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THE MONITORING OF THE TERRESTRIAL ENVIRONMENT AROUND ALMIRANTE ÁLVARO ALBERTO NUCLEAR POWER STATION

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ABSTRACT

The goal of this paper is to evaluate the environmental monitoring around Almirante Álvaro Alberto Nuclear Power Station (AAANPS) after the beginning the operation of Unit II, in July 2000. The Environmental Monitoring Laboratory (EML) has, for purpose, to monitor the environment around the station to verify if there is a potential impact caused by the operation of the units. The EML collects several environmental samples and analyses radiometrically to determine the presence of artificial radionuclides. The types of the samples are marine samples (sea water, fish, algae, beach sand and sediments), terrestrial (milk, banana, soil, grass, superficial and "underground" water and river water and sediment) and aerial samples (rain water, airborne for iodine and particulate). This paper only describes the monitoring of terrestrial samples. At the EML, the samples are prepared and analysed following international procedures. The samples of milk, banana, soil, grass, surface and underground water, river water and river sediment are analysed by gamma spectrometry in a Multi-Channel Analyser (MCA) GENIE-2000 System with High-purity Germanium (HpGe) detectors to determine the activities of the detectable radionuclides. The EML also analyses tritium in surface water by liquid scintillation counting. In adittion, analysis of $^{89}Sr/^{90}Sr$, by beta counting and ^{131}I by gamma spectrometry are performed in the processed milk. The results are, then, compared with those obtained in pre-operational time of Angra 1 (1978 – 1982) and those obtained in operational time of the units until 2010. The results show us that, from 1982 until now, there is no impact in terrestrial environment caused by the operation neither of Angra 1 nor both Angra 1 and Angra 2.

1. INTRODUCTION

The Almirante Álvaro Alberto Nuclear Power Station (AAANPS) is located in Itaorna Beach, in Angra dos Reis, Rio de Janeiro and belongs to Eletrobras Eletronuclear S.A. – ELETRONUCLEAR. It is formed by three units: Angra 1, a 650 MW PWR (Pressurized Water Reactor) designed by Westinghouse, in commercial operation since 1985, Angra 2, a 1,350 MW plant, designed by Siemmens-KWU, in commercial operation since 2001 and Angra 3, a unit similar to Angra 2, under construction.

The Environmental Monitoring Laboratory is an installation belonging to ELETRONUCLEAR and is located in Mambucaba Residencial Village, 13 Km far from AAANPS. It was created in 1978 with the purpose to monitor the environment around the Station to verify if there is a potential impact caused by the operation of the units.
The Environmental Monitoring Laboratory is responsible for the execution of several environmental programs, between the cities of Angra dos Reis and Paraty. One of these

programs is the Operational Radiological Environmental Monitoring Program [1], that establishes which the matrices are, the points and the frequencies of the collection and the analysis to be done in these matrices, of marine (sea water, beach sand, sediment, algae and fish), terrestrial (milk, grass, banana, soil, surface water, sediment and river water and superficial and "underground" water) and aerial (air and rain water) origin. This paper presents an evaluation of the monitoring on terrestrial environment, around the Station, in the period from 2000 to 2010, after the beginning the operation of Angra 2.

The results of radiometric analysis of terrestrial samples, collected in the operational time of the two units, are compared with those from pre-operational time of Angra 1 (1978 – 1982) and they show that, during the evaluated time, there was no significant impact to the environment caused by the operation of Angra 1 & 2.

Every year, reports are emitted to CNEN, IBAMA and INEA having an evaluation of each monitoring done [2].

2. METHODOLOGY

Some samples of terrestrial origin were chosen to be the indicators of the critical ways of radionuclides transference to people and by the experience acquired during the pre-operational program.

The sample collection points were determined from geographical, hydrological, oceanographical data, population habits and uses of the ground . These points are divided in impact area, in which is expected some effects due to the discharge of liquid and/or gaseous effluents of the AAANPS, and control area, in which such effects are not expected [3, 4].

The sample collections, the preparation methods and the analysis of the samples are according to the specific procedures [5, 6].

2.1 Milk

10 to 15 L of milk are collected, two times a year, in two small farms near the AAANPS and one in Paraty. At the lab, formol (10 mL/L sample) are added to preserve the sample. 4 L are separated and methymazole (70 mg) is added before the milk be counted "in nature". They are put into appropriated plastic flasks (4 L Marinelli), weighted and analysed by gamma spectrometry in HpGe detector with a MCA system, during 17 hours.

7 L of the sample are passed through an ion-exchange resin (anionic resin, 20-50 mesh, Cl^- form) to separate iodine. The resin is put into a plastic flask (100 mL) and analysed by gamma spectrometry again to ^{131}I, during 70 hours.

In 1.5 L remaining milk, $^{89}Sr/^{90}Sr$ are separated radiochemically by using several reagents (Na_2CO_3 3N / Sr, Rare Earths and Barium carriers / EDTA / NH_4OH P.A. / NaCl 4N / Ammonium Acetate / Acetic Acid / HNO_3 70% / $Na_2CrO_4.4H_2O$ 0.75M and cationic resin – 20-50 mesh – H^+ form) to separate every radionuclides which can be present in the sample and will cause interference in beta counting analysis (the most important radionuclide to be separated is ^{90}Y, beta emitter like ^{90}Sr and its decay radionuclide). 3 to 4 days after the

radiochemical separation, the final sample containing only $^{89}Sr/^{90}Sr$ is analysed by beta counting using a gas flux proportional detector during 5 hours.

2.2 Surface, "underground" and river water

10 L of surface water samples (water which is consumed by local population) are collected, four times a year, at Naval School, Frade Village, Praia Brava Village and Paraty. At the lab, the samples are filtered and 4 L aliquots are acidulated with 10 mL/L sample of concentrated nitric acid. The samples are, then, put into appropriated plastic flasks (4 L Marinelli), weighted and analysed by gamma spectrometry during 3 hours. A 50 mL fraction of samples not acidulated, is separated to be analysed for tritium (^{3}H) by liquid scintillation counting during 5 hours.

10 L of "underground" water sample are collected, two times a year, in Itaorna. At the lab, the sample is filtered and 4 L aliquot is acidulated with 10 mL/L sample of concentrated nitric acid. River water samples are collected 1 m depth once a year, in two points (Mambucaba and Frade rivers). At the lab, the samples are filtered and 4 L aliquots are acidulated with 10 mL/L sample of concentrated nitric acid. The samples are, then, put into appropriated plastic flasks (4 L Marinelli), weighted and analysed by gamma spectrometry during 3 hours.

2.3 Grass

Grass sample is collected in same place where milk is collected. At the lab, the grass is weighted (about 1.5 Kg), cleaned to remove residues of soil and put in a tray to be calcinated. The samples are calcinated for 12 hours at 400^{o}C. The ashes are passed through 16, 32 and 60 mesh sieves to separate the material that was not calcinated, weighted to obtain the mass correction factor and transferred to appropriated plastic flasks (200 mL), and analysed by gamma spectrometry during 17 hours.

2.4 Banana

Banana sample is collected in two points (Itaorna and Paraty), two times a year. At the lab, the banana without peel is weighted (about 8 Kg) and put in a tray to be calcinated. The samples are calcinated for 12 hours at 400^{o}C. The ashes are passed through 16 mesh sieve to separate the material that was not calcinated, weighted to obtain the mass correction factor and transferred to appropriated plastic flasks (200 mL) and analysed by gamma spectrometry during 17 hours.

2.5 Soil

Surface soil sample is collected in same place where banana is collected. At the lab, the soil is weighted (about 2 Kg) and transferred to appropriated plastic flasks (1 L Marinelli) and analysed by gamma spectrometry during 17 hours.

2.6 River sediment

The river sediment samples are collected at the bottom (1.5 m), once a year, in the same rivers where the water is collected, using a Van Veen grab.

At the lab, the samples are weighted (2 Kg), put into appropriated plastic flasks (1 L Marinelli) and analysed by gamma spectrometry.

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3. RESULTS

The average results of the analysis of terrestrial samples, from 1978 to 1982 (pre-operational time of Angra 1), from 1996 to 2000 (pre-operational time of Angra 2) and from 2001 to 2010, are shown below in tables 1 to 6 and the graphics of the figures 1 to 3. It's important to say that banana and soil began to be collected only in 2002 by requirement of CNEN and that river and "underground" water and river sediment, in 1999, by requirement of IBAMA.
The table 7 shows the LLD (Low Limit Detectable) values of the Regulatory Guide 4.8 [7] and NUREG 1301 [8]. The table 8 shows the MDA (Minimum Detectable Activity) of the equipments of the EML.

Table 1: Activities of natural (^{40}K) and artificial (^{131}I, ^{137}Cs, ^{89}Sr and ^{90}Sr) radionuclides in milk

YEARS	^{40}K (Bq/L)	^{131}I (Bq/L)	^{137}Cs (Bq/L)	^{89}Sr (Bq/L)	^{90}Sr (Bq/L)
Pre-operational Angra 1 (1978 – 1982)	50,86 ± 5,13	< MDA	0,42 ± 0,08	0,12 ± 0,03	0,21 ± 0,06
Pre-operational Angra 2 (1996 – 2000)	51,15 ± 5,10	< MDA	0,24 ± 0,04	0,06 ± 0,03	0,10 ± 0,03
2001	52,12 ± 5,03	< MDA	0,24 ± 0,05	0,07 ± 0,03	0,11 ± 0,04
2002	50,30 ± 3,20	< MDA	0,19 ± 0,06	0,06 ± 0,04	0,10 ± 0,02
2003	43,19 ± 6,28	< MDA	0,16 ± 0,04	0,06 ± 0,05	0,11 ± 0,04
2004	42,56 ± 4,20	< MDA	0,18 ± 0,07	0,20 ± 0,08	0,11 ± 0,05
2005	50,01 ± 4,00	< MDA	0,19 ± 0,05	0,12 ± 0,05	0,10 ± 0,03
2006	50,24 ± 5,34	< MDA	0,15 ± 0,05	0,06 ± 0,05	0,05 ± 0,02
2007	46,11 ± 3,39	< MDA	0,19 ± 0,03	0,09 ± 0,03	0,05 ± 0,02
2008	45,30 ± 4,27	< MDA	0,18 ± 0,04	0,10 ± 0,02	0,06 ± 0,02
2009	43,66 ± 2,75	< MDA	< MDA	< MDA	< MDA
2010	44,49 ± 2,48	< MDA	< MDA	< MDA	< MDA

Table 2: Activities of natural (^{40}K) and artificial (^{137}Cs) radionuclides in grass

YEARS	^{40}K (Bq/Kg) wet	^{137}Cs (Bq/Kg) wet*
Pre-operational Angra 1 (1978 – 1982)	191,36 ± 19,85	< MDA
Pre-operational Angra 2 (1996 – 2000)	165,31 ± 16,58	< MDA
2001	168,38 ± 15,05	< MDA
2002	198,79 ± 17,05	< MDA
2003	215,05 ± 16,95	< MDA
2004	188,18 ± 9,57	< MDA
2005	191,41 ± 20,63	< MDA
2006	200,39 ± 20,96	< MDA
2007	173,76 ± 10,60	< MDA
2008	209,73 ± 17,03	< MDA
2009	146,42 ± 7,42	< MDA

Table 3: Activities of natural (^{40}K) and artificial (^{137}Cs) radionuclides in soil

YEARS	^{40}K (Bq/Kg)	^{137}Cs (Bq/Kg)
Pre-operational Angra 1 (1978 – 1982)	---	---
Pre-operational Angra 2 (1996 – 2000)	---	---
2001	---	---
2002	741,69 ± 66,77	1,71 ± 0,40
2003	726,76 ± 64,46	0,70 ± 0,16
2004	769,52 ± 89,93	0,42 ± 0,13
2005	549,78 ± 97,64	0,56 ± 0,13
2006	411,75 ± 44,15	0,54 ± 0,15
2007	201,82 ± 20,20	1,31 ± 0,19
2008	601,72 ± 25,38	0,45 ± 0,13
2009	149,92 ± 20,47	< MDA
2010	221,66 ± 20,37	< MDA

Note of Table 2 (*) – Wet means natural sample before calcinate.

Table 4: Activities of natural (^{40}K) and artificial (^{137}Cs and ^{131}I) radionuclides in banana

YEARS	^{40}K (Bq/Kg) wet	^{137}Cs (Bq/Kg) wet	^{131}I (Bq/Kg) wet
Pre-operational Angra 1 (1978 – 1982)	---	---	---
Pre-operational Angra 2 (1996 – 2000)	---	---	---
2001	---	---	---
2002	92,16 ± 16,47	< MDA	< MDA
2003	126,95 ± 6,10	< MDA	< MDA
2004	131,41 ± 15,87	< MDA	< MDA
2005	123,14 ± 9,87	< MDA	< MDA
2006	140,86 ± 18,23	< MDA	< MDA
2007	110,17 ± 17,66	< MDA	< MDA
2008	106,99 ± 10,28	< MDA	< MDA
2009	114,81 ± 21,85	< MDA	< MDA
2010	97,55 ± 26,55	< MDA	< MDA

Table 5: Activities of natural (^{40}K) radionuclide in river sediment

YEARS	^{40}K (Bq/Kg)	Artificial (Bq/Kg)
Pre-operational Angra 1 (1978 – 1982)	---	---
Pre-operational Angra 2 (1999 – 2000)	766,50 ± 38,32	< MDA
2001	678,39 ± 33,91	< MDA
2002	744,06 ± 37,20	< MDA
2003	586,11 ± 29,30	< MDA
2004	478,37 ± 23,90	< MDA
2005	643,15 ± 32,15	< MDA
2006	521,40 ± 26,07	< MDA
2007	335,08 ± 16,75	< MDA
2008	603,82 ± 30,19	< MDA
2009	655,57 ± 32,78	< MDA
2010	683,81 ± 34,19	< MDA

Table 6: Activities of ^{3}H and artificial radionuclides in surface water, river and underground water

YEARS	Surface Water (Bq/L)		"Underground" & River Water (Bq/L)
	^{3}H	Artificial	Artificial
Pre-operational Angra 1 (1978 – 1982)	< MDA	< MDA	---
Pre-operational Angra 2 (1996 – 2000)	< MDA	< MDA	< MDA*
2001	< MDA	< MDA	< MDA
2002	< MDA	< MDA	< MDA
2003	< MDA	< MDA	< MDA
2004	< MDA	< MDA	< MDA
2005	< MDA	< MDA	< MDA
2006	< MDA	< MDA	< MDA
2007	< MDA	< MDA	< MDA
2008	< MDA	< MDA	< MDA
2009	< MDA	< MDA	< MDA
2010	< MDA	< MDA	< MDA

Note (*) – Pre-operational of Angra 2 – 1999 - 2000

Table 7: Low level detectable values [7,8]

VIA / RADIONUCLIDES	MILK (Bq/L)	GRASS (Bq/Kg)wet	BANANA (Bq/Kg)wet	SOIL (Bq/Kg)	RIVER SEDIMENT (Bq/Kg)	WATER (Bq/L)
^{3}H	---	---	---	---	---	74,00
^{54}Mn	---	---	---	---	6,70	0,56
^{58}Co	---	---	---	---	---	0,56
^{60}Co	---	---	---	---	6,70	0,56
^{131}I	0,037	2,96	2,22	---	---	0,037
^{134}Cs	0,56	2,96	2,22	5,55	5,55	0,56
^{137}Cs	0,67	2,96	2,96	5,55	6,67	0,67
^{89}Sr	0,37	---	---	---	---	0,37
^{90}Sr	0,074	---	---	5,55	---	0,074

Table 8: Minimum detectable activity values

VIA / RADIONUCLIDES	MILK (Bq/L)	GRASS (Bq/Kg)wet	BANANA (Bq/Kg)wet	SOIL (Bq/Kg)	RIVER SEDIMENT (Bq/Kg)	WATER (Bq/L)
^{3}H	---	---	---	---	---	10,0
^{54}Mn	0,25	0,20	---	---	0,37	0,30
^{58}Co	0,21	0,18	---	---	0,48	0,32
^{60}Co	0,28	0,24	---	---	0,45	0,30
^{131}I	0,006	2,96	0,13	---	---	0,90
^{134}Cs	0,18	0,13	0,06	0,07	0,36	0,25
^{137}Cs	0,17	0,16	0,07	0,60	0,43	0,25
^{89}Sr	0,06	---	---	---	---	0,37
^{90}Sr	0,04	---	---	---	---	---

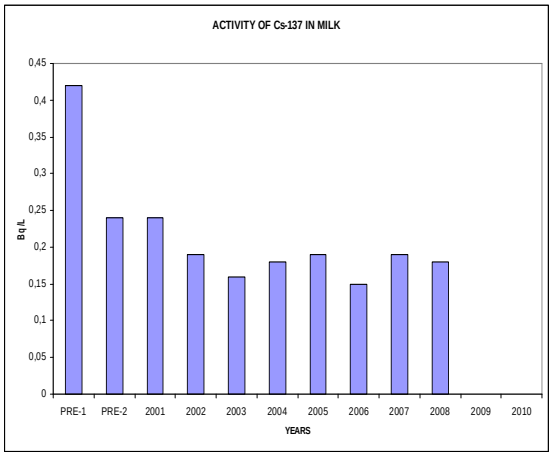

Figure 1: Activity of ^{137}Cs in milk

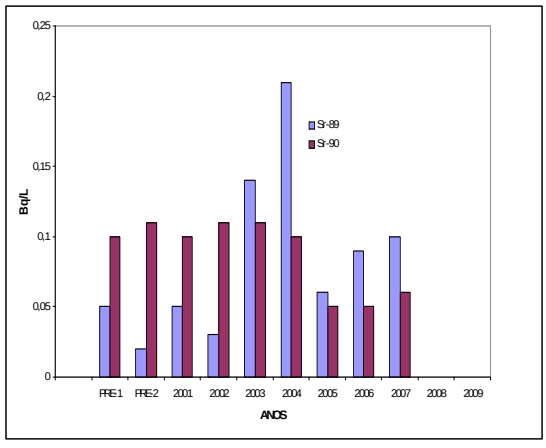

Figure 2: Activity of $^{89}Sr/^{90}Sr$ in milk

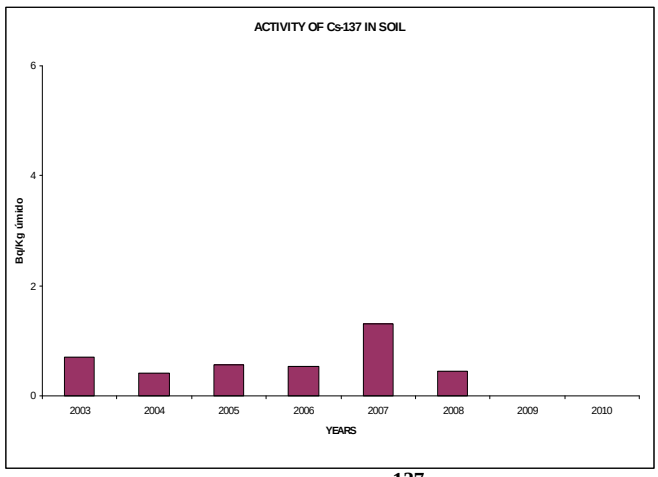

Figure 3: Activity of ^{137}Cs in soil

3. CONCLUSIONS

As can be noted, in the tables 1 to 5, ^{40}K (natural radionuclide) was detected in terrestrial samples. In surface, "underground" and river water no natural radionuclides were detected. Concerning artificial radionuclides, the presences of ^{137}Cs and ^{89}Sr/^{90}Sr were detected in milk and ^{137}Cs in soil samples (Tables 1 and 3), probably due to the atomic tests realized in the 60's and 70's, called "fall-out" deposition. This can be seen since pre-operation of Angra 1 [3].

The pictures shown that the activities obtained form 2001 to 2010, of ^{137}Cs (Figure 1) and ^{89}Sr/^{90}Sr (Figure 2) in the samples of milk and ^{137}Cs in soil (Figure 3), are statistically similar those from pre-operational time of Angra 1 and Angra 2.

It can be concluded that from 1982 until today, there is no significant impact detected at the terrestrial environment caused by the operation of both nuclear plants.

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