Radioactive characterization of the Pinheiros river bottom sediment

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Radionuclide contents were determined in the bottom sediment of the Pinheiros river, into which the Instituto de Pesquisas Energéticas e Nucleares (IPEN) has been continuously discharging low level radioactive liquid effluents. The results showed that the activity of natural radionuclides and the activity of ^{137}Cs found in the sediment were within the range of the expected background for the region. ^{60}Co was the only other artificial radionuclide detected, with concentrations ranging from 0.20 to 0.85 Bq per kilogram dry weight, at some points of the river.

Determinou-se a concentração de radionuclideos no sedimento de fundo do Rio Pinheiros, no qual o Instituto de Pesquisas Energéticas e Nucleares (IPEN) tem continuamente liberado efluentes liquidos radioativos. Os resultados obtidos mostram que a atividade dos radionuclideos naturais e do ^{137}Cs presentes no sedimento são da mesma ordem de magnitude dos valores esperados da radiação de fundo da região. O ^{60}Co foi o unico outro radionuclideo artificial detectado em alguns pontos de amostragem do rio, em concentrações variando de 0,20 a 0,85 Bq por quilograma de peso seco de sedimento.

This study evaluates the concentration of radioactive elements in the bottom sediment of the Pinheiros river, originating from the liquid effluent discharged from facilities of the Instituto de Pesquisas Energéticas e Nucleares (IPEN). The Pinheiros river drains the region surrounding IPEN, and is located at the western metropolitan area of São Paulo city.

The continuous release of low level radioactive liquid effluent to the Pinheiros river started soon after the establishment of the IPEN in 1957, and has continuously increased since than, reaching a relatively stable condition in the last years. Such releases are controlled and limited in accordance with the discharge limits adopted at IPEN (1). In the last 5 years before the begining of this study, in 1992, the total cumulative quantity of radionuclides discharged into the river has not exceeded 8.3×10^9 Bq; the major contributors for this activity were natural uranium (5.4×10^9 Bq), ^{60}Co (1.9×10^9 Bq) and ^{137}Cs (4.8×10^8 Bq). The annual average amount of the main radionuclides released during this period is presented in Table 1 (2).

The Pinheiros river is an artificial unlined channel extending 26.2 km from the Tietê river to the Billings reservoir, presenting an average width of 85 m and a typical flow rate of 70 $m^3 s^{-1}$. Two elevator stations allow water flow reversion in some special circumstances. Although the flux, at the present, is toward the Tietê river, in the years before the time of sample collection water flow was predominantly toward the Billings reservoir. The IPEN's effluent enters the Pinheiros river at a point located 7 km downstream from the junction with the Tietê river (3).

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By now, it does not support any aquatic life due to the high degree of pollution of the water, arising from industrial effluents and sewage discharged into the river. The tributary streams are also sources of a large quantity of eroded soils and wastes that reduce its flow capacity. To prevent flooding on rainy days, periodic dredging is carried out at critical points of the river. The excess bed load is deposited in specific places along the river bank, where some recreational activities for children have been observed.

Since the dredged sediment could become a potential source of radiation exposure to man, radioactive characterization of the bottom sediment along the river and at two dredged sediment deposit sites was performed.

The bottom sediment was collected in a cooperative programme with the Instituto de Pesquisas Tecnológicas do Estado de São Paulo (IPT), in October, 1992. The river was divided into 47 sampling sections, each measuring about 500 meters extending from the junction with the Tietê river downstream to the Billings reservoir. One snapshot sample was collected at each sampling section, alternately at the left hand, center and right hand of the river. The bottom sediment was sampled using a manual dredger, mounted on a motorized boat. About 5 to 10 kg of superficial layer of the bottom sediment was collected, at each section.

Also, four samples were collected from two sediment deposit sites, one located near the Tietê river and another near the Billings reservoir. At both sites, the sediment was sampled from its superficial layer and at two meters deep in the soil.

The collected sediment was oven dried at 100°C for 24 hours, and then calcinated in a muffle furnace for 12 hours, at 400°C, to remove organic matter and to minimize pathogenic risk associated with sample handling. The samples were crushed and then sieved to yield granular material with less than 0.125 mm particle size for determination of ^{238}U, ^{232}Th and high energy gamma emitter content (4).

^{238}U and ^{232}Th activities were measured by neutron activation analysis. Samples of 300 mg of sediment were irradiated in a flux of epithermal neutrons of 1.5×10^{11} n cm^{-2} s^{-1} and ^{238}U and ^{232}Th determined by passive gamma spectrometry, measuring the decay products ^{239}Np and ^{233}Pa in an hyperpure germanium detector with 25% relative efficiency.

The high energy gamma emitters were measured using a 20% relative efficiency hyperpure germanium detector, in a 850 cm^3 Marinelli beaker, for a counting time of 60,000 seconds. The Marinelli beaker was previously sealed to assure radioactive equilibrium between ^{226}Ra and its short-lived daughters to be reached. The ^{226}Ra activity was determined using the 609 keV line of ^{214}Bi.

Table 1 - Annual average activity of radionuclides released into the Pinheiros river from 1988 to 1992 and detection limits for gamma emitters.

Radionuclide	*Half-life (year)*	*Amount released (Bq per year)*	*Detection limit (Bq per kg dry wt)*
^{24}Na	1.71×10^{-3}	3.5×10^{7}	0.4
^{51}Cr	7.58×10^{-2}	8.4×10^{6}	2.5
^{58}Co	1.94×10^{-1}	3.2×10^{6}	0.3
^{65}Zn	6.69×10^{-1}	1.2×10^{7}	1.2
^{60}Co	5.27×10^{0}	3.7×10^{8}	0.2
^{95}Nb	9.60×10^{-2}	1.6×10^{5}	0.4
^{95}Zr	1.75×10^{-1}	5.4×10^{4}	1.7
^{99}Tc	2.13×10^{5}	3.1×10^{6}	[a]
^{106}Ru	1.01×10^{0}	6.1×10^{5}	3.0
^{108m}Ag	1.27×10^{2}	4.0×10^{5}	0.8
^{110m}Ag	6.84×10^{-1}	8.3×10^{5}	0.3
^{121}Te	4.60×10^{-2}	1.1×10^{6}	0.6
^{122}Sb	7.39×10^{-3}	5.0×10^{5}	0.7
^{121m}Te	4.22×10^{-1}	8.4×10^{5}	2.7
^{123m}Te	3.28×10^{-1}	6.8×10^{6}	0.3
^{124}Sb	1.65×10^{-1}	6.6×10^{6}	0.3
^{125}Sb	2.77×10^{0}	8.7×10^{4}	1.2
^{131}I	2.20×10^{-2}	3.2×10^{7}	0.4
^{132}Te	8.92×10^{-3}	4.1×10^{5}	0.3
^{134}Cs	2.06×10^{0}	5.0×10^{6}	0.8
^{137}Cs	3.02×10^{1}	9.5×10^{7}	0.3
^{144}Ce	7.78×10^{-1}	1.3×10^{6}	1.7
^{152}Eu	1.36×10^{1}	8.1×10^{5}	1.3
^{192}Ir	2.03×10^{-1}	1.3×10^{5}	0.8
^{203}Hg	1.28×10^{-1}	3.6×10^{5}	2.1
^{228}Ra	5.75×10^{0}	1.3×10^{7}	3.2
^{232}Th	1.41×10^{10}	1.9×10^{7}	22
^{238}U	4.47×10^{9}	5.4×10^{8}	12

[a] Not determided (beta emitter).

Table 2 - Radionuclide concentration in the bottom sediment of the Pinheiros river.

Radionuclide	Observed range (Bq per kg dry wt)	Arithmetic mean (Bq per kg dry wt)	Natural background (Bq per kg dry wt)
^{238}U	22.4 - 260	109 57	1.8 - 520 [a]
^{232}Th	22.3 - 464	199 111	1.5 - 440 [a]
^{226}Ra	25.6 - 128	70 20	21 - 290 [b]
^{228}Ra	31.6 - 170	95 26	18 - 770 [b]
^{228}Th	30.0 - 170	88 24	26 - 530 [b]
^{7}Be	3.8 - 80	21 18	6 - 81 [c]
^{40}K	182 - 543	361 70	130 - 1830 [b]
^{60}Co	0.20 - 0.85	0.43 0.20	-
^{137}Cs	0.30 - 1.3	0.48 0.22	-

[a] Area-weighted mean for China (5);
[b] Sediment from Sorocaba-SP region (6);
[c] Sediment from French rivers (7).

Results of the radionuclide determination at each one of the 47 sections of the river, and at the 4 points of

the sediment deposit sites, are presented in Table 2. For those radionuclides not detected anywhere in the river, typical gamma detection limits of the system, for the samples analized, are presented in Table 1.

The results show that radionuclide concentration in the bottom sediment of the Pinheiros river lies within the expected range for natural radionuclides determined elsewhere, not allowing any clear correlation with the IPEN's discharge into this river. Regarding artificial radionuclides, ^{60}Co and ^{137}Cs were the only two radionuclides detected, at levels ranging from 0.20 to 0.85 Bq per kilogram dry weight for ^{60}Co and from 0.30 to 0.98 Bq per kilogram dry weight for ^{137}Cs, at some sections of the river.

There is no observable trend of radionuclide accumulation at any location downstream the discharge point. This is due to the relatively small amount of radionuclides released into the river, and also to the continuous input of solid materials carried by tributary streams, causing the periodic dredging at the major sediment accumulation points along the river.

From the above results one can conclude that the radioactive liquid effluent discharged by IPEN is being properly controlled and that its contribution to the enhancement of the radionuclide concentration in the bottom sediment of the Pinheiros river is negligible regarding radiological concern. ■

References and notes

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