International Journal of Pure and Applied Physics. ISSN 0973-1776 Volume 13, Number 1 (2017), pp. 232-237

Natural Radioactivity Measurements in Soils of Jalandhar and Hoshiarpur Districts of Punjab, India

Komal Badhan[1]
[1]*S.G.G.S.Khalsa, College, Mahilpur, Hoshiarpur, Punjab, India.*

Rohit Mehra[2]
[2]*Dr. B.R.Ambedkar National Institute of Technology, Jalandhar, Punjab, India*

R.G.Sonkawade[3]
[3] *Department of Physics, Shivaji University, Kolhapur-416 004 (M.S.)*

***Abstract*— Soil acts as a source of continuous radiation exposure to human and as a medium of migration for transfer of radionuclides to the biological systems hence causes the radiological contamination in the environment. So, it is necessary to study the natural radioactivity in soil to assess the dose due to terrestrial gamma radiation levels in order to know the health risks. The Primordial Radioactivity (^{238}U, ^{232}Th, and ^{40}K) contents in soil were determined in Jalandhar and Hoshiarpur districts of Punjab, India, using high-resolution gamma-ray spectrometric analysis. The concentration of natural radionuclides viz., ^{238}U, ^{232}Th and ^{40}K, in the soil varies from 6.37±0.13 to 56.71±0.76 Bq kg^{-1}, 24.03±0.95 to 334.47±6.96 Bq kg^{-1} and 738.71±8.58 to 1064.97±11.46 Bq kg^{-1} respectively. The total absorbed dose rate calculated from activity concentration of ^{238}U , ^{232}Th and ^{40}K ranged from 48.49 to 261.84 nGy h^{-1}. The radium equivalent (R_{eq}) activity and the external hazard index (H_{ex}), vary from 92.44 to 573.19 Bq kg^{-1}and from 0.26 to 1.57 respectively. The radium equivalent activities in all the soil samples were lower than the limit (370 Bq kg^{-1}) set in the Organization for Economic Cooperation and Development (OECD) report and the dose equivalent was within the safe limit of 1 mSv y^{-1}.**

***Keywords:* Gamma-Ray Spectrometry; HPGE Detector; Re_{eq} Activities**

I. INTRODUCTION

Radioactivity is common in the rocks and soil that makes up our planet, in the water and oceans, and even in our building materials and homes. Natural radioactivity in soil varies on soil type, mineral make up and density. Man-made activities, such as mining, may accelerate the movement of primordial radionuclides into soil. Another way radionuclides become part of the soil is through natural cosmic radiation, radiation produced in outer space when heavy particles from other galaxies (nuclei of all known natural elements) bombard Earth. Some of these radionuclides fall to Earth and are deposited on the soil .The main radioactive materials in NORM are long-lived radionuclides such as ^{238}U, ^{232}Th and ^{40}K. In addition to being the main source of continuous radiation exposure to human, soil acts as a medium of migration for transfer of radionuclides to the biological systems and hence, it is the basic indicator of radiological contamination in the environment. Natural radiation is the largest contributor to the external dose of the world population [1]. These dose rates vary from one place to another depending upon the concentration of natural radionuclides like ^{238}U, ^{226}Ra, ^{232}Th and 40K present in soil. These radionuclides pose exposure risks externally due to their gamma-ray emissions and internally due to radon and its progeny that emit alpha particles [2]. Moreover, the soil radioactivity is usually important for the purposes of establishing baseline data for future radiation impact assessment, radiation protection and exploration [3]. The primary objective of the present study is to determine the activity concentrations of natural radionuclides viz. ^{238}U, ^{232}Th and ^{40}K in soil samples of Hoshiarpur and Jalandhar districts of Punjab, India and hence the dose rates in order to assess the health risks. Figure 1 shows the study area.

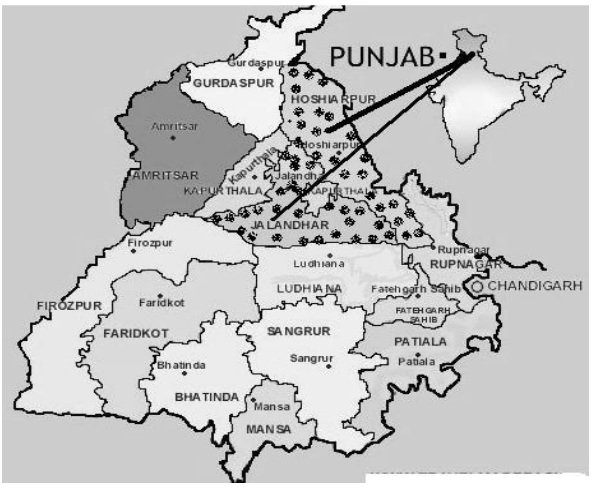

Figure 1 : Study area for present study

II. EXPERIMENTAL

A. Measurement of Natural Radioactivity

In order to measure the natural radioactivity in soil, surface soil sample were collected from different locations of study area. After collection, samples are crushed into fine powder by using Mortar and Pestle. Fine quality of the sample is obtained using scientific sieve of 150micron-mesh size. Before measurement samples are dried in an oven at a temperature of 383K for 24hours. Each sample is packed and sealed in an airtight PVC container and kept for about 4 week's period to allow radioactive equilibrium among the daughter products of radon (^{222}Rn), thoron (^{220}Rn) and their short lived decay products. An average 0.25 kg of soil is used per sample.

Using HPGe detector based on high-resolution gamma spectrometry system, the activity of samples is counted. The detector is a co-axial n-type high purity germanium detector (make EG&G, ORTEC, Oak Ridge, US). The detector has a resolution of 2.0 keV and relative efficiency of 20% for 1.332 MeV gamma energy of Co-60. The output of the detector is analyzed using a 4K MCA system connected to PC. The spectral data is analyzed using the software "CANDLE" (Collection and Analysis of Nuclear Data using Linux Network) developed locally by Inter University Accelerator Centre, New Delhi. The detector is shielded using 4" lead on all sides to reduce the background level of the system. The efficiency calibration for the system is carried out using secondary standard source of uranium ore in geometry available for the sample counting. Efficiency values are plotted against energy for particular geometry and are fitted by least squares method to an empirical relation that takes care of the nature of efficiency curve for the HPGe detector. For calibration of the low background counting system a secondary standard was used. The secondary standard was calibrated with the primary standard (RGU-1) obtained from the International Atomic Energy Agency. Gamma transitions of 1461 keV for ^{40}K; 186 keV of ^{226}Ra and 609 keV of ^{214}Bi for ^{238}U; 338, 463, 911, 968 keV of ^{228}Ac, 727 keV of ^{212}Bi, 238 keV of ^{212}Pb and 583 keV of ^{208}Tl for ^{232}Th, were used for the laboratory measurement of activity concentration potassium, uranium and thorium. The samples were counted for a period of 72000 seconds and the spectra (Fig. 2) are analyzed of the photo peak of radium, thorium daughter products and K-40. The net count rate under the most prominent photo peaks of radium and thorium daughter peaks are calculated by subtracting the respective count rate from the background spectrum obtained for the same counting time. Then the activity of the radionuclide is calculated from the background subtracted area prominent gamma ray energies. The concentrations of radionuclides are calculated using the following equation:

$$Activity\,(Bq) = \frac{CPS \times 100 \times 100}{B.I. \times Eff} \pm \frac{CPS_{error} \times 100 \times 100}{B.I. \times Eff}$$

Where, *CPS* = Net count rate per second
B.I. = Branching Intensity, and
Eff = Efficiency of the detector.

B. Radium Equivalent Activity

The distribution of ^{226}Ra, ^{232}Th and ^{40}K in soil is not uniform. Uniformity with respect to exposure to radiation has been defined in terms of radium equivalent activity (Ra_{eq}) in Bq kg^{-1} to compare the specific activity of materials containing different amounts of ^{226}Ra, ^{232}Th and ^{40}K. It is calculated through the following relation[4]:

$$Ra_{eq} = C_{Ra} + 1.43\,C_{Th} + 0.07\,C_K$$

Where C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq kg^{-1}, respectively. While defining Ra_{eq} activity, it has been assumed that 370 Bq kg^{-1} ^{226}Ra or 259 Bq kg^{-1} ^{232}Th or 4810 Bq kg^{-1} ^{40}K produce the same gamma dose rate.

C. Calculation of Air-Absorbed Dose Rate

The external terrestrial γ-radiation absorbed dose rate in air at a height of about 1meter above the ground are calculated by using the conversion factor of 0.0414 nGy h^{-1}/Bq kg^{-1} for ^{40}K, 0.461 nGy h^{-1}/Bq kg^{-1} for ^{226}Ra, and 0.623 nGy h^{-1}/Bq kg^{-1} for ^{232}Th [5] assuming that ^{137}Cs, ^{90}Sr and the ^{235}U decay series can be neglected as they contribute very little to the total dose from environmental background [6],[7],[8].

$$D\ (nGyh^{-1}) = 0.461\,C_{Ra} + 0.623\,C_{Th} + 0.0414\,C_K$$

Where, C_{Ra}, C_{Th} and C_K are the activity concentrations (Bq.kg^{-1}) of radium, thorium and potassium in the samples.

D. Calculation of Annual Effective Dose

To estimate annual effective doses, account must be taken of (a) the conversion coefficient from absorbed dose in air to effective dose and (b) the indoor occupancy factor. Annual estimated average effective dose equivalent received by a member is calculated using a conversion factor of 0.7 Sv.Gy-1, which is used to convert the absorbed rate to human effective dose equivalent with an outdoor occupancy of 20% and 80% for indoors[5].

The annual effective doses are determined as follows:

Indoor (nSv) = (Absorbed Dose) nGy^{-1} x 8760h x 0.8 x 0.7 SvGy^{-1}

Outdoor (nSv) = (Absorbed Dose) nGy^{-1} x 8760h x 0.2 x 0.7 SvGy^{-1}

E. External Hazard Index (H_{ex})

The external hazard index H_{ex} can be calculated by the following equation [9]:

$$H_{ex} = C_{Ra}/370 + C_{Th}/259 + C_K/4810 \leq 1$$

where C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq kg^{-1}, respectively.

III. RESULTS AND DISCUSSION

The calculated activity concentration values for ^{238}U, ^{232}Th and ^{40}K ranges from 6.37±0.13 to 56.71±0.76 Bq kg^{-1}, 24.03±0.95 to 334.47±6.96 Bq kg^{-1} and 738.71±8.58 to 1064.97±11.46 Bq kg^{-1} with average values of 15.44 Bq kg^{-1}, 167.15 Bq kg^{-1}and 876.96 Bq kg^{-1} respectively (Table 1). The calculated average value of activity concentration of ^{238}U is lower and the calculated average values of the activity concentration of ^{232}Th and ^{40}K are higher than the world's average documented in the [1] (35 Bq kg^{-1}, 30 Bq kg^{-1} and 400 Bq kg^{-1} for ^{238}U, ^{232}Th and ^{40}K, respectively). The

higher activity for ^{232}Th and ^{40}K might be due the high content of thorium in the soil and the use of potassium rich fertilizers for agriculture, respectively. Also the high values of thorium may have some other geological reasons which require a further detailed investigation of the study area.

Table 1: The values ^{238}U, ^{232}Th and ^{40}K activity content using Gamma ray spectrometry and Ra_{eq} activity in the soil samples from Jalandhar and Hoshiarpur Districts of Punjab.

Sr. No.	Sample location (village)	Uranium Concentration in Soil $C_{Uranium}$ (Bq kg^{-1})	Thorium Concentration in Soil $C_{Thorium}$ (Bq kg^{-1})	Potassium Concentration in Soil $C_{Potassium}$ (Bq kg^{-1})	Radium equivalent R_{eq} (Bq kg^{-1})
Jalandhar District					
1	Philaur	9.83	186.61	773.07	330.8
2	Goraya	7.97	174.01	833.7	315.16
3	Jalandhar city	21.69	293.67	887.7	503.78
4	Adampur	6.39	37.79	888.7	122.64
5	Alawalpur	6.37	24.03	738.71	92.44
6	Bhogpur	12.48	42.11	912.03	136.54
7	JanduSingha	10.08	148.07	898.09	284.69
8	Shahkot	13.43	33.02	778.03	115.11
9	Nakodar	12.33	39.42	797.75	124.54
10	Rama Mandi	11.05	159.26	830.06	296.9
Hoshiarpur District					
1	Talwara	11.5	202.8	891.95	363.94
2	Badla	8.89	137.32	823.62	262.91
3	TandaUrmur	20.35	334.47	1064.97	573.19
4	Dasuya	14.44	226.63	1002.93	408.73
5	Mukerian	15.75	195.21	888.18	357.07
6	Datarpur	56.71	227.39	843.53	440.92
7	Nasrala	16.74	244.22	974.32	434.18
8	Garshankar	24.31	196.21	879.32	366.44
9	Mahilpur	19.18	201.74	897.48	370.49
10	SailaKhurd	9.32	239.01	935.32	416.58

The calculated values for ^{238}U, ^{232}Th and ^{40}K are on the higher side than those activity values for ^{238}U, ^{232}Th and ^{40}K reported for Sirasa district of Haryana and for parts of western Haryana [10],[11].The calculated values for ^{238}U are on the lower side and the calculated values for ^{232}Th and ^{40}K are higher than the activity values for ^{238}U, ^{232}Th and ^{40}K reported for Jaduguda uranium mines area, Jharkhand, India[12]. The calculated values for ^{238}U are almost comparable and the calculated values for ^{232}Th and ^{40}K are higher than with those reported for Malwa region of Punjab [13]. The present activity concentration values for ^{238}U, ^{232}Th and ^{40}K are higher than those reported for the soil samples from the upper Siwaliks and Punjab[14]. The calculated activity concentration values for ^{238}U, ^{232}Th and ^{40}K are on the higher side than the activity concentration values reported for ^{238}U, ^{232}Th and ^{40}K for the districts Faridkot and Mansa of Punjab [15].

The calculated average radium equivalent activity value is 249.63 Bq kg^{-1} which is lower than the world's average value 370 Bq kg^{-1} reported by Organization of Economic and Control Department [16].Table 2 represents the results for absorbed dose, annual effective dose rates and external health hazard index (H_{ex}).The calculated value for the total absorbed dose varies from 48.49 nGyh^{-1} to 261.84 nGyh^{-1} with an average value of 147.56 nGyh^{-1}. The calculated value of external health hazard index varies from 0.26 to 1.57 with an average value of .87. For most of the locations of the study area the value of H_{ex} is lower than safe limit value recommended by the Radiation Protection 112 [17]. But also the values of H_{ex} for soil of some villages are higher than unity so further investigation are required to reach at final conclusion.

Table 2: Air-absorbed dose rates and annual effective doses at various locations of Jalandhar and Hoshiarpur Districts of Punjab.

Sr. No.	Sample location (Village)	Absorbed dose (nGy h^{-1})				External Hazard Index H_{ex}	Annual effective dose (m Sv)	
		U	Th	K	Total		Indoor	Outdoor
Jalandhar District								
1	Philaur	4.53	116.26	32.01	152.8	0.91	0.75	0.19
2	Goraya	3.67	108.41	34.52	146.6	0.87	0.72	0.18
3	Jalandhar	10	182.96	36.75	229.71	1.38	1.13	0.28
4	Adampur	2.95	23.54	36.79	63.28	0.35	0.31	0.08
5	Alawalpur	2.94	14.97	30.58	48.49	0.26	0.24	0.06
6	Bhogpur	5.75	26.23	37.76	69.74	0.39	0.34	0.09
7	JanduSingha	4.65	92.25	37.18	134.08	0.79	0.66	0.16
8	Shahkot	6.19	20.57	32.21	58.97	0.33	0.29	0.07
9	Nakodar	5.68	24.56	33.03	63.27	0.35	0.31	0.08
10	RamaMandi	5.09	99.22	34.36	138.67	0.82	0.68	0.17
Hoshiarpur District								
1	Talwara	5.3	126.34	36.93	168.57	1	0.83	0.21
2	Badla	4.1	85.55	34.1	123.75	0.73	0.61	0.15
3	TandaUrmur	9.38	208.37	44.09	261.84	1.57	1.28	0.32
4	Dasuya	6.66	141.19	41.52	189.37	1.12	0.93	0.23
5	Mukerian	7.26	121.62	36.77	165.65	0.98	0.81	0.2
6	Datarpur	26.14	141.66	34.92	202.72	1.21	0.99	0.25
7	Nasrala	7.72	152.15	40.34	200.21	1.19	0.98	0.25
8	Garshankar	11.21	122.24	36.4	169.85	1.01	0.83	0.21
9	Mahilpur	8.84	125.68	37.16	171.68	1.02	0.84	0.21
10	SailaKhurd	4.3	148.9	38.72	191.92	1.14	0.94	0.24

Table 3 shows the comparison of the reported values of natural radionuclides in the soil samples, obtained in other countries with those determined in the present survey. On comparison it is found that the range of ^{238}U and ^{40}K almost match those of the other countries. However the activity values for ^{232}Th are on the higher side when compared with world's activity ranges for ^{232}Th [18].

Table 3: Comparison of natural radioactivity levels in soil and air absorbed dose at different locations of districts of Doaba Region of Punjab (India) with those in other countries as given in UNSCEAR (2000)

Region/country	Concentration in soil (Bqkg^{-1})						Absorbed dose rate in air (nGyh^{-1})	
	^{238}U		^{232}Th		^{40}K			
	Mean	Range	Mean	Range	Mean	Range	Average	Range
Egypt	17	5-64	18	2-96	320	29-650	32	20-133
United States	40	8-160	35	4-130	370	100-700	47	14-118
Bangladesh	34	21-43	41	1-360	350	130-610		
China	32	2-440	95	16-200	440	9-1800	62	2-340
Hong Kong SAR	59	20-110	64	14-160	530	80-1100	87	51-120
India	29	7-81	28	2-88	400	38-760	56	20-1100
Japan	33	6-98			310	15-990	53	21-77
Korea			22	5-42	670	17-1500	79	18-200
Iran	28	8-55	19	8-30	640	250-980	71	36-130
Denmark	17	9-29	27	5-50	460	240-610	52	35-70
Belgium	26	5-50	50	7-70	380	70-900	43	13-80
Luxembourg	35	6-52	25	4-70	620	80-1800	49	14-73
Switzerland	40	10-900	30	7-160	370	40-1000	45	15-120

Bulgaria	45	12-210	21	4-77	400	40-800	70	48-96
Poland	26	5-120	38	11-75	410	110-970	45	18-97
Romania	32	8-60	21	1-190	490	250-1100	59	21-122
Greece	25	1-240	51	22-100	360	12-1570	56	30-109
Portugal	44	8-65	33	2-210	840	220-1230	84	4-230
Spain	32	6-250	220.5	35-125	470	25-1650	76	40-120
Present study	15.44	6.37-56.71	167.15	24.03-334.47	877	738.71-1064.97	147.56	48.49-261.84

IV. CONCLUSIONS

I. The calculated average activity concentration value for ^{238}U was found to be within the world's average range but for ^{232}Th and ^{40}K the calculated activity values were on the higher side of the worldwide ranges. The higher activity for^{232}Th and ^{40}K might be due the high content of thorium in the soil and the use of potassium rich fertilizers for agriculture, respectively.

II. The calculated results for indoor and outdoor annual effective doses due to natural radioactivity of soil samples were lower than the average world recommended value of 1.0 $mSvy^{-1}$ except for indoor annual effective dose calculated for few locations of study area, so further deep investigation is needed.

III. The calculated Ra_{eq} activity values were found to be lower than the safe limit value of 370 $Bqkg^{-1}$ recommended by OECD 1979 except for Jalandhar city (503.78 $Bqkg^{-1}$), Pojewal (385.83 $Bqkg^{-1}$), SailaKhurd (416.58 $Bqkg^{-1}$), Nasrala(434.18 $Bqkg^{-1}$), Datarpur(440.92 $Bqkg^{-1}$), Dasuya(408.73 $Bqkg^{-1}$), and TandaUrmur(573.19 $Bqkg^{-1}$).

IV. The calculated external health hazard index (H_{ex}) values were found to be lower than recommended safe limit values except for few places of Hoshiarpur and Jalandhar districts where values of H_{ex} are more than unity. Also H_{ex} values for Pojewal (1.07), Talwara(1), Garhshankar(1.01)and Mahilpur(1.02) are almost unity.

V. These high values for Ra_{eq} and H_{ex} for few sampling sites indicates that the inhabitants of these villages/towns are subjected to a radiation exposure, which is significantly higher than the corresponding exposure levels reported in other areas worldwide.

ACKNOWLEDGEMENTS

We would like to thank to officials of health Physics lab of IUAC, New Delhi for providing us the necessary equipments for the experimental work.

REFERENCES

[1] UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation (2000) ''Sources and Effect of Ionizing Radiation" Vol.1, United Nations, New York.

[2] UNSCEAR (1988) "Sources and Effects of Ionizing Radiation" United Nations Scientific Committee on the Effect of Atomic Radiation, United Nations, New York.

[3] Rami AT, Wahab A, Hussein MA and Khalik Wood A (2005) "Environmental ^{238}U and ^{232}Th concentration measurements in an area of high level natural background radiation at Palong, Johor, Malaysia" Journal of *Environmental Radioactivit*y Vol.80, No. 3, pp. 287-304.

[4] Yu K N, Guan Z J, Stoks M J and Young E C, ''The assessment of natural radiation dose committed to the Hong Kong people" ,J. of Environmental Radioactivity, 1992, pp. 17-31.

[5] UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation (1993), Sources and Effect of Ionizing Radiation, New York, United Nations.

[6] Kocher D C and Sjoreen A L, ''Dose-rate conversion factors for external exposure to photon emitters in soil", Health Physics, Vol. 48, 1985, pp. 193-205.

[7] Jacob P, Paretzke H G, Rosenbaum H and Zankl M,''Effective dose equivalents for photon exposure from plane sources on the ground" , J.of Radiat. Prot. Dosim., Vol. 14,1986, pp. 299-310.

[8] Leung K C, Lau S Y and Poon C B, ''Gamma radiation dose from radionuclides in Hong Kong soil", Journal of Environmental Radioactivity, Vol. 11,1990, pp. 279-290.

[9] Beretka J and Mathew P J, ''Natural radioactivity of Australian building materials, industrial wastes and by-products", Health Physics, Vol. 48, 1985, pp. 87-95.

[10] Mehra R,''Measurements of 226Ra, 232Th and 40K using gamma spectrometry to assess a first-order exposure risk for residents of Western Haryana" ,Int. J. Low Radiation, Vol. 7, No. 3,2010, pp. 198-207.

[11] Mehra R, Kumar S, Sonkawade R G, Singh N P and Badhan K , ''Analysis of terrestrial naturally occurring radionuclides in soil samples from some areas of Sirsa district of Haryana, India using gamma ray spectrometry", Environmental Earth Sciences, Vol. 59,2010, pp.1159-1164.

[12] Mahur A K, Kumar R, Mishra M, Ali S A, Sonkawade R G, Singh B P, Bhardawaz V N and Prasad R,''Study of exhalation rate and natural radioactivity in soil samples collected from East Singhbhum shear zone in Jaduguda U-mines area, Jharkhand, India and its radiological implications", Indian journal of pure and applied physics, vol. 48,2010, pp. 486-492.

[13] Mehra R, Singh S, Singh K, Sonkawade R G,'' ^{226}Ra, ^{232}Th and ^{40}K analysis in soil samples from some areas of Malwa region, Punjab, India using gamma ray spectrometry", Environ Monit Assess, Vol.134,2007, pp. 333–342.

[14] Singh J, Singh H, Singh S, Bajwa B S and Sonkawade R G, "Comparative study of natural radioactivity levels in soil samples from the Upper Siwaliks and Punjab, India using gamma-ray spectrometry", Journal of Environmental Radioactivity Vol. 100, 2009, pp. 94-98.

[15] Mehra R, Singh S and Singh K,''Analysis of ^{226}Ra, ^{232}Th and ^{40}K in soil samples for the assessment of the average effective dose", Indian Journal of Physics, Vol. 83, No. 7, 2009, pp. 1031-1037.

[16] Organization for Economic Cooperation and Development,''Exposure to radiation from the natural radioactivity in building materials" Report by a group of experts of the OECD Nuclear Energy Agency (Paris, France: OECD) 1979.

[17] European Commission. Radiation Protection 112, Radiological protection principles concerning the natural radioactivity of building materials, Brussels, European Commission 1999.

[18] ICRP (1993) International Commission on Radiological Protection: Annals of the ICRP 23, 2. ICRP Publication 65, Pergamon Press, Oxford.