

## 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 2001) 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 2001, 571 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 158 recounts had been performed through 1 October 2001. In

addition, 71 new volunteers have participated in the program since 1 October 2000. These new volunteers form an additional baseline cohort for future comparisons.

Demographic characteristics (Table 19) of the current LDBC cohort are statistically unchanged from those reported in previous CEMRC reports, 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 females and Hispanics represented. As soon as the data become available, 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  $^{232}\text{Th}$  via  $^{212}\text{Pb}$ ,  $^{235}\text{U}$  /  $^{226}\text{Ra}$ ,  $^{60}\text{Co}$ ,  $^{137}\text{Cs}$ ,  $^{40}\text{K}$ ,  $^{54}\text{Mn}$ ,  $^{232}\text{Th}$  via  $^{228}\text{Ac}$  and  $^{65}\text{Zn}$  (Table 20). As discussed in detail in the 1998 report, five of these ( $^{232}\text{Th}$  via  $^{212}\text{Pb}$ ,  $^{60}\text{Co}$ ,  $^{40}\text{K}$ ,  $^{54}\text{Mn}$  ( $^{228}\text{Ac}$  interference)

and  $^{232}\text{Th}$  (via  $^{228}\text{Ac}$ ) are part of the shield-room background and positive detection is expected at low frequency.  $^{40}\text{K}$  is a naturally occurring isotope of an essential biological element, so detection in all individuals is expected.  $^{137}\text{Cs}$  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).

For the operational monitoring counts (Table 20, N = 357), the percentage of results greater than  $L_C$  were consistent with baseline at a 95% confidence level (margin of error), except for  $^{60}\text{Co}$  and  $^{232}\text{Th}$  (via  $^{228}\text{Ac}$ ). For these radionuclides, the percentage of results greater than  $L_C$  decreased relative to the baseline. This would be expected for  $^{60}\text{Co}$ , since the radionuclide has a relatively short half life (5 years), and the content within the shield has decreased via decay by approximately 28% since the baseline phase of monitoring. The  $^{232}\text{Th}$  (via  $^{228}\text{Ac}$ ) results were unexpected and are likely due to the replacement of aluminum (tends to contain Th and U) components with those manufactured from low radiation background steel.

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.

$^{40}\text{K}$  results were positive for all participants (n = 571), ranging from 1026 to 5558 Bq per person with an overall mean ( $\pm$  SE) of 2676 ( $\pm$  33) 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  $^{40}\text{K}$ . The mean  $^{40}\text{K}$  value for males ( $\pm$  SE), was 3252 ( $\pm$  37) Bq per person, which was significantly greater ( $p < 0.0001$ ) than that of females, which was 2011 ( $\pm$  28) Bq per person. This result was expected since, in general, males tend to have larger body sizes and greater muscle content than females.

Detectable  $^{137}\text{Cs}$  is present in  $26 \pm 4\%$  (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 reports and elsewhere (Webb, J. L. et al., 2000, loc. cit.). Detectable  $^{137}\text{Cs}$  body burdens ranged from 4.9 to 62.9 Bq per person with an overall mean ( $\pm$  SE) of 10.2 ( $\pm$  0.5) Bq per person. The mean  $^{137}\text{Cs}$  body burden for males ( $\pm$  SE), was 10.9 ( $\pm$  0.6) Bq per person, which was significantly greater ( $p = 0.02$ ) than that of females, which was 8.9 ( $\pm$  0.4) Bq per person. As previously reported (CEMRC Reports; Webb, J. L. et al., 2000, loc. cit.) the presence of  $^{137}\text{Cs}$  was independent of ethnicity, age, radiation work history, consumption of wild game, nuclear medical treatments and European travel. Occurrence of detectable  $^{137}\text{Cs}$  was associated with gender where males had higher prevalence of  $^{137}\text{Cs}$  relative to females. Presence of  $^{137}\text{Cs}$  was 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  $^{40}\text{K}$  results. The association of  $^{137}\text{Cs}$  with smoking could be related to the presence of fallout  $^{137}\text{Cs}$  in tobacco, decreased pulmonary clearing capability in smokers, or other as yet unidentified factors. Further study is warranted, but no additional investigations into this observation were conducted during this reporting period.

As reported in previous CEMRC reports, the percentage of results greater than  $L_C$  for  $^{235}\text{U} / ^{226}\text{Ra}$  (10%) 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  $^{137}\text{Cs}$ , but the large sample size of the current cohort tends to support the observed pattern. Although  $^{235}\text{U}$  and  $^{226}\text{Ra}$  cannot be differentiated via gamma spectroscopy, it is likely the signal is the result of  $^{226}\text{Ra}$  because the natural abundance of  $^{226}\text{Ra}$  is much greater than that of  $^{235}\text{U}$ . However, further study is needed; but no additional investigations into this observation were conducted during this reporting period.

**Table 19. Demographic Characteristics of the "Lie Down and Be Counted" Population Sample through 1 October 2001**

Characteristic		2001 Sample Group ( <sup>a</sup> margin of error)	<sup>b</sup> Census, 1990
Gender	Male	53.4% (48.0 to 58.8%)	48.0%
	Female	46.6% (41.2 to 52.0%)	52.0%
Ethnicity	Hispanic	14.1% (10.3 to 18.0%)	33.4%
	Non-Hispanic	83.1% (79.0 to 87.4%)	63.0%
	Other	2.8% (0.9 to 4.7%)	3.6%
Age 60 or older		29.9% (24.9 to 35.0%)	33.7%
Currently or previously classified as a radiation worker		5.4% (3.0 to 7.9%)	<sup>c</sup> NA
Consumption of wild game within last 3 months		18.1% (13.8 to 22.2%)	NA
Medical treatment, other than x-rays, using radionuclides		8.0% (5.1 to 11.0%)	NA
European travel within the last 2 years		4.4% (2.1 to 6.7%)	NA
Current smoker		14.8% (11.0 to 18.7%)	NA

<sup>a</sup>The 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.

<sup>b</sup>United States Department of Commerce, Economics and Statistics Administration, Bureau of the Census. *1990 Census of Population*. Washington, DC: US Government Printing Office

<sup>c</sup>NA = not available

**Table 20. "Lie Down and Be Counted" Results through 1 October 2001**

Radionuclide	In Vivo Count Type	Baseline Counts (prior to 27 March 1999) <sup>a</sup> N = 367	Operational Monitoring Counts (27 March 1999 – 1 October 2001) N = 357	
		% of Results ≥ <sup>b</sup> L <sub>C</sub>	% of Results ≥ L <sub>C</sub>	<sup>c</sup> Margin of Error (%)
<sup>241</sup> Am	Lung	5	4	1 to 7
<sup>144</sup> Ce	Lung	5	3	0 to 6
<sup>252</sup> Cf	Lung	4	6	3 to 9
<sup>244</sup> Cm	Lung	6	5	2 to 8
<sup>155</sup> Eu	Lung	7	4	1 to 7
<sup>237</sup> Np	Lung	4	3	0 to 6
<sup>210</sup> Pb	Lung	4	7	4 to 10
Plutonium Isotope	Lung	6	4	1 to 7
<sup>d</sup> <sup>232</sup> Th via <sup>212</sup> Pb	Lung	34	35	28 to 42
<sup>232</sup> Th	Lung	5	5	2 to 8
<sup>232</sup> Th via <sup>228</sup> Th	Lung	4	5	2 to 8
<sup>233</sup> U	Lung	6	9	5 to 13
<sup>235</sup> U / <sup>226</sup> Ra	Lung	11	10	6 to 14
Natural Uranium via <sup>234</sup> Th	Lung	5	6	3 to 9
<sup>133</sup> Ba	Whole Body	4	3	0 to 6
<sup>140</sup> Ba	Whole Body	5	4	1 to 7
<sup>141</sup> Ce	Whole Body	4	5	2 to 8
<sup>58</sup> Co	Whole Body	4	4	1 to 7
<sup>d</sup> <sup>60</sup> Co	Whole Body	55	34	27 to 41
<sup>51</sup> Cr	Whole Body	6	4	1 to 7
<sup>134</sup> Cs	Whole Body	2	3	0 to 6
<sup>137</sup> Cs	Whole Body	28	23	17 to 29
<sup>152</sup> Eu	Whole Body	7	5	2 to 8
<sup>154</sup> Eu	Whole Body	4	3	0 to 6
<sup>155</sup> Eu	Whole Body	4	3	0 to 6
<sup>59</sup> Fe	Whole Body	4	7	4 to 10
<sup>131</sup> I	Whole Body	5	2	0 to 5
<sup>133</sup> I	Whole Body	3	4	1 to 7
<sup>192</sup> Ir	Whole Body	4	4	1 to 7
<sup>40</sup> K	Whole Body	100	100	<sup>e</sup> NC
<sup>d</sup> <sup>54</sup> Mn	Whole Body	12	10	6 to 14
<sup>103</sup> Ru	Whole Body	2	1	0 to 5
<sup>106</sup> Ru	Whole Body	4	3	0 to 6

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**Table 20. "Lie Down and Be Counted" Results through 1 October 2001 (Cont.)**

Radionuclide	<i>In Vivo</i> Count Type	Baseline Counts (prior to 27 March 1999) <sup>a</sup> N = 367	Operational Monitoring Counts (27 March 1999 – 1 October 2001) N = 357	
		% of Results ≥ <sup>b</sup> L <sub>C</sub>	% of Results ≥ L <sub>C</sub>	<sup>c</sup> Margin of Error (%)
<sup>125</sup> Sb	Whole Body	5	4	1 to 7
<sup>232</sup> Th via <sup>228</sup> Ac	Whole Body	35	25	19 to 31
<sup>88</sup> Y	Whole Body	8	6	3 to 9
<sup>95</sup> Zr	Whole Body	7	4	1 to 7

<sup>a</sup>N = number of individuals

<sup>b</sup>To determine whether or not activity has been detected in a particular person, the parameter L<sub>C</sub> is used; the L<sub>C</sub> represents the 95<sup>th</sup> 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<sub>C</sub>

<sup>c</sup>The 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

<sup>d</sup>These radionuclides are present in the shield background, so they are expected to be detected periodically

<sup>e</sup>NC = 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 <sup>40</sup>K cannot be calculated since this radionuclide is present in all individuals