RA-226 COLLECTIVE DOSIMETRY FOR SURFACE WATERS IN THE URANIUM MINING REGION OF POÇOS DE CALDAS*

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A monitoring survey of the ^{226}Ra concentrations in river waters in the vicinity of the uranium mining, and future milling facilities, in the Poços de Caldas region started in January 1977. Results of this survey have been published elsewhere (1). Dosimetric and environmental models are used in the present work to calculate the Annual Collective Dose Equivalent (ACDE) to the populations potentially exposed. The ACDE for the whole-body, bone, gastro-intestinal tract - lower large intestine (GI tract-LLI), kidneys, and liver, via the pathways of drinking water and ingestion of food, grown in irrigated fields, are presented as a function of the ^{226}Ra concentrations in the surface waters of the Poços de Caldas region.

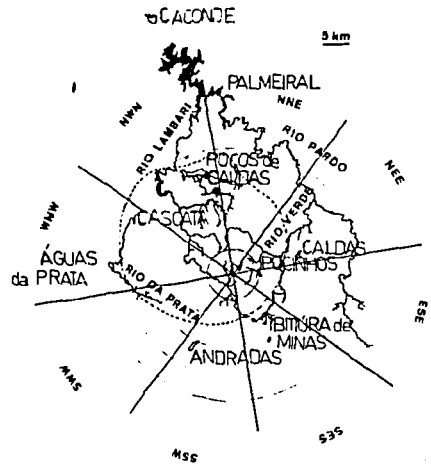
POPULATION DISTRIBUTION

Most of the population of the Poços de Caldas region are concentrated in cities located near the quasi-circular border of the plateau, which is represented by a dashed line in Figure 1. The central region of the plateau looks uninhabited at a permanent basis, except for the resident farm workers of the rural properties extant in the internal area of the plateau. The economical growth of the Poços de Caldas plateau, allied with the generalized use of motor vehicles in the region, made the local population much more mobile today than in 1970. Besides that, most cities of the plateau are touristic resorts with large seasonal fluctuations in the temporary population.

The Poços de Caldas plateau was divided in areas defined by concentric subregions having the common central point in the mining site of Campo do Cercado, as shown in Figure 1. The subregions are denoted by their radial border limits followed by the distance from the center to the outer ring. The populations, P_i, of the subregions i are shown in Table 1.

The approximate populational distribution of the Poços de Caldas plateau given in Table 1 is based upon the results of the 1970 census, which is the last census available. The city of Poços de Caldas had about 5.8×10^4 inhabitants in 1970, over 95% living within the city limits. The 1980 brazilian census has just started, but new populational data will not be available before two years from now. However, preliminary data collected, unofficially, indicated that the population of the municipality of Poços de Caldas might have exceeded 1.0×10^5 inhabitants sometime along the last ten years. Today the population distribution in the plateau is such that 90% of the entire population

* This work was supported by the International Atomic Energy Agency, Comissão Nacional de Energia Nuclear, Financiadora de Estudos e Projetos, and Conselho Nacional de Desenvolvimento Científico e Tecnológico.



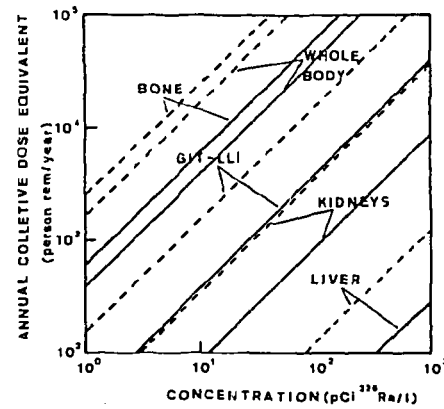


Figure 1. Hydrographic chart and subregions of the P.C. plateau.

Figure 2. ACDEs for the populations of the Poços de Caldas plateau (drinking water) and subregions NWN20 and NWN25 (food ingestion) as a function of ^{226}Ra concentrations in waters.

reside in urban areas, while 10% can be found in rural areas. As a consequence of the facts mentioned above, the populational data shown in Table 1 do not correspond to the actual population of the region at any given time today, but shall only be interpreted as an indication of the percentual distribution that one can expect to find in the region, if the seasonal variations and other fluctuations in the population of the Poços de Caldas plateau are discounted. Collective dosimetry for ^{226}Ra concentrations in the surface waters of the region were undertaken with full awareness of these and other shortcomings.

DOSIMETRIC MODEL

The ACDE, $\dot{S}_j$, for the population of the Poços de Caldas plateau was calculated based upon the formulae recommended by the International Commission on Radiological Protection (ICRP). In particular, the ACDE to an organ j, in person-rem/year, was calculated from the per caput annual dose equivalent, $\dot{H}_j$, in rem/year, for an organ j of a generic individual of a population, assuming that P_i persons in the subgroup i of the total population were submitted to the same dose equivalent (2). However, to evaluate the annual absorbed dose, $\dot{R}_j$, in mrad/year, to an organ j, the dose factors, $\dot{D}_j$, were derived from the exponential models recommended by ICRP (3). The dosimetric data of Tables 1 and/or Figure 2 reflect the following simplifying assumptions: (i) Urban and rural populations are considered together for the calculational purpose of regarding a population, P_i, characteristic of a particular subregion i; (ii) Temporal and spatial variations in the populations P_i of each subregion i were not taken into account; (iii) The maximum ^{226}Ra concentrations as listed in Table 1 for each subregion were considered as indicators for the constant values adopted to allow estimates of the annual absorbed doses, $\dot{R}_j$, to an organ j of a generic individual of

TABLE 1. Populational distribution, ^{226}Ra concentration in water, and ACDEs for the Poços de Caldas plateau

Subregion	City or village	Population P_i ($\times 10^3$) *	%	Maximum ^{226}Ra concentration pCi/ℓ	Collective annual dose equivalent (person rem/yr)				
					Whole body	Bone	Liver	Kidneys	GI-tract-LLI
NWN 20† NWN 25	Poços de Caldas	58.0	57.5	0.6	1.3×10^{2}	1.9×10^{2}	9.5×10^{-2}	2.7	1.2×10
NWN 25	Águas da Prata e Cascata	4.1	4.1	29	4.3×10^{2}	6.6×10^{2}	3.3×10^{-1}	9.3	4.0×10
SSW 15 SSW 20	Andradas	17.4	17.2	$\leq$ 0.2	$\leq$ 6.4	$\leq$ 9.7	$\leq 4.7\times10^{-3}$	$\leq 1.4\times10^{-1}$	$\leq 5.9\times10^{-1}$
SES 15	Ibitiúra de Minas	2.7	2.7	$\leq$ 0.2	$\leq$ 2.2	$\leq$ 3.4	$\leq 1.6\times10^{-3}$	$\leq 4.7\times10^{-2}$	$\leq 2.0\times10^{-1}$
ESE 20	Santa Rita de Caldas	7.0	6.9	$\leq$ 0.2	$\leq 1.3\times10$	$\leq 1.9\times10$	$\leq 9.4\times10^{-3}$	$\leq 2.7\times10^{-1}$	$\leq$ 1.2
NEE 10 NEE 15	Caldas e Pocinhos	8.7	8.6	$\leq$ 0.2	$\leq$ 2.0	$\leq$ 3.0	$\leq 1.5\times10^{-3}$	$\leq 4.2\times10^{-2}$	$\leq 1.8\times10^{-1}$
NNE 20	Santana de Caldas	3.0	3.0	$\leq$ 0.2	$\leq$ 5.2	$\leq$ 7.8	$\leq 3.8\times10^{-3}$	$\leq 1.1\times10^{-1}$	$\leq 4.8\times10^{-1}$
				TOTAL	$\leq 5.9\times10^{2}$	$\leq 8.9\times10^{2}$	$\leq 4.5\times10^{-1}$	$\leq 1.3\times10$	$\leq 5.5\times10$

* *According to the most recent data available.*

† *NWN 20 means subregion limited by radii defining, respectively, the directions NW and N, and between concentric rings distant 10 and 20 km from the Campo do Cercado uranium mine.*

the population P_i; (iv) The ^{226}Ra concentrations in food products grown in irrigated fields were estimated based upon local data, from the 1970 census, on agricultural production, and site specific environmental models; (v) The usage factors for drinking water and food consumption, used in the calculations, were essentially those of the Reference Man (4) for Latin American inhabitants. This assumption is made based upon the fact that there are wide variations in usage factors for regions of fast changing parameters and non-uniform distribution of wealth, so the Reference Man values can be considered suitable for the present dosimetric calculations, because of the uncertainties associated to alternative values; (vi) The ACDEs were calculated by assuming no ^{222}Rn loss by gaseous diffusion after ^{226}Ra uptake by the human body.

The above simplifying assumptions are not in complete agreement with the recommendations of ICRP26 (2). However, one should bear in mind when applying the ICRP26 recommendations to a particular region of a developing country, that the demographic distribution as well as food habits may experience significant fluctuations under certain conditions like, for example, fast population growth and local economical development. As a consequence, care must be exercised when using the estimates of collective dose equivalent, from data of a fast developing region, as the basis for decision-making processes as suggested by the ICRP26 (2), since dramatic changes may occur in the calculational parameters within relative short periods of time. Accordingly, ACDEs values of Table 1, like 590 person-rem/year for the population of the Poços de Caldas plateau, are not to be used in decision-making processes.

Figure 2 shows graphs of the annual collective dose equivalents to the whole-body and selected organs as a function of the ^{226}Ra concentrations in water via the pathway of drinking water for the population of the Poços de Caldas plateau, and via the pathway of food ingestion for the populations of the subregions NWN20 and NWN25, by far the most populated subregions. These estimates were made as a contribution for future comparisons, although other parameters used in the dosimetric calculations may also change considerably along the future.

CONCLUDING REMARKS

Paragraph 22 of ICRP26 (2) is very carefully worded to warn about the complexity of the relationship between the distribution of dose equivalent in an exposed population and the assessment of detriment. Furthermore the careful wording of ICRP26, can be found notably also in paragraphs 219, 221 and 232 which are bound to prevent misuses of the concept of collective dose equivalent to make dubious quantitative appraisals of detriment associated with practices, however decisions are likely to be made based upon such appraisals.

The present work intends to be a contribution to the understanding of the shortcomings involved in calculating collective dose equivalent due to the potential enhancement of ^{226}Ra concentrations in the surface waters near the uranium mining region of Poços de Caldas.

General observations and tentative conclusions are listed as follows:

1. The ACDEs for selected populational subgroups as well as for the total population living in the Poços de Caldas plateau have been calculated based upon simplifying assumptions. These ACDEs, rather than the dose-equivalent commitments or the collective dose-equivalent commitments for the predicted time of operation of the uranium mine of the Poços de Caldas region were calculated, because there were several intrinsic uncertainties in the parameters available for the calculations.
2. The fluctuations expected to occur in the data on populational distribution, irrigational practices, agricultural production, and food consumption in developing regions, like the Poços de Caldas plateau, makes the quantitative assessment of the collective dose-equivalent commitments meaningless, unless reliable long range predictions can be made on the varying parameters to enable time integration.
3. Linear models can be used to estimate the ACDE as a function of the ^{226}Ra concentration, based on parameters which may be valid at a particular time, but the actual collective dose equivalent commitment is difficult to predict.
4. Dosimetric models based upon site specific environmental models are helpful to estimate collective dose equivalents to populations from a particular practice, but extreme care should be exercised by competent national authorities when using such estimates in decision-making processes.
5. Paragraphs 22, 219, 221 and 232 of ICRP26 (2) should be taken into full account when estimating collective dose equivalents.

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