who live close to the Nevada Test Site. It has recently been possible for us to measure Cesium 137[2] in twenty residents of Southwest Utah (near the Nevada Test Site) and compare these values with those for residents of Salt Lake City, Utah, and elsewhere. Measurements were made with a whole body gamma-ray scintillation counter patterned after Van Dilla's original dog counter[3] and the Los Alamos human counter[4]. Cesium 137 and Potassium 40 were determined by a method similar to that described by Anderson[5].

The twenty residents of Southwestern Utah were divided into two groups; those who lived in St. George, Utah, where the fallout was fairly heavy in 1953, and those from surrounding areas in which the fallout was considerably lower. All these persons had lived in Southwest Utah at least one year prior to our measurements and most had lived there all their lives. All persons were measured between November 1957 and November 1958.

Results are as follows:

LOCATION	NUMBER OF PERSONS	MICROMICRO CURIES OF Cs^{137} / GRAM OF POTASSIUM
St. George, Utah	11	59
Other S.W. Utah Areas	9	61
Salt Lake City, Utah	43	67
Outside of Utah	11	51

Individual measurements[6] were normally distributed with a standard deviation of $\pm 36\%$. The difference in Cesium values between residents of Southwest Utah and Salt Lake City was not significant. This came as a surprise as we had anticipated a higher Cesium content in people living near the

Nevada Test Site. However, the difference in Cesium values between residents of Salt Lake City and points outside Utah was significant to a level of 1%. This trend for persons in the Intermountain West to have slightly higher Cesium values than persons in the rest of the United States has been recently confirmed by Anderson(7) who found an average value of 51 μμc Cs^{137}/gram K for 35 persons from Utah, Colorado, and Wyoming, which is lightly larger than his average value of 44 μμc Cs^{137}/gram K, corresponding to 207 persons from all over the United States. All these values are close to the average value of 51 μμc Cs^{137}/gram K for residents in the United States measured in 1958 at the Argonne National Lab by Miller(8).

In summary, we have found the levels of fallout Cesium 137 in persons who live near the Nevada Test Site to be similar to the levels in persons in Salt Lake City. While the average level seems slightly higher for Utah than the rest of the United States this level is not alarming, being only about 1/1000 of the maximum permissible Cs^{137} concentration for the general population.

We are very appreciative of the generous assistance of Drs. B.C. Anderson and M.A. Van Dilla of the Los Alamos Scientific Laboratory and Drs. C.E. Miller and R.B. Rowland of the Argonne National Laboratory in checking the results(9) of our human measurements. D.W. Glad, D.H. Taysum, G.C. Westenskow, L. Jackson, L.W. Blake, and W.M. Hammer of our laboratory contributed significantly to the success of these measurements.

REFERENCES AND NOTES

1. N. Bauer, Fallout near the Nevada Test Site, Science, Vol. 128, No. 3314, pg. 40 (July 4, 1958).

2. Cesium 137 from atomic test was first detected in humans in 1955 by C.E. Miller and L.D. Marinelli, Gamma-ray Activity of Contemporary Man, Science, Vol. 124, No. 3212, p. 122-123 (July 20, 1956).

3. M.A. Van Dilla, R.L. Schuch, and E.C. Anderson, K-9, A large Whole Body Gamma Detector, Nucleonics 12(9) 22 - 27 (1954).

4. E.C. Anderson, R.L. Schuch, J.D. Perrings, and W.H. Langham, The Los Alamos Human Counter, Nucleonics 14(1), 26 (1956).

5. E.C. Anderson, R.L. Schuch, W.R. Fisher, and W.H. Langham, Radioactivity of People and Foods, Science Vol. 125, No. 3261, p. 1273-1278 (June 27, 1957).

6. To compute the μμc of Cs^{137} in a 70 Kg man multiply the Cesium/Potassium ratio by 139 grams of Potassium(7).

7. E.C. Anderson, Radioactivity of people and milk: 1957, Science, Vol. 128, No. 3329, p. 882-886 (October 17, 1958).

8. C.E. Miller, Use of Low-level Gamma-ray spectroscopy for Radiation Emitted from Human Beings, Meeting of the AEC Industrial Physicians, Health Physicists, Health Physicians and Industrial Hygienists, Cincinnati, Ohio (October 29, 1958).

9. When persons measured in our counter were also measured at Los Alamos and at Argonne, it was found that the Los Alamos and Argonne Cesium values were about 10% and 30% lower than our values, whereas our Potassium values all agreed very well. The reason for this discrepancy is not known, but it may well be that our Cesium values are consistently high.