Poster Presentation

RADIONUCLIDES OF NATURAL ORIGIN IN ENVIRONMENTAL SAMPLES COLLECTED IN THE CATCHMENT AREA OF PONTE NOVA RESERVOIR, SÃO PAULO, BRAZIL

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Abstract

Natural radiation is generally classified as terrestrial primordial radiation or cosmogenic radiation. Primordial radiation is mostly due to the decay series of ^{238}U and ^{232}Th and is present in soil, sediments and water; another important source of natural radiation is ^{40}K. Reservoirs are a very dynamic system with several phenomena to study, due to their huge impact on ecosystems and river flow. Ponte Nova reservoir (23°34'43.23"S, 45°56'56.76"W) is the first reservoir in a cascade system that was built in the 1970s to control the Upper Tietê River basin water flow. In the present work, the activity concentrations of ^{238}U, ^{226}Ra, ^{210}Pb, ^{232}Th, ^{228}Th, ^{228}Ra and ^{40}K were determined using instrumental neutron activation analysis and gamma spectrometry in soil profiles collected in the catchment area of Ponte Nova Reservoir and sediment cores collected close to the soil samples. The highest concentration obtained in the soil samples was for ^{40}K that varied from 49 to 2410 Bq/kg and ^{210}Pb in the sediment samples, which varied from 20 to 774 Bq/kg. Cluster analysis and principal component analysis were applied to all the results obtained to verify a probable correlation between the radionuclides determined in the soil and sediment samples.

1. INTRODUCTION

Natural radioactivity characterization is the basis of radioecology and environmental monitoring [1]. The average worldwide dose due to natural radiation is 2.4 mSv/a [2], although individual values can be considerably higher. Natural radiation can be classified as terrestrial primordial radiation or cosmogenic radiation. Primordial radiation is mostly due to the decay series of ^{238}U and ^{232}Th and is ubiquitous in soil, sediments, and water. Another important source of natural radiation is ^{40}K, which is present in a wide range of rocks and soil [3]. These rocks underwent and still undergo weathering processes which in geological time turns them into the soil; eventually, this soil will be carried by wind and water and will become part of rivers, sediments, lakes, reservoirs, and oceans, as well as absorbed by fauna and flora [4]. Although slower moving than rivers, reservoirs are very dynamic systems with a large range of phenomena to study, due to their huge impact on ecosystems and river flow. As a result of a drought in the south-eastern region of Brazil in the years 2013–2015 [5], the Upper Tietê basin was severely affected and focused the attention of the media and the general population on Brazilian water resources. The Ponte Nova reservoir, located in the state of São Paulo, is the first reservoir in a cascade system that was built in the 1970s to control the Upper Tietê River basin water flow. This water basin serves millions of people with water in the São Paulo metropolitan area and the São Paulo greenbelt that provides this metropolitan area with agricultural products [6]. In the present work, the activity concentrations of ^{238}U and ^{232}Th were determined by instrumental neutron activation analysis (INAA) and ^{226}Ra, ^{210}Pb, ^{228}Ra, ^{228}Th

and ^{40}K by gamma spectrometry in soil profiles collected in the catchment area of Ponte Nova reservoir, and also in sediment cores collected close to the soil samples.

2. METHODOLOGY

Soil samples were collected vertically at three locations in the main lithology of the reservoir, from the top down to 1 m, sampled every 5 cm. The sediment cores were sliced every 3 cm. The real and apparent soil density and grain size analysis were determined in accordance with the manual of the Brazilian Agricultural Research Corporation [7]. Grain size analysis was performed on the soil and sediment samples by sieving 5 g of each sample with Milli-Q water in sieves capable of separating the soil fractions in sand, silt and clay and the sediment fractions in sand and silt–clay. The activity concentrations of ^{238}U and ^{232}Th were determined by INAA. Approximately 200 mg of the soil and sediment samples and IAEA reference material SL1 and Montana II (NIST) were irradiated for 6 h in a thermal neutron flux of 1012 $n \cdot cm^{-2} \cdot s^{-1}$ at the IEA-R1 Research Reactor at Instituto de Pesquisas Energéticas e Nucleares [8]. The activity concentrations of ^{226}Ra, ^{210}Pb, ^{228}Ra, ^{228}Th and ^{40}K were determined by gamma-ray spectrometry. Approximately 100 g of the soil and 15 g of the sediment samples were measured in a coaxial Be-layer high purity germanium detector with 25% relative efficiency, 2.09 keV resolution at 1.33 MeV and associated electronic devices, with a live counting time of 150 000 s. The spectra were acquired by an Ethernim multi-channel analyser and, for the analysis, WinnerGamma software was used [8].

3. RESULTS AND DISCUSSION

The grain size analysis showed that all the soil and sediment samples were composed predominantly of sand, with some exceptions in both matrixes, classifying them as sandy clay (see Figs 1 and 2). The soil samples presented a mean apparent density of 1.11 g/cm^3 and a real density of 2.96 g/cm^3, which implies a mean porosity of 56.57%, indicating a high permeability of the soil, allowing the radionuclides to move easily through the layers of soil.

Table 1 shows the activity concentrations measured in the soil and sediment samples. Soil profile 1 shows a higher activity concentration for ^{40}K and ^{232}Th than the other profiles. Soil profile 2 shows a similar activity concentration for ^{238}U and ^{232}Th, and soil profile 3 shows the lowest concentration of ^{232}Th. These differences may be due to differences in lithology.

Sediment cores 1 and 2 showed a higher concentration of ^{210}Pb than sediment core 3, which is located upstream and close to the source of the Tiête River and may be less affected by human activity. In cores 1 and 2 the ^{210}Pb activity concentration was elevated in relation to ^{226}Ra — the two locations are close to a highway and several farms. The mean worldwide values for ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K in soil are 33, 32, 45 and 412 Bq/kg, respectively [2]. Comparing the values obtained in this work with the worldwide values shows that the majority of the samples exhibited elevated values.

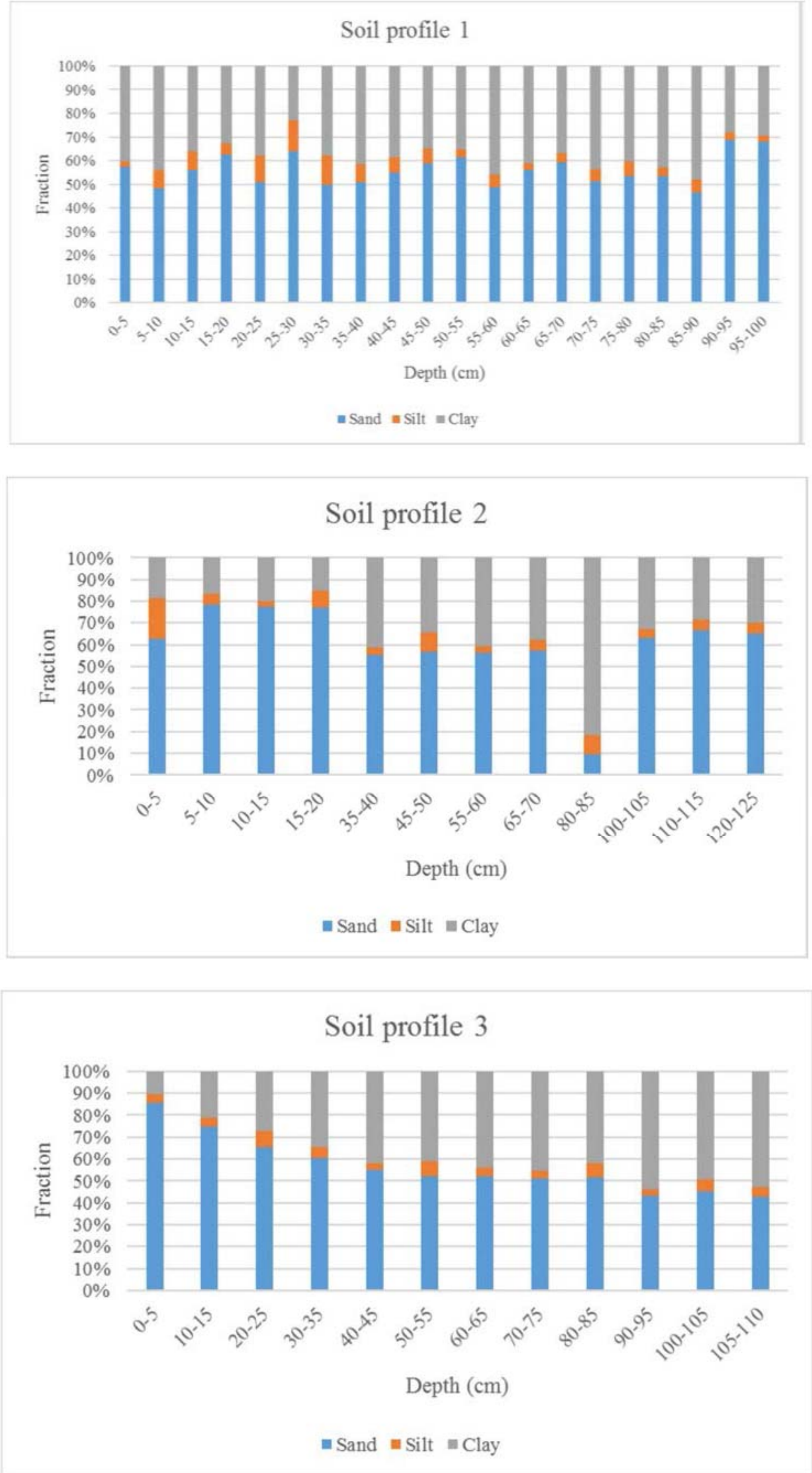

FIG. 1. Grain size results for soil.

FIG. 2. Grain size results for sediment.

TABLE 1. ACTIVITY CONCENTRATION RESULTS FOR SOIL
(Uncertainties in parentheses)

Depth (cm)	Activity concentration (Bq/kg)						
	U-238	Ra-226	Pb-210	Th-232	Th-228	Ra-228	K-40
Soil profile 1:							
0–5	41(4)	37(2)	95(10)	71(4)	126(13)	84(6)	639(94)
5–10	46(3)	41(2)	88(9)	99(7)	130(12)	102(6)	649(45)
10–15	42(4)	43(2)	80(7)	155(8)	177(17)	106(6)	780(52)
15–20	49(4)	47(2)	43(6)	111(8)	168(15)	139(8)	1157(79)
20–25	53(4)	40(2)	44(6)	128(9)	179(17)	128(8)	1208(82)
25–30	43(3)	31(1)	31(6)	117(8)	175(23)	143(9)	1358(131)
30–35	42(5)	38(2)	45(5)	207(10)	155(14)	140(8)	1430(96)
35–40	40(3)	40(1)	41(5)	107(8)	161(16)	127(8)	601(41)
40–45	49(3)	39(1)	49(6)	166(8)	137(14)	113(7)	636(44)
45–50	33(3)	37(2)	48(6)	90(6)	123(12)	99(6)	510(36)
50–55	35(3)	37(2)	44(5)	142(7)	111(11)	99(6)	312(22)
55–60	42(2)	33(2)	40(5)	124(6)	116(11)	87(5)	178(13)
60–65	43(2)	33(2)	42(5)	116(6)	108(11)	92(6)	169(13)
65–70	34(2)	31(1)	37(3)	123(6)	109(15)	89(6)	178(18)
75–80	34(3)	32(1)	35(5)	147(7)	143(14)	93(6)	155(23)
80–85	41(2)	34(2)	22(3)	–	133(13)	104(6)	167(12)
85–90	49(4)	36(1)	35(7)	118(6)	102(14)	113(7)	144(16)
90–95	62(4)	33(1)	30(4)	165(8)	59(6)	66(4)	129(19)
95–100	34(3)	33(1)	39(6)	66(3)	32(6)	47(3)	161(17)
Range	*33–62*	*31–47*	*31–95*	*71–207*	*32–179*	*47–143*	*129–1430*
Soil profile 2:							
0–5	32(2)	25(2)	45(5)	33(2)	31(3)	26(2)	49(8)
5–10	44(2)	30(3)	50(6)	51(3)	36(5)	33(2)	59(9)
10–15	44(2)	38(2)	51(6)	48(2)	46(3)	37(3)	69(18)
15–20	53(3)	40(4)	50(6)	54(3)	46(3)	40(3)	64(10)
20–25	49(3)	33(1)	23(3)	51(3)	37(2)	36(2)	60(5)
35–40	52(3)	41(4)	39(4)	59(3)	52(3)	47(3)	64(10)
55–60	53(3)	42(2)	47(5)	55(3)	63(3)	50(3)	65(5)
65–70	56(3)	35(1)	26(3)	69(3)	47(2)	66(4)	64(5)
80–85	42(3)	32(1)	25(3)	55(3)	41(2)	42(2)	63(5)
100–105	53(3)	45(2)	40(5)	59(3)	62(3)	56(4)	113(17)
110–115	40(2)	38(2)	29(3)	50(3)	56(3)	51(3)	88(6)
120–125	48(3)	45(2)	46(5)	56(3)	64(3)	53(3)	101(8)
Range	*32–56*	*25–45*	*23–51*	*33–69*	*31–64*	*26–66*	*49–113*
Soil profile 3:							
0–5	36(4)	38(3)	39(5)	11(1)	46(6)	37(3)	69(11)
10–15	50(4)	44(2)	33(4)	13(1)	61(3)	53(4)	61(10)
20–25	66(6)	48(2)	21(2)	17(1)	59(3)	58(3)	57(5)
30–35	70(6)	47(2)	21(2)	19(1)	63(3)	60(3)	55(4)
40–45	54(5)	46(2)	28(3)	16(1)	73(3)	56(3)	44(4)
50–55	63(5)	46(2)	33(3)	17(1)	78(4)	61(4)	55(4)
Range	*36–70*	*38–48*	*21–39*	*11–19*	*46–78*	*37–61*	*44–69*

TABLE 2. ACTIVITY CONCENTRATION RESULTS FOR SEDIMENT
(Uncertainties in parentheses)

Depth	Activity concentration (Bq/kg)						
(cm)	U-238	Ra-226	Pb-210	Th-232	Th-228	Ra-228	K-40
Sediment core 1:							
0–6	65(4)	58(8)	105(24)	203(10)	181(12)	175(15)	–
6–9	73(4)	74(4)	356(52)	247(12)	157(15)	174(15)	–
9–12	65(4)	75(6)	306(49)	372(18)	319(20)	294(25)	–
15–18	42(3)	36(3)	178(35)	124(6)	101(8)	93(8)	–
21–24	20(1)	22(2)	108(26)	36(2)	22(2)	24(2)	–
27–30	49(3)	23(2)	75(26)	83(1)	26(4)	21(2)	–
33–36	38(2)	27(2)	133(17)	23(1)	24(2)	32(3)	–
Range	*20–73*	*22–75*	*75–356*	*23–372*	*22–319*	*21–294*	
Sediment core 2:							
0–5	89(5)	82(7)	774(99)	96(5)	76(15)	68(7)	–
14–17	63(4)	24(3)	132(28)	42(2)	21(8)	26(3)	–
32–35	68(3)	76(6)	401(56)	60(3)	43(11)	54(5)	–
41–44	68(3)	62(5)	252(40)	53(3)	41(10)	40(4)	–
44–47	16(1)	72(4)	308(46)	12(1)	44(12)	50(5)	–
53–56	74(3)	62(4)	212(36)	62(3)	43(10)	45(4)	–
56–59	67(3)	70(4)	266(42)	62(3)	47(12)	52(5)	–
62–65	69(4)	48(3)	186(34)	68(3)	36(9)	34(3)	–
68–72	86(5)	60(4)	249(40)	71(4)	48(10)	51(5)	–
Range	*16–89*	*24–82*	*132–774*	*12–96*	*21–76*	*26–68*	–
Sediment core 3:							
0–5	50(4)	38(2)	47(7)	65(3)	62(5)	41(4)	148(14)
8–11	50(5)	54(3)	63(8)	71(3)	76(5)	62(5)	168(14)
14–17	54(5)	68(3)	33(4)	80(4)	70(4)	71(5)	–
20–23	76(6)	75(4)	37(5)	94(5)	78(6)	81(6)	–
26–29	66(6)	66(4)	69(8)	98(5)	79(5)	64(6)	154(14)
Range	*50–76*	*38–75*	*33–69*	*65–98*	*62–79*	*41–81*	*148–168*

4. CONCLUSION

Soil and sediment samples showed an overall association with the lithology and the grain size of the samples. Radionuclide activity concentrations were consistent with average and elevated values in soil reported worldwide.

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