

Occurrence of Radionuclides in Residents of the Carlsbad, New Mexico Area

Introduction

Citizen volunteers from the Carlsbad, New Mexico area were monitored for internally deposited radionuclides through a project entitled "Lie Down and Be Counted" (LDBC). This project is provided as an outreach service to the public to support education about naturally occurring and man-made radioactivity present in people who live in the vicinity of the WIPP. The data collected prior to the opening of the WIPP facility (26 March 1999) serve as a baseline for comparisons with periodic follow-up measurements that are slated to continue throughout the 35-year operational phase of the WIPP. It is important to note that these data represent an interim summary (through 1 October 2000) of an ongoing study.

Participating in the LDBC consists of a lung and whole body count every two years. Volunteers are recruited through presentations to local community groups and businesses. The entire measurement process takes approximately one hour. A detailed description of the measurement protocol, analysis and instrument detection limits is provided in the CEMRC 1998 Report. In addition, the status of the project and results are updated quarterly on the CEMRC website (<http://www.cemrc.org>) and reported semi-annually through a newsletter distributed throughout the local community.

Results

As of 1 October 2000, 500 individuals had participated in the LDBC project. At the time the WIPP opened, 367 individuals had been measured using the *in vivo* protocol. This group of 367 measurements constitutes the pre-operational baseline to which subsequent results are compared. Counts performed after the opening of the WIPP are considered to be a part of the operational monitoring phase of the WIPP EM. Recounts of the original cohort began in July 1999, and 98 recounts had been performed through 1 October 2000. In

addition, 133 new volunteers have participated in the program since 1 October 1999. These new volunteers form an additional baseline cohort for future comparisons.

Demographic characteristics (Table 18) of the current LDBC cohort are statistically unchanged from those reported in the CEMRC 1999 Report, and are generally consistent with those reported in the 1990 census for citizens living in Carlsbad. The largest deviations reported in the 1999 report between the LDBC cohort and 1990 census were the over-sampling of males and under-sampling of Hispanics. Since that time, slight improvements have been made with respect to the percent of males and Hispanics represented, but Hispanics are still 50% under-sampled relative to the 1990 census. During 2001, demographic characteristics of the LDBC project will be compared to results of the 2000 census, which will provide a more accurate representation of the current population. In addition, it is important to note that if the presence of a radionuclide is dependent on a subclass of interest (gender, ethnicity, etc.), valid population estimates can still be made by correcting for the proportion of under- or over-sampling for the particular subclass.

As discussed in detail in the CEMRC 1998 Report and elsewhere (Webb et al., 2000, *Radiat. Prot. Dosim.* 89, 183), the criterion, L_C , was used to evaluate whether a result exceeds background, and the use of this criterion will result in a statistically inherent 5% false positive error rate per pair-wise comparison (5% of all measurements will be determined to be positive when there is no activity present in the person). For the baseline measurements ($N = 367$), the percentage of results greater than L_C were consistent with a 5% random false positive error rate, at the 95% confidence level (1 to 9%), for all radionuclides except ^{232}Th via ^{212}Pb , ^{235}U / ^{226}Ra , ^{60}Co , ^{137}Cs , ^{40}K , ^{54}Mn , ^{232}Th via ^{228}Ac and ^{65}Zn (Table 19). As discussed in detail in the 1998 report, five of these (^{232}Th

via ^{212}Pb , ^{60}Co , ^{40}K , ^{54}Mn (^{228}Ac interference) and ^{232}Th (via ^{228}Ac) are part of the shield-room background and positive detection is expected at low frequency. ^{40}K is a naturally occurring isotope of an essential biological element, so detection in all individuals is expected. ^{137}Cs and $^{235}\text{U} / ^{226}\text{Ra}$ are not components of the shielded room background and were observed at frequencies greater than the 95% confidence interval for the false positive error rate (discussed in more detail later). It is interesting that no result above L_C has been observed for ^{65}Zn in the baseline or monitoring phase. It is unlikely that this result is a statistical anomaly, since results greater than L_C were observed for all other radionuclides. This observation suggests an abnormality in the analysis algorithm at that photon energy and further investigation is underway.

For the operational monitoring counts (Table 19, $N = 226$), the percentage of results greater than L_C were consistent with baseline at a 95% confidence level (margin of error), except for ^{60}Co and ^{232}Th (via ^{228}Ac). For these radionuclides, the percentage of results greater than L_C decreased relative to the baseline. This would be expected for ^{60}Co , since the radionuclide has a relatively short half life (5 years), and the content within the shield has decreased via decay by approximately 45% since the baseline phase of monitoring. The ^{232}Th (via ^{228}Ac) results were unexpected and further investigation is necessary to explain this observation.

The margin of error could not be calculated for the ^{103}Ru percentage because the sample size of the operational monitoring counts was too small at the time of this summary. When sufficient operational monitoring counts are performed, the margin of error will be calculated. In addition, margins of error can not be calculated for percentages of 100 and 0 (^{40}K and ^{65}Zn , respectively), applying binomial statistics, since these percentages represent non-binomial data.

It is important to note that operational monitoring includes the counting of new individuals and the recounting of previously measured participants. Based on the data reported herein, there is no evidence of an increase in the frequency of detection of

internally deposited radionuclides for citizens living within the vicinity of the WIPP, since the WIPP began receipt of radioactive waste.

^{40}K results were positive for all participants ($n = 500$), ranging from 1088 to 4462 Bq per person with an overall mean (\pm SE) of 2868 (± 40) Bq per person. Such results are expected since K is an essential biological element contained primarily in muscle, and a theoretical constant fraction of all naturally occurring K is the radioactive isotope ^{40}K . The mean ^{40}K value for males (\pm SE), was 3474 (± 41) Bq per person, which was significantly greater ($p < 0.0001$) than that of females, which was 2156 (± 34) Bq per person. This result was expected since, in general, males tend to have larger body sizes and greater muscle content than females.

Detectable ^{137}Cs is present in $26.1 \pm 3.5\%$ (95% confidence level, baseline and operational monitoring counts) of citizens living in the Carlsbad area. These results are consistent with findings previously reported in CEMRC 1998 and 1999 reports and elsewhere (Webb, J. L. et al., 2000, loc. cit.). Detectable ^{137}Cs body burdens ranged from 5.2 to 62.9 Bq per person with an overall mean (\pm SE) of 10.4 (± 0.5) Bq per person. The mean ^{137}Cs body burden for males (\pm SE), was 11.1 (± 0.7) Bq per person, which was significantly greater ($p = 0.02$) than that of females, which was 8.9 (± 0.4) Bq per person. As previously reported (CEMRC 1998 Report; CEMRC 1999 Report; Webb, J. L. et al., 2000, loc. cit.) the presence of ^{137}Cs was independent of ethnicity, age, radiation work history, consumption of wild game, nuclear medical treatments and European travel. Occurrence of detectable ^{137}Cs was associated with gender, where males had higher prevalence of ^{137}Cs relative to females. Presence of ^{137}Cs was also associated with smoking (where smokers had a higher prevalence relative to non-smokers). It is likely that the association with gender is related to the tendency for larger muscle mass in males than in females, as supported by the ^{40}K results. The association of ^{137}Cs with smoking could be related to the presence of fallout ^{137}Cs in tobacco, decreased pulmonary clearing capability in smokers, or other as yet

unidentified factors, and further study is warranted.

As reported in the CEMRC 1998 and 1999 reports, the percentage of results greater than L_C for ^{235}U / ^{226}Ra (12%) are significantly (although slightly) higher than the distribution-free confidence interval for a 5% random false positive error rate (1 to 9%). These data are not nearly as compelling as those for ^{137}Cs , but the large sample size of the current cohort tends to support the observed pattern. Although ^{235}U and ^{226}Ra cannot be

differentiated via gamma spectroscopy, it is likely the signal is the result of ^{226}Ra because the natural abundance of ^{226}Ra is much greater than that of ^{235}U . However, further study, possibly involving *in vitro* bioassay for the two radionuclides (the nuclides can be distinguished via alpha spectrometry), is needed. No additional investigations into this observation were conducted during this reporting period.

Table 18. Demographic Characteristics of the "Lie Down and Be Counted" Population Sample through 1 October 2000

Characteristic		2000 Sample Group (^a margin of error)	1999 Sample Group	^b Census, 1990
Gender	Male	54.0% (49.6 to 58.4%)	56.6%	48.0%
	Female	46.0% (41.6 to 50.4%)	43.4%	52.0%
Ethnicity	Hispanic	13.6% (10.6 to 16.6%)	12.9%	33.4%
	Non-Hispanic	83.6% (80.4 to 86.8%)	84.2%	63.0%
	Other	2.8% (1.2 to 4.4%)	2.9%	3.6%
Age 60 or older		25.2% (21.4 to 29.0%)	24.8%	33.7%
Currently or previously classified as a radiation worker		5.8% (3.8 to 7.8%)	4.9%	^c NA
Consumption of wild game within last 3 months		17.6% (14.2 to 21.0%)	15.3%	NA
Medical treatment, other than x-rays, using radionuclides		8.8% (6.2 to 11.4%)	9.0%	NA
European travel within the last 2 years		3.8% (2.0 to 5.6%)	3.9%	NA
Current smoker		14.6% (11.4 to 17.8%)	14.6%	NA

^aThe margin of error represents the 95% confidence interval of the observed proportion.; under complete replication of this experiment, one would expect the confidence interval to include the true population proportion 95% of the time if the sample was representative of the true population.

^bUnited States Department of Commerce, Economics and Statistics Administration, Bureau of the Census. *1990 Census of Population*. Washington, DC: US Government Printing Office

^cNA = not available

Table 19. "Lie Down and Be Counted" Results through 1 October 2000

Radionuclide	In Vivo Count Type	Baseline Counts (prior to 27 March 1999) ^a N = 367	Operational Monitoring Counts (27 March 1999 – 1 October 2000) N = 226	
		% of Results ≥ ^b L _C	% of Results ≥ L _C	^c Margin of Error (%)
²⁴¹ Am	Lung	5	4	1 to 7
¹⁴⁴ Ce	Lung	5	3	0 to 6
²⁵² Cf	Lung	4	8	4 to 12
²⁴⁴ Cm	Lung	6	6	2 to 10
¹⁵⁵ Eu	Lung	7	4	1 to 7
²³⁷ Np	Lung	4	3	0 to 6
²¹⁰ Pb	Lung	4	8	4 to 12
Plutonium Isotope	Lung	6	4	1 to 7
^{d 232} Th via ²¹² Pb	Lung	34	37	30 to 45
²³² Th	Lung	5	6	2 to 10
²³² Th via ²²⁸ Th	Lung	4	6	2 to 10
²³³ U	Lung	6	9	4 to 13
²³⁵ U / ²²⁶ Ra	Lung	11	12	7 to 17
Natural Uranium via ²³⁴ Th	Lung	5	8	4 to 12
¹³³ Ba	Whole Body	4	5	1 to 8
¹⁴⁰ Ba	Whole Body	5	3	0 to 6
¹⁴¹ Ce	Whole Body	4	5	1 to 8
⁵⁸ Co	Whole Body	4	4	1 to 7
^{d 60} Co	Whole Body	55	36	29 to 43
⁵¹ Cr	Whole Body	6	4	1 to 7
¹³⁴ Cs	Whole Body	2	4	1 to 7
¹³⁷ Cs	Whole Body	28	23	16 to 29
¹⁵² Eu	Whole Body	7	4	1 to 7
¹⁵⁴ Eu	Whole Body	4	2	0 to 5
¹⁵⁵ Eu	Whole Body	4	4	1 to 7
⁵⁹ Fe	Whole Body	4	7	3 to 11
¹³¹ I	Whole Body	5	2	0 to 5
¹³³ I	Whole Body	3	4	1 to 7
¹⁹² Ir	Whole Body	4	4	1 to 7
⁴⁰ K	Whole Body	100	100	^e NC
^{d 54} Mn	Whole Body	12	11	6 to 16
¹⁰³ Ru	Whole Body	2	1	NC
¹⁰⁶ Ru	Whole Body	4	4	1 to 8

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Table 19. "Lie Down and Be Counted" Results through 1 October 2000 (Cont.)

Radionuclide	In Vivo Count Type	Baseline Counts (prior to 27 March 1999) ^a N = 367	Operational Monitoring Counts (27 March 1999 – 1 October 2000) N = 226	
		% of Results ≥ ^b L _C	% of Results ≥ L _C	^c Margin of Error (%)
¹²⁵ Sb	Whole Body	5	4	1 to 7
²³² Th via ²²⁸ Ac	Whole Body	35	24	17 to 30
⁸⁸ Y	Whole Body	8	6	2 to 10
⁶⁵ Zn	Whole Body	0	0	NC
⁹⁵ Zr	Whole Body	7	4	1 to 7

^aN = number of individuals

^bTo determine whether or not activity has been detected in a particular person, the parameter L_C is used; the L_C represents the 95th percentile of a null distribution that results from the differences of repeated, pair-wise background measurements; an individual result is assumed to be statistically greater than background if it is greater than L_C

^cThe margin of error represents the 95% confidence interval of the observed percentage; under complete replication of this experiment, one would expect the confidence interval to include the true population percentage 95% of the time, if the sample was representative of the true population

^dThese radionuclides are present in the shield background, so they are expected to be detected periodically

^eNC = not calculated; the margin of error cannot be calculated for the observed percentage because the sample size for operational monitoring counts is as yet too small; when sufficient counts are performed, the margin of error will be calculated; the margin of error for ⁴⁰K cannot be calculated since this radionuclide is present in all individuals

