



ABSTRACT

The Brazilian Navy is monitoring the concentration of the radionuclides Cesium 137 and Strontium 90 in samples of water, sediment, fish, and mussels from the marine environment along the Brazilian Coast since 1996. The aim of this work is to establish the background of these radionuclides to assess possible increase of the values due to human activities with nuclear test, nuclear power station accident or other event. The results are stored in a database at the Admiral Paulo Moreira Marine Research Institute. Twenty three sites are annually monitored, between the latitudes of 0° 36' 49"S and 32° 02' 06"S and longitudes of 34° 50' 0" W and 52° 05' 55" W. The highest values of Cesium 137 measured were 4.1 Bq.m⁻³ in seawater at Atafona, in 2001; 4.14 Bq.kg⁻¹ in the sediment at Santos, in 1998; 1.72 Bq.kg⁻¹ in fish at Macae, in 2000; and 1.75 Bq.kg⁻¹ in mussels at Angra dos Reis, in 2000. The highest values of Strontium 90 measured were 0.23 Bq.kg⁻¹ in fish at Santos, in 2000 and 0.175 Bq.kg⁻¹ in mussels at Vitoria, in 2006. The only source known of these radionuclides is probably from the nuclear atmospheric tests made before the end of the II World War.

METHODOLOGY

The sampling points coordinates are shown in Table 1. The program was started in 1997 with only one sampling point and new sampling points were added step by step until there were 23 sampling points (Figure 1). The sampling points were located according the following criteria: region with higher probability of a nuclear ship visit or with important on-shore or off-shore activities, such as the existence of nuclear power plants, and the existence of ports nearby. The seawater samples (Figure 2) were taken one meter below the surface. Eighty-liter samples were filtered on-line (2 µm pre-filter and 0.45 µm filter) directly into hundred liter plastic drums. On board, the samples were acidified to pH 3 with HCl, 1 Bq ¹³⁴Cs and 11 grams Ammonium Molybdophosphate (AMP) added. In order to obtain a 100% chemical yield, ¹³⁷Cs coprecipitation with AMP is usually carried out at pH 1. Notwithstanding, aiming to perform it on board, it was performed at pH 3. The mean chemical yield observed was 75%. After 1 h mixing, the solids were left settling down for 24 h and, afterwards, the water was discharged off. The AMP was filtered through a 5-cm diameter filter paper and kept on a plastic petri dish. The ¹³⁷Cs activities were determined by gamma spectrometry applying a 40% intrinsic germanium detector and 1000 min counting time. The fish samples (Figure 3) were bought directly from fishermen at local harbors, in general, croaker (*Micropogonias furnieri*) and white weakfish (*Cynoscion leiarchus*). About 5 kg fish muscle were ash at 400 °C over 24 h and transferred to a 7-cm polyethylene pot. The ¹³⁷Cs activity was determined as above. A 10 grams ash aliquot was taken from those samples with detectable levels of ¹³⁷Cs. After the sample total dissolution, ⁹⁰Sr were determined through ⁹⁰Y separation with DEHPA (di-2-ethylhexyl phosphoric acid) and Aliquat-336 (dimetil octil ammonium). Yttrium carrier was precipitated as oxalate and ⁹⁰Y activity measured applying a low-level proportional gas flow detector EG&G Prof. Berthold LB-550 and 400 minutes counting time. The sediment samples (Figure 4) were taken using a van Veen grab sampler. About 5 liters wet sediment sample were taken and, after dried, 400 grams were weighed on a 7-cm polyethylene pot. After 30 days, to allow a simultaneous ²²⁶Ra determination, the samples were analyzed by gamma spectrometry as above.



Figure 1. Brazil's map showing 23 sampling points from Salinópolis (PA) to Rio Grande (RS).

Sampling Points	Latitude (S)	Longitude (W)
Salinópolis	00°36,67'	047°29,13'
Itaqui	02°43,78'	044°22,09'
Fortaleza	03°44,22'	038°34,19'
Cabedelo	07°00,24'	034°50,00'
Recife	08°07,87'	034°59,80'
Maceió	09°48,45'	035°46,84'
Salvador	12°57,15'	038°35,00'
Ilhéus	14°45,40'	039°00,70'
Vitória	20°19,19'	040°17,57'
Macaé	22°22,68'	041°44,99'
Arraial do Cabo	22°58,16'	041°59,94'
Rio de Janeiro	22°52,22'	043°08,86'
Sepetiba	22°57,35'	043°59,68'
Sepetiba A	22°54,50'	043°50,85'
Sepetiba B	22°54,99'	043°51,74'
Sepetiba C	22°55,95'	043°50,99'
Sepetiba D	22°56,09'	043°49,34'
Angra dos Reis	23°01,51'	044°27,70'
São Sebastião	23°50,40'	045°27,13'
Santos	24°00,04'	046°20,76'
Paranaguá	25°31,33'	048°34,19'
Itajaí	26°54,96'	048°44,44'
Rio Grande	32°02,10'	052°05,92'

Table 1. Brazilian coastal region monitoring program sampling points coordinates.



Figure 2 - Filtering seawater



Figure 3 - Fish samples



Figure 4 - Sediment samples

RESULTS

¹³⁷ Cs - Seawater				
Sampling Points	Samples	Max (Bq.m ⁻³)	Min (Bq.m ⁻³)	Mean (Bq.m ⁻³)
Angra dos Reis	15	3,11E+00	5,00E-01	1,34E+00
Arraial do Cabo	16	2,97E+00	4,60E-01	1,64E+00
Atafona	12	4,10E+00	1,21E+00	2,17E+00
B. Sepetiba	19	3,50E+00	1,80E-01	1,25E+00
B. Guanabara	15	4,10E+00	4,64E-01	1,31E+00
Cabedelo	3	1,13E+00	4,60E-01	8,60E-01
Fortaleza	3	1,46E+00	4,10E-01	9,50E-01
Ilhéus	4	1,00E+00	5,45E-01	7,40E-01
Itajaí	4	1,00E+00	7,20E-02	4,40E-01
Itaóca	10	2,94E+00	9,80E-01	1,56E+00
Itaqui	3	1,70E+00	4,20E-01	1,04E+00
Macaé	17	2,48E+00	4,60E-01	1,51E+00
Maceió	3	1,00E+00	6,30E-01	7,80E-01
Paranaguá	4	1,00E+00	2,65E-01	4,80E-01
Recife	3	1,00E+00	3,00E-01	7,50E-01
Rio Grande	4	1,00E+00	8,00E-02	4,50E-01
Salinópolis	3	1,00E+00	5,80E-01	7,20E-01
Salvador	4	1,00E+00	4,40E-01	7,00E-01
Santos	16	3,58E+00	5,15E-01	1,45E+00
São Sebastião	16	2,20E+00	6,41E-01	1,22E+00
Ubatuba	11	3,00E+00	6,00E-01	1,57E+00
Vitória	16	2,28E+00	2,40E-01	1,45E+00
Total	201			

¹³⁷ Cs - Sedimento				
Sampling Points	Samples	Max (Bq.Kg ⁻¹)	Min (Bq.Kg ⁻¹)	Mean (Bq.Kg ⁻¹)
Angra dos Reis	15	6,80E-01	1,75E-01	2,80E-01
Arraial do Cabo	16	1,15E+00	1,70E-01	2,90E-01
Atafona	9	1,76E+00	2,10E-01	4,90E-01
Baía de Sepetiba	31	2,20E+00	1,30E-01	5,00E-01
Baía de Guanabara	15	1,89E+00	1,00E-01	4,40E-01
Cabedelo	3	7,50E-01	5,00E-01	5,90E-01
Fortaleza	3	3,00E-01	1,50E-01	2,30E-01
Ilhéus	4	7,80E-01	1,80E-01	4,10E-01
Itajaí	4	8,70E-01	2,40E-01	4,40E-01
Itaóca	10	1,12E+00	1,90E-01	4,30E-01
Itaqui	3	7,00E-01	9,00E-02	3,10E-01
Macaé	16	1,88E+00	3,10E-01	7,90E-01
Maceió	3	6,40E-01	2,00E-01	4,90E-01
Paranaguá	4	3,90E-01	1,60E-01	2,40E-01
Recife	3	5,80E-01	3,00E-01	4,40E-01
Rio Grande	4	2,64E+00	1,60E+00	2,20E+00
Salinópolis	3	3,80E-01	1,70E-01	2,80E-01
Salvador	4	8,70E-01	5,20E-01	6,20E-01
Santos	17	4,14E+00	1,60E-01	6,70E-01
São Sebastião	16	2,31E+00	1,30E-01	4,20E-01
Ubatuba	10	1,21E+00	3,20E-01	7,00E-01
Vitória	15	1,46E+00	2,60E-01	5,00E-01
total	208			

¹³⁷ Cs - Fishes				
Sampling Points	Samples	Max (Bq.Kg ⁻¹)	Min (Bq.Kg ⁻¹)	Mean (Bq.Kg ⁻¹)
Angra dos Reis	10	1,50E-01	3,00E-02	6,00E-02
Arraial do Cabo	12	5,20E-01	1,00E-02	1,40E-01
Atafona	6	1,45E+00	4,00E-02	4,00E-01
Baía de Sepetiba	14	1,00E-01	2,00E-02	5,00E-02
Baía de Guanabara	12	6,50E-01	1,00E-02	1,10E-01
Cabedelo	3	1,00E-01	1,00E-02	6,00E-02
Fortaleza	3	1,10E-01	9,00E-02	1,00E-01
Ilhéus	4	1,50E-01	3,00E-02	7,00E-02
Itajaí	4	2,00E-02	1,00E-02	1,00E-02
Itaóca	7	7,40E-01	4,00E-02	2,30E-01
Itaqui	3	9,00E-02	4,00E-02	7,00E-02
Macaé	16	1,72E+00	3,00E-02	2,00E-01
Maceió	3	1,10E-01	2,00E-02	5,00E-02
Paranaguá	4	6,00E-02	2,00E-02	4,00E-02
Recife	3	4,00E-02	3,00E-02	4,00E-02
Rio Grande	4	5,00E-02	3,00E-02	4,00E-02
Salinópolis	3	6,00E-02	2,00E-02	4,00E-02
Salvador	4	4,00E-02	2,00E-02	3,00E-02
Santos	12	2,60E-01	1,00E-02	6,00E-02
São Sebastião	10	4,20E-01	1,00E-02	8,00E-02
Ubatuba	8	7,00E-01	1,00E-02	1,30E-01
Vitória	13	1,18E+00	2,00E-02	1,50E-01
Total	158			

⁹⁰ Sr - Fishes				
Sampling Points	Samples	Max (Bq.Kg ⁻¹)	Min (Bq.Kg ⁻¹)	Mean (Bq.Kg ⁻¹)
Angra dos Reis	15	1,20E-02	4,90E-02	1,00E-03
Arraial do Cabo	13	1,50E-02	3,70E-02	7,00E-04
Atafona	12	2,50E-02	9,50E-02	5,00E-03
Baía de Sepetiba	31	2,00E-02	7,00E-02	2,00E-03
Baía de Guanabara	16	2,00E-02	5,40E-02	3,00E-03
Cabedelo	3	8,00E-03	1,10E-02	5,00E-03
Fortaleza	3	1,40E-02	2,40E-02	6,00E-03
Ilhéus	4	3,10E-02	1,07E-01	3,00E-03
Itajaí	4	1,60E-02	4,10E-02	5,00E-03
Itaóca	10	8,00E-03	2,00E-02	8,00E-04
Itaqui	3	6,60E-02	1,31E-01	1,00E-02
Macaé	18	2,80E-02	1,46E-01	3,00E-03
Maceió	3	1,90E-02	3,35E-02	5,00E-03
Paranaguá	4	2,10E-02	3,20E-02	6,00E-03
Recife	3	1,30E-02	3,20E-02	3,00E-03
Rio Grande	4	1,10E-02	2,50E-02	4,00E-03
Salinópolis	3	1,80E-02	2,80E-02	1,00E-02
Salvador	4	9,00E-03	1,20E-02	6,00E-03
Santos	17	4,90E-02	1,75E-01	4,00E-03
São Sebastião	16	3,00E-02	1,32E-01	4,00E-03
Ubatuba	11	4,40E-02	1,20E-01	3,00E-03
Vitória	16	2,00E-02	8,00E-02	9,00E-04
Total	213			

CONCLUSIONS

- 1 – The concentration of artificial radionuclides along the Brazilian coast is very low.
- 2 – Brazil has not contributed with any contamination of artificial radionuclides along the coast. The current concentrations are possibly from fallout caused by atmospheric nuclear test in the 1940 decade.
- 3 – The maximum value observed in seawater was 4,1E+00 Bq.m⁻³ of ¹³⁷Cs in Atafona and Guanabara Bay.
- 4 – The maximum value observed in sediment was 4,1E+00 Bq.kg⁻¹ of ¹³⁷Cs in Santos.
- 5 – The maximum value observed in fish was 1,7E+00 Bq.kg⁻¹ of ¹³⁷Cs in Macae and 6,6E-02 Bq.kg⁻¹ of ⁹⁰Sr in Itaqui.