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A Procedure for Evaluating Environmental Radiation Dose to Children in the Vicinity of the Hanford Project in Washington, April 1965–January 1967

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The Hanford Atomic Energy Commission Installation in southeastern Washington releases small amounts of radioactive materials to the local environment in low-level waste effluents. Radioactive materials enter the Columbia River with reactor cooling water released after a short hold-up period. Once released to the river, this radioactive material enters a number of ecological pathways of varying complexity which may result ultimately in some of the radioactivity reaching human populations living adjacent to the Hanford project. The radiation dose received by populations affected by Hanford operations is evaluated annually (*1*). Part of the dose such people receive is the result of internal deposition of radionuclides obtained from locally produced foodstuffs. The necessary information for estimating such deposition is the concentration of radionuclides in locally-produced foodstuffs, the consumption levels of such foods by local people, and the metabolic behavior of the radionuclides when consumed.

A conventional environmental program such as that followed at Hanford for many years will adequately provide information concerning the average concentration of radionuclides in locally-produced foodstuffs and the distribution of nuclide concentrations about the sample mean (*1*). Likewise, the literature *e.g.*, the ICRP Report of Committee II on Permissible Dose for Internal Radiation (*2*), provides information concerning the uptake and retention of most radionuclides of interest when consumed by man. In the absence of any more definitive information concerning absorption of nuclides from specific foodstuffs these data are utilized in our dose estimates.

The middle step in this calculation process (the estimation of consumption levels and the population distribution of various consumption levels) is actively being studied by Battelle-Northwest Laboratory. To obtain dietary data for a sample of the adult population, a diet form was prepared which is routinely presented to all people measured in the Hanford whole-body counters. The questionnaire requires a subjective estimate of consumption levels of various significant foodstuffs on the part of the subject. For example, he is asked to estimate "how many glasses of water usually drunk per day." Similar questions are also asked regarding consumption of milk, seafood, game birds, Columbia River fish, and fresh meat. Supporting information concerning sources of such foodstuffs is obtained to help identify the size of the population routinely consuming certain kinds of foods from local sources. An initial report of this investigation was recently issued (*3*).

The Hanford whole-body counter is used routinely as a monitoring tool in the plant; thus, the vast majority of the people measured are plant employees. These employees are assumed to be a representative sample of the local adult population but they obviously cannot be representative of the entire population. The major population group missing from this survey is children living near the Hanford facilities. The dietary habits of children are vastly different from those of adults and cannot really be derived from adult data. To study the children's dietary levels we have initiated an investigation in cooperation with the local school system. This paper describes the program that was developed and presents some of the results obtained to date.

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Description of the procedure

In establishing a research procedure to investigate diets and radionuclide body burdens in local children we had to provide motivation for the schools to cooperate with us, for the parents to give permission for their children's participation, and for the children to take part in the study. A serious attempt was made to inform the children about radioactivity and radiation along with the introduction of the program. Questions that arose were answered frankly and information concerning the measurements and the results were made available to anyone interested. More than 80 percent of the 1,800 school children in the eight elementary schools (grades 1–6) so far approached participated in this study.

Questions requiring evaluation by the child of the amounts of various foodstuffs consumed cannot reliably determine consumption levels for children. Instead the child is asked to keep a record of the pertinent foodstuffs eaten and drunk during a consecutive 7-day period. This record is maintained by recording each helping or cup of foodstuff consumed. Some diet records, perhaps between 1 and 2 percent, were discarded because the child obviously did not understand what was required.

About 2 weeks after the classroom discussion the Hanford mobile whole-body counter was moved to the school and parked in a convenient location on the schoolground. The counter uses a shadow shield and incorporates an 11-inch sodium iodide crystal (*4, 5*). It requires about 1 month to count the children in one elementary school. Each child is counted for 10 minutes in the shadow shield counter and about 2 minutes are required for printing and recording the data. Thus, it is possible to measure 25 to 30 children each day. Each child is absent from class about 30 minutes.

Diet study results

The data obtained from diet record forms are reduced to punch cards for use in an electronic computer system and will ultimately be entered on a magnetic tape file. To date a little over 1,500 such records have been analyzed and more than twice that number have been collected from school children. Some of the consumption level distributions assembled by electronic data processing techniques are shown in figures 1 through 4.

Figure 1 shows the water consumption reported by children. Older children averaged slightly higher water consumption than the younger children, although the difference is probably not significant. When adults estimated their own water consumption levels they reflected a significant bias for even numbers and multiples of 5. The children's results, being a tabulation of actual consumption observations, do not have this kind of bias.

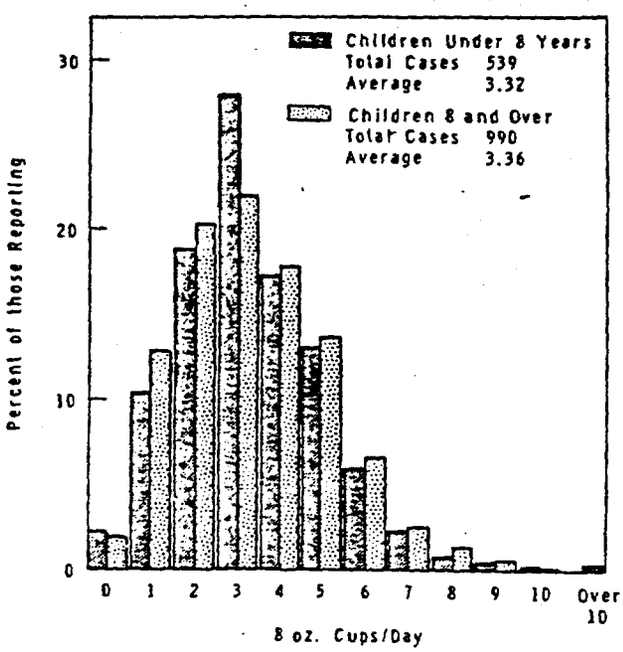

Figure 1. Water consumption during a 7-day recording period

Figure 2 shows milk consumption as reported by children. The children averaged about 2.7 cups of milk per day compared to an adult average of 1.7 cups per day.

Figure 3 shows the children's estimates of their seafood consumption. The study attempted to obtain estimates of the number of times per year that they ate seafood produced along the Washington coast, such as fresh oysters, fresh clams and fresh crab meat. This chart does not represent actual consumption data but the children's estimates of their annual consumption levels. The bias introduced by human preference for certain numbers can be noted. The children estimated an average consumption

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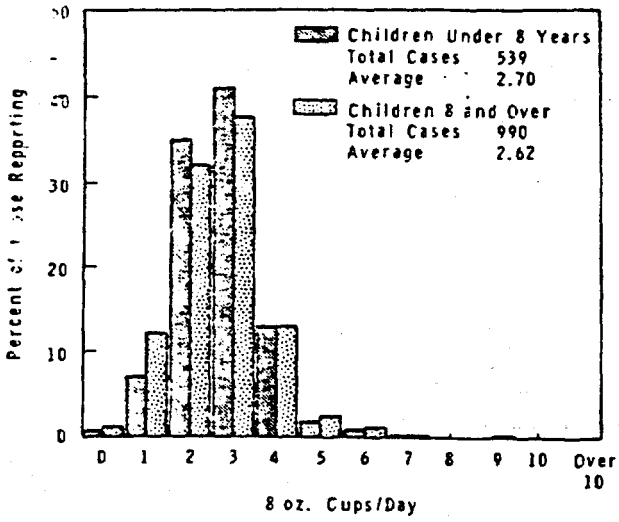

Figure 2. Milk consumption reported by elementary school children

of local seafood of about 2.8 meals per year compared to the adult estimate of 6 meals per year. Over 60 percent of the children reported never eating local seafood compared to only 35 percent of adults.

In figure 4 the consumption level distribution for fish caught in the Columbia River below the Hanford plant is shown. Children under 8 report an average of 2.4 meals per year while the older children report an average of 2.7 meals per year. This probably reflects a mistaken interpretation of the question on the part of the children. They probably are including all fish consumption, in some cases, rather than limiting it to Columbia River fish. Adults, when asked the same question, estimated 1.9 meals per year. Seventy-five percent of the adults indicated that they never eat Columbia River fish.

Whole-body counter measurements

None of the more than 3,000 children measured in the mobile whole-body counter to date have had body burdens of radionuclides outside of the range anticipated on the basis of known environmental conditions. Typical values of radionuclide burdens measured in children were 3 to 5 nCi of each of the radionuclides, zinc–65, sodium–24 and cesium–137. Body burdens ranging up to several times the typical values were occasionally detected where unusual circumstances resulted in diet sources more directly related to the Columbia River. These ranges agree with those that would be predicted from our knowledge of the environmental concentration levels. The quantitative measurement of radionuclides in children depends on the construction of a suitable calibration function for the shadow shield counter. It cannot be assumed that the calibration factors derived for standard man are applicable to children's measurements. A calibration study was conducted concurrently with the measurement of children. In the absence of a definition

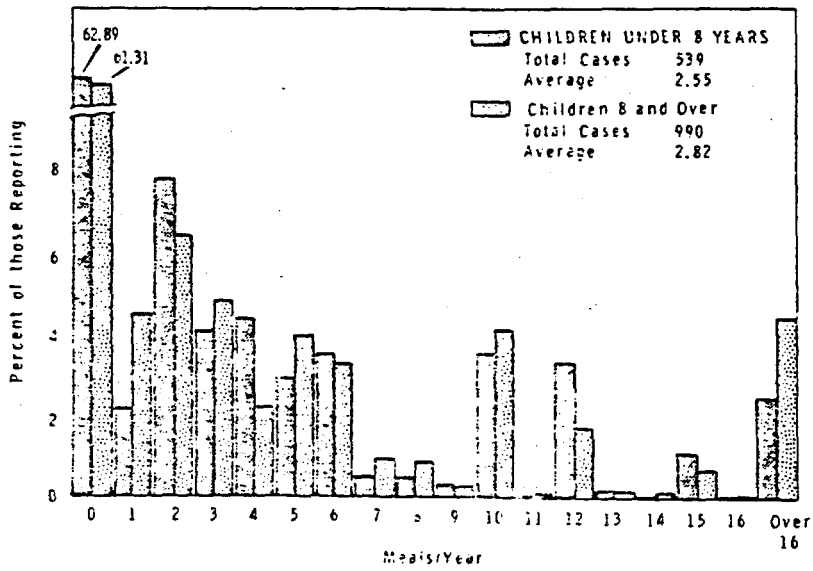

Figure 3. Consumption levels for locally produced seafood

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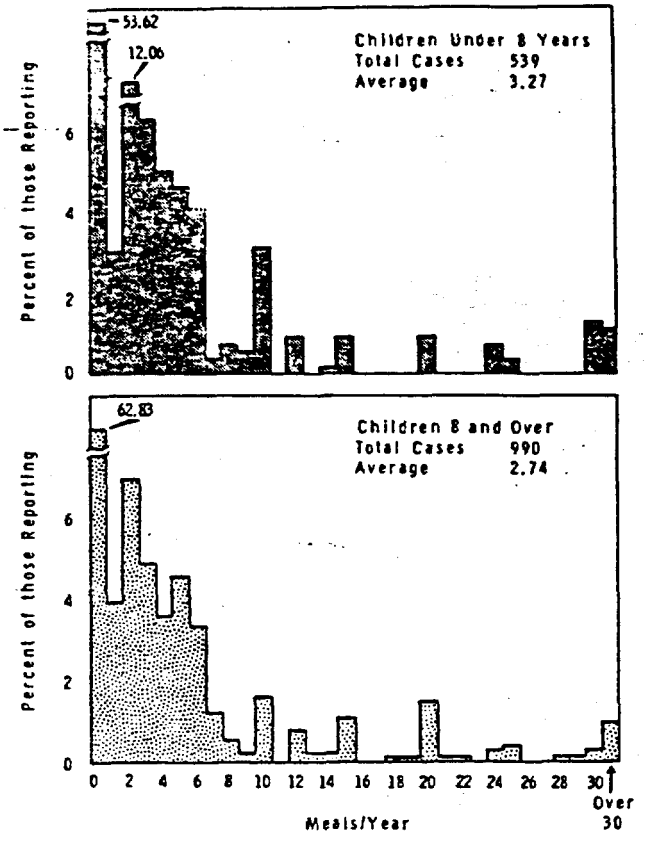

Figure 4. Columbia River fish consumption reported by Richland school children

for a standard child we developed an array of 9 phantoms for children ranging in size from 48 to 107 pounds. The phantoms are constructed of 1-pound boxes of sugar as shown in figure 5. A phantom containing no added radioactivity is first constructed on the bed of the counter and measured to provide background data. Then a phantom using sugar boxes containing known amounts of radionuclides is constructed in an identical way and measured with the counter. After subtracting background readings the measurements may be used to calculate a calibration factor for the radionuclides and phantom size used. In this way, calibration factors for each of the 9 phantoms for zinc–65, potassium–40, cesium–137, and sodium–24 were derived.

These data were used to construct an empirical function relating body size to calibration factor which can be programmed for the computer to provide absolute body burden measurements. Linear, exponential and power functions were examined for these data. The goodness of fit of functions obtained with a parameter of pounds weight per inch of height as compared to functions involving simply pounds was also evaluated. A linear correlation technique was used for selecting the best fit for each of these functions. The calibration curves that best fit the data were exponential functions calculated in this way and the calibration points from which the functions were derived. It would be most helpful if some calibration data from children were available to confirm these calibration functions.

Application of the procedure

Environmental dose estimates for the population living adjacent to the Hanford plant include the dose to a typical resident and to a special population group having diet habits that maximize exposure. The procedure described for obtaining data from school children will assist with the identification and study of the affected population

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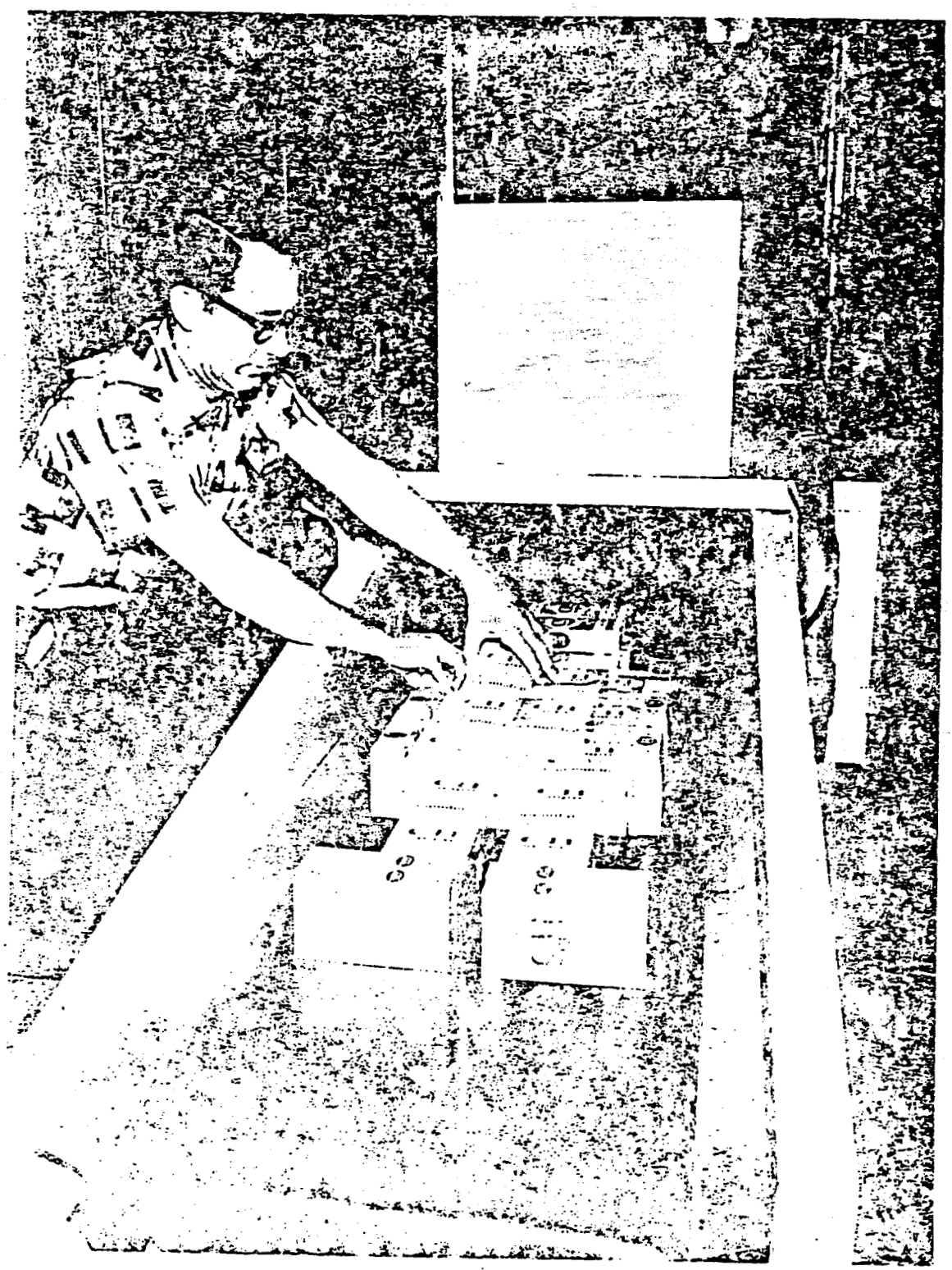

Figure 5. Shadow-shield whole body counter with phantom in place

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