IDENTIFICATION OF ENVIRONMENTALLY DERIVED CESIUM-137 BURDENS IN A WORKER POPULATION

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ABSTRACT

During 1990, whole body measurements of a number of workers with little probability of onsite occupational exposure showed positive evidence of $^{137}$Cs. Further investigation revealed that many of these workers supplemented their diet with a significant portion of wild game, mainly deer and elk. To validate the assumption of an environmental source, donated samples of venison and other game were analyzed by gamma spectroscopy. Results ranged from less than 0.1 to almost 100 Bq kg$^{-1}$ (0.003 to 2.7 nCi kg$^{-1}$) and showed a correlation with the habitat from which the game was taken. Venison samples obtained from the two workers with the highest body burdens showed the highest activity. A questionnaire is now used to identify workers with an elevated potential for environmental intakes.

INTRODUCTION

During 1990, whole body measurements of a number of Hanford workers with little probability of onsite occupational exposure showed positive evidence of $^{137}$Cs. The two highest amounts of total body $^{137}$Cs for workers without any reasonable potential for occupational intake were 370 and 740 Bq (10 and 20 nCi). As may be seen in Figure 1, these body burdens were well above the normal distribution for unexposed workers.

The primary whole body counter used by the Pacific Northwest Laboratory (PNL) for Hanford workers consists of a column of five vertically mounted detectors in a lead shielded booth. Four detectors are 238-cm sodium iodide (NaI) crystals and the fifth detector, positioned for measurement of the thorax region, is a 292-cm NaI crystal. Data from the five detectors are recorded as a sum of the counts from all five detectors, as well as an individual count from each of the upper three detectors and a combined count from the two lower detectors. The relative counts from each detector output provide a rough approximation of the distribution of activity in the body. The minimum detectable activity (MDA) and decision level ($L_d$) for the measurement of $^{137}$Cs using this system are 120 and 70 Bq (3.2 and 1.9 nCi), respectively.

Conversations with the two workers revealed that they both supplemented their diet with a significant portion of wild game, mainly deer and elk. An investigation to confirm dietary intake as the cause of the measured burdens was then begun by the Battelle Internal Dosimetry Group.
MATERIALS AND METHODS

Donated samples of venison and other game were collected from the two workers described above and from other volunteers. The meat samples were analyzed by the Battelle Nuclear Chemistry Department using a high-resolution germanium diode detector coupled to a multichannel analyzer.

The individual workers were interviewed to determine the locations from which the game samples were taken. As shown in Figure 2, the samples were primarily from the Pacific Northwest, but samples from Arizona and Alaska were also included.

RESULTS

As shown in Table 1, $^{137}$Cs concentrations in the game samples collected for this investigation ranged from less than 0.1 to almost 100 Bq kg$^{-1}$ (0.003 to 2.7 nCi kg$^{-1}$) and showed a correlation with the habitat from which the game was taken. The $^{134}$Cs:$^{137}$Cs ratio was about 1% or less, and more consistent with fallout from atmospheric weapons testing than the release from Chernobyl (Jantunen et al. 1991). Even allowing for decay, the isotopic ratio from a Chernobyl source would be expected to be greater than 10%.

Concentrations of $^{137}$Cs in the game varied between species and locations. Concentrations in muscle of deer from the Hanford Site (Woodruff and Hanf 1991, p. 103) and other areas of Eastern Washington (see Figure 3) ranged from 0 to about 1 Bq kg$^{-1}$ (0 to 0.03 nCi kg$^{-1}$). Deer samples from Arizona and eastern Montana were equivalent to those from eastern Washington, while samples from Idaho, western Montana, and western Oregon showed higher concentrations. Elk samples tended to have slightly higher concentrations of $^{137}$Cs when compared with deer samples from the same area. Only one bear, one cougar, and one moose sample were submitted. The concentration of $^{137}$Cs in the bear sample was higher than most deer samples, but much lower than the deer and elk samples from the same area. The cougar and moose samples were also high, but there were no deer samples from the same areas with which to compare them. Other studies have reported muscle activity concentrations of 2.7 Bq kg$^{-1}$ (0.07 nCi kg$^{-1}$) for Rocky Mountain elk using the Los Alamos National Laboratory lands (Meadows and Salazar 1982), and 4 to 63 Bq kg$^{-1}$ (0.11 to 1.7 nCi kg$^{-1}$) for deer from the southeastern United States (Watts et al. 1983). The differences in the deer samples were attributed primarily to differences in soil composition, soil moisture, and deer diet.

Venison samples obtained from the two workers with the highest body burdens showed the highest activity. These animals were from the Coast Range of Oregon and the western slope of the Rocky Mountains in Montana, areas with relatively high precipitation. The higher precipitation will affect both the fallout rate from the atmosphere and the type of vegetation available to the animals. Selective grazing of contaminated vegetation species is often animal specific. Sheep will show different concentration ratios than goats grazed in the same areas, as will deer and elk (Howard et al. 1991). In Washington State during the 1960s, the highest concentrations of radiocesium in mule deer were found during the winter months. This was thought to be due to the consumption of older plant parts that had been exposed to fallout for longer periods than the new growth grazed in the summer.
The CINDY dose assessment computer code (Strenge et al. 1990) was used to investigate the chronic exposure situation. As shown in Figure 4, a 5.2 Bq (0.14 nCi) daily intake will result in an equilibrium whole body retention of 744 Bq (20 nCi) when the International Commission on Radiological Protection (ICRP) 30 model (ICRP 1979) is used. The meat portion of the diet of the individual with the highest $^{137}$Cs body burden consisted mainly of deer and elk with a $^{137}$Cs concentration of about 70 Bq kg$^{-1}$ (2 nCi kg$^{-1}$). Therefore, the 744 Bq body burden was assumed to result from eating about 74 g (2.6 oz.) of meat per day or about 520 g (1.1 lb.) per week - a reasonable amount.

Countermeasures established in European countries after the Chernobyl incident restrict introduction of meat into the human food chain if the radiocesium activity is above a specified limit, ranging from 300 to 1250 Bq kg$^{-1}$ (8 to 34 nCi kg$^{-1}$) in different countries (Howard et al. 1991). There was therefore no attempt to counsel the worker to restrict his intake of wild game. The annual committed effective dose equivalent associated with a daily intake of 5.2 Bq (0.14 nCi) is about 25 μSv (2.5 mrem).

RECOMMENDATION

To alert the PNL internal dosimetry staff when dietary sources should be investigated, a questionnaire is now completed by each worker showing a positive $^{137}$Cs whole body count (see Figure 5). Except for rare circumstances, the worker is asked to fill out the questionnaire before leaving the in vivo bioassay facility. The completed questionnaire is placed in the worker’s dosimetry records and included as part of the internal dose assessment if one is written.

From the 1960s through the mid 1970s almost everyone had detectable burdens of $^{137}$Cs from fallout, but the small doses attributable to these burdens were generally not calculated for individuals. As shown in Figure 1 the average person no longer has $^{137}$Cs activities detectable by current in vivo counters, but there is increased regulatory pressure to investigate all positive results. This means that it is extremely important to distinguish between environmental and occupational sources of $^{137}$Cs in the body. A questionnaire similar to the one used at Hanford provides information vital to the identification of non-occupationally derived sources.
REFERENCES


Table 1. Analysis Results for Cesium-137 Whole Body Measurements and Wild Game.

<table>
<thead>
<tr>
<th>Hunter's</th>
<th>Whole Body $^{137}$Cs, Bq</th>
<th>Game</th>
<th>Year</th>
<th>Location</th>
<th>Meat $^{137}$Cs, Bq/kg (Fresh Wt.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>407 (11 nCi)</td>
<td>Deer 1989</td>
<td>Cottage Grove, OR</td>
<td>6.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>744 (20 nCi)</td>
<td>Deer 1989</td>
<td>Saltese, MT</td>
<td>67.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not available</td>
<td>Moose 1990</td>
<td>Mt. Redoubt, AK</td>
<td>13.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not available</td>
<td>Deer 1988</td>
<td>Big Snowy (hills), MT</td>
<td>2.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not available</td>
<td>Deer 1988</td>
<td>Big Snowy (farms), MT</td>
<td>&lt;.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not available</td>
<td>Deer 1989</td>
<td>Malta, MT</td>
<td>.46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not available</td>
<td>Deer 1990</td>
<td>Asotin County, WA</td>
<td>&lt;.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not available</td>
<td>Deer 1990</td>
<td>Columbia County, WA</td>
<td>&lt;.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not available</td>
<td>Elk 1990</td>
<td>Ellensburg, WA</td>
<td>2.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1. Distribution of $^{137}$Cs Measurements for Hanford Workers.
Figure 3. Concentrations of $^{137}$Cs in Deer Muscle.

Figure 4. Retention of $^{137}$Cs From Chronic Ingestion of 5.2 Bq d$^{-1}$. 
Your whole body count (WBC) on the above date detected the presence of a small quantity of cesium-137. This isotope can result from environmental as well as occupational sources. Please answer the following questions to help determine the follow-up required.

1. Have you recently (last two years) been to Europe or Russia? YES NO
   If YES, please describe:
   Locale visited/resided:
   When were you there:
   Any potential occupational contact with radioactive material while you were there:

2. Do you eat wild “big game” meat? (e.g., deer, elk, etc.) YES NO
   If YES, please describe:
   Type of Game Where Bagged How often do you eat it? How much do you eat?
   ___________________________ ___________________________ ___________________________ ___________________________
   ___________________________ ___________________________ ___________________________ ___________________________
   ___________________________ ___________________________ ___________________________ ___________________________

3. Since your last whole body exam, have you been involved in any personal contamination or other radiological incidents? YES NO
   If YES, please describe:
   Type of Incident Isotope(s) Involved (if known) Dates (may be approximate)
   ___________________________ ___________________________ ___________________________ ___________________________
   ___________________________ ___________________________ ___________________________ ___________________________
   ___________________________ ___________________________ ___________________________ ___________________________

4. If you wish to make any additional comments that you think might be helpful in determining source of the detected cesium-137, please note them here:
   ________________________________________________________________________________________________
   ________________________________________________________________________________________________
   ________________________________________________________________________________________________
   ________________________________________________________________________________________________

Please sign and date this form as indicated below. Return it to the technician who gave it to you or mail it to Internal Dosimetry at MSIN No. A3-60. If you have any questions, contact your dosimetry representative.

Your Signature ___________________________ Date ___________________________

Figure 5. Questionnaire for Workers with Positive $^{137}$Cs Measurements.
END

DATE FILMED

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