

External Exposure Rates from Terrestrial Radiation at Guarapari and Meaipe in Brazil

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INTRODUCTION

Recently epidemiological and cytogenetic studies have been focused on inhabitants living in high background radiation areas (HBRAs) in order to examine health effects of exposure to low dose radiation¹⁻²⁾. Guarapari and Meaipe are towns built on the monazite sand region along the Atlantic coast in Brazil, which is one of the most widely known HBRAs in the world. The UNSCEAR 1982 Report³⁾ has described the towns as follows: Guarapari is a community of 12000 people which receives an influx of about 30000 vacationers every summer. In that town, the absorbed dose rates in air were found to range from 1 to 2 $\mu\text{Gy/h}$ in the streets and up to 20 $\mu\text{Gy/h}$ over selected spots on the beach. Cullen by means of thermoluminescent dosimeters distributed to 317 inhabitants of Guarapari determined the average absorbed dose rate from external terrestrial irradiation (indoors plus outdoors) to be 0.63 $\mu\text{Gy/h}$, with a range of 0.1 to 3.2 $\mu\text{Gy/h}$. Meaipe is a fishing village of about 3000 people, situated 50 km to the South of Guarapari, where the radiation environment is similar: the outdoor average absorbed dose rate in air is about 1 $\mu\text{Gy/h}$, with levels up to 10 $\mu\text{Gy/h}$.

Few epidemiological and cytogenetic studies, however, have been made on inhabitants living there. As an initial step toward international collaborative studies in this field, a preliminary radiological survey was carried out in these towns in cooperation with the Brazilian Nuclear Industries in September 1998. These results are dealt with in the present paper.

MATERIALS AND METHODS

Measurements of absorbed dose rate in air were made at one meter above the ground and on the surface with a portable NaI(Tl) scintillation survey meter: Aloka TCS-166. In-situ γ -spectrometry was also carried out on the Areia Preta Beach with a portable spectro-survey-meter: Hmamatsu Photonics SS- γ /C3475. Each of us carried a personal dosimeter: Aloka PDM-101 at all times.

Sand and soil were sampled in Guarapari and Meaipe, and brought to Japan. These samples were dried, crushed and sieved. About 100 g of each sample was stored in a measurement container for an ingrowth period longer than 40 days. These containers were sealed after shutting so that Rn-222 and Rn-220 could not escape. Ra-226 and Th-232 concentrations in each sample were determined from intensities of γ -ray from Pb-214 and Bi-214, and Ac-228, Pb-212 and Tl-208, respectively.

Figure 1 shows the locations of Guarapari and Meaipe in Brazil. In Guarapari, the present survey was carried out mainly around the Areia Preta Beach and the Pedro Caetano Street, where high absorbed dose rates have been reported⁴⁻⁸⁾. These survey points are seen in Fig.2, where a numeral in angle brackets means a survey point number in Tables 1 – 6.

RESULTS

1. Outdoor absorbed dose rate in air in Guarapari

Table 1 indicates absorbed dose rates in air at streets and sidewalks in Guarapari. The highest dose rate of 0.6 $\mu\text{Gy/h}$ at one meter height was observed at the street in front of the Centro Post Office and the dose rate on the surface exceeded 1 $\mu\text{Gy/h}$. Dose rates at one meter height in the streets and sidewalks were however lower than 0.4 $\mu\text{Gy/h}$ except for this point and a few places near the Areia Preta Beach.



Fig.1 Locations of Guarapari and Meaipe in Brazil.

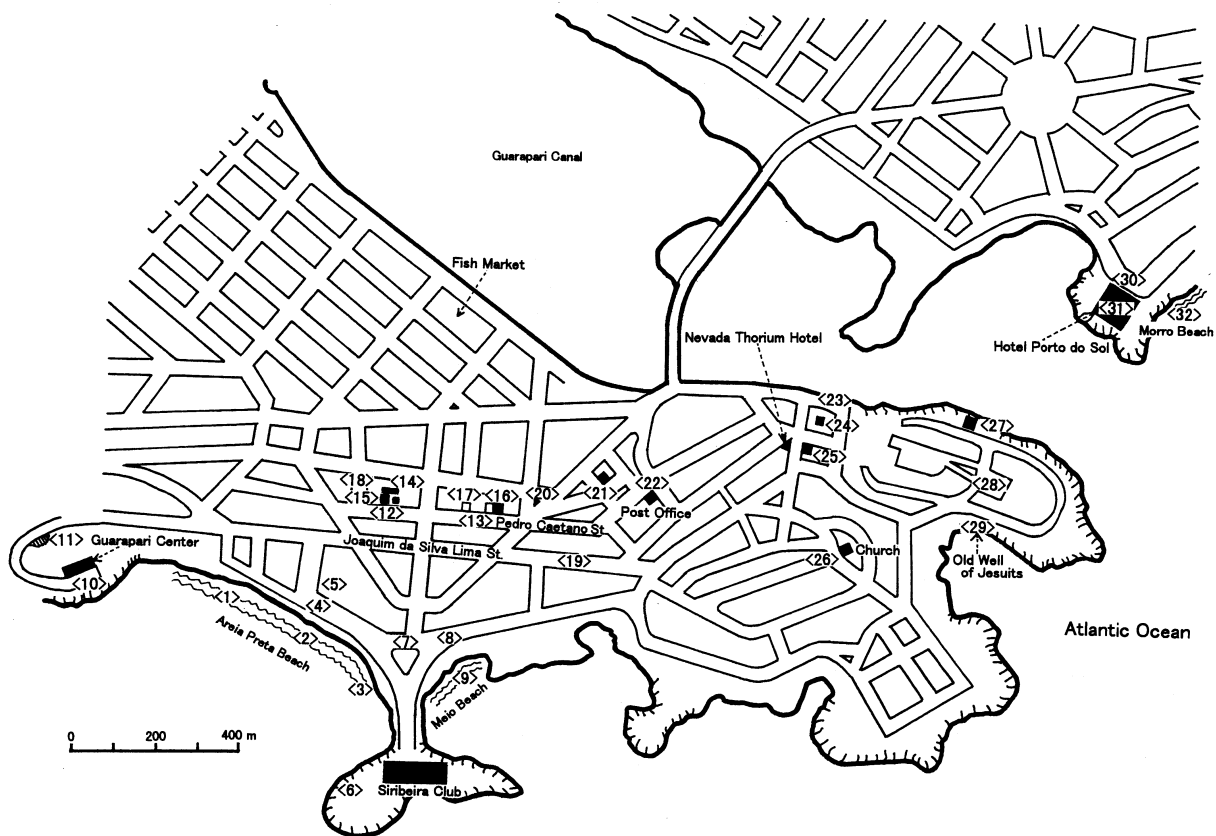


Fig.2 Survey points in Guarapari.

Table 1 Absorbed dose rate in air at streets and sidewalks in Guarapari.

Place	Point No.	Dose rate (μGy/h)	Range (μGy/h)	Remarks	Measuring condition
developing quarter	28	0.20	0.18-0.22	unpaved : red soil	↑ at 1m height ↓
Areia Preta Beach St.	4	0.20	0.19-0.20	paved	
Pedro Caetano St.	13	0.13		paved	
Pedro Caetano St.	12	0.13		paved with stones, in front of House2<15>	
lane in Centro	21	0.26		paved with stones	
in front of Hotel Porto do Sol	30	0.28	0.25-0.30	paved	
Joaquim da Silva Lima St.	19	0.16	0.15-0.17	paved, shopping quarter	
Dr. Roberto Calmon St.	20	0.14	0.13-0.15	paved, near Cash dispenser	
Joaquim A. de Castro St.	23	0.39		concrete slabs had been removed	
in front of Matriz N.S. Church	26	0.25		paved with stones	
in front of Centro Post Office	22	0.60		paved	
M. Silva St.	18	0.19		excavated area	
Areia Preta Beach St.	4	0.43	0.23-0.62	paved	↑ surface ↓
Areia Preta-Meio Beach St.	7	0.24		paved	
Meio Beach St.	8	0.10		paved	
in front of Hotel Porto do Sol	30	0.15	0.10-0.20	paved	
Joaquim da Silva Lima St.	19	0.12	0.10-0.14	shopping quarter	
developing quarter	28	0.30		unpaved : red soil	
Pedro Caetano St.	13	0.15		paved	
Joaquim A. de Castro St.	23	0.71	0.69-0.73	concrete slabs had been removed	
Dr. Roberto Calmon St.	20	0.18	0.17-0.19	near Cash dispenser	
in front of Matriz N.S. Church	26	0.32		paved with stones	
in front of Centro Post Office	22	0.94	0.80-1.07	paved	
M. Silva St.	18	0.30		bottom of excavated hole	
Sidewalk Areia Preta Beach St.	4	0.50		paved	

Table 2 Absorbed dose rate in air at beaches in Guarapari.

Place	Point No.	Dose rate (μGy/h)	Range (μGy/h)	Remarks	Measuring condition
Areia Preta Beach	1	2.0	1.0-3.0		↑ at 1m height ↓
		6.0	5.8-6.2	hot spot	
	4.7		0m from breakwater (at the ebb)		
	6.2		1m from breakwater		
	5.6		2m from breakwater		
	5.0		3m from breakwater		
	4.1		4m from breakwater		
	2	3.9		5m from breakwater	
		3.7		6m from breakwater	
		2.7		7m from breakwater	
		1.7		8m from breakwater	
		0.98		9m from breakwater	
		0.60		10m from breakwater	
Areia Preta Beach	3	0.09	0.08-0.10	white sand	
		0.09			
Meio Beach	9	0.09			
Morro Beach	32	0.20		near Hotel Porto do Sol	
Areia Preta Beach	1	4.0	3.0-5.0		↑
	2	11	7.2-15.0	hot spot	surface
		1.5		sun and sand bathing spot	↓

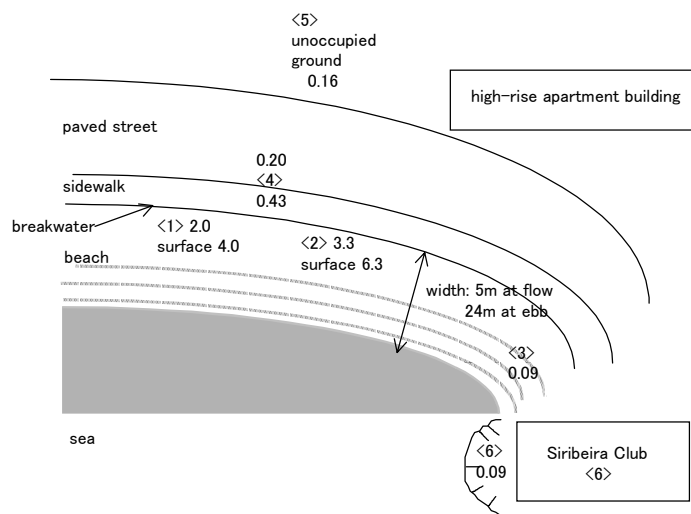


Fig. 3 Absorbed dose rates in air around the Areia Preta Beach. (unit : μGy/h)

Table 2 gives absorbed dose rates in air at beaches in Guarapari and Fig.3 shows dose rates around the Areia Preta Beach. It is clear from these results that absorbed dose rates at the Areia Preta Beach were higher than any other places. The highest rate at one meter height was 6.2 μGy/h and the highest rate on the surface of beach sands 15 μGy/h. The “Areia Preta,” which means black sand, is so much sought after by Brazilian people for their alleged benefits to health that they come from long distances to spend their vacations on the black sands⁸⁾. Figure 4a is an in-situ γ-spectrum observed on the surface of the highest spot in the Areia Preta Beach with a spectro-survey-meter, while Fig.4b is a γ-spectrum of a monazite sample. Both the spectra are similar to each other. At the area where black sand was not found in the Areia Preta Beach, however, the absorbed dose rate was 0.09 μGy/h, and in the Meio Beach which is the next white-sands beach separated from the Areia Preta Beach by a small cape, the dose rate was 0.09 μGy/h.

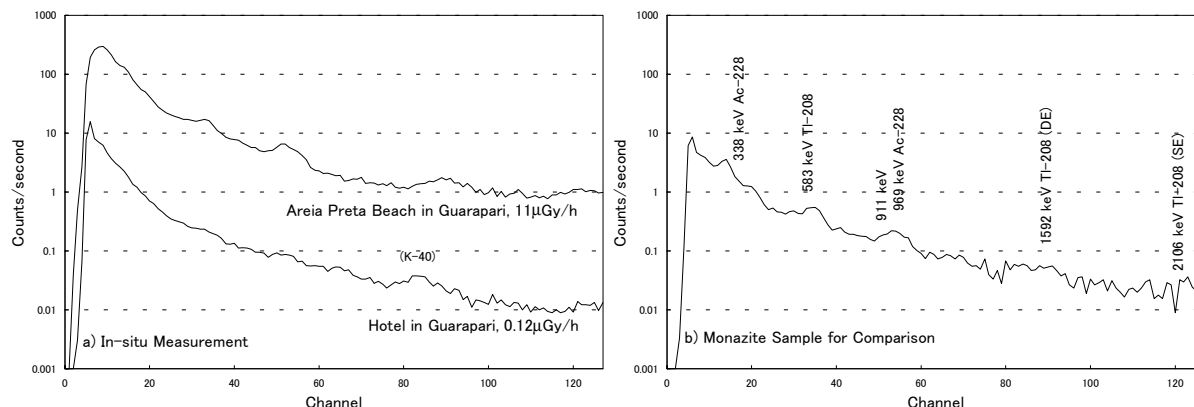


Fig.4 In-situ γ -spectra observed with a spectro-survey-meter.

2. Indoor absorbed dose rate in air in Guarapari

There were many high-rise apartment buildings along the Areia Preta Beach Street. The Joaquim da Silva Lima Street had become a shopping quarter with many buildings. On the contrary, there were hardly any stores or high buildings along the Pedro Caetano Street, and many old one-storied dwelling houses remained. The house, however, could not be found, which had been located on this street in the 1960s and whose indoor dose rate had been reported by Roser and Cullen⁶⁾ to be 2 μ Gy/h. Three old one-storied houses which appeared to have been built using beach sand, were therefore surveyed on this street.

Table 3 Absorbed dose rate in air inside houses in Guarapari. (at 1m height)

	Place	Point No.	Dose rate (μ Gy/h)	Range (μ Gy/h)	Remarks	Measuring condition
House 1	living room 1	14	0.14		Pedro Caetano St. built about 45 years ago surveyed by PUC-RJ	↑ at 1m height ↓
	living room 2		0.14			
	bedroom 1		0.15			
	bedroom 2		0.16			
	dining room		0.12			
	kitchen		0.12			
House 2	living room	15	0.20		Pedro Caetano St.	
	kitchen		0.18			
House 3	living room	16	0.30		Pedro Caetano St.	
	bedroom 1		0.30			
	bedroom 2		0.26			
	dining room		0.39			
	kitchen	0.40				
Library	center of the 1st floor	25	0.20			
Post Office	center of the 1st floor	22	0.10		Centro Post Office	
House 6	porch on the 3rd floor	27	0.09	0.08-0.09	house under construction	
	center		0.12	0.11-0.12		
Room 24	bed 1	31	0.12		Beira Mar St.01, Morro Beach	
	bed 2		0.12			
Hotel	table 1	31	0.10		Beira Mar St.01, Morro Beach	
	table 2		0.10			
Porto do Sol	table 3	31	0.11		Beira Mar St.01, Morro Beach	
	desk		0.10			
	bathroom		0.11			
	wardrobe		0.11			
	near entrance		0.11			
	near door to porch		0.11			
	porch		0.11			

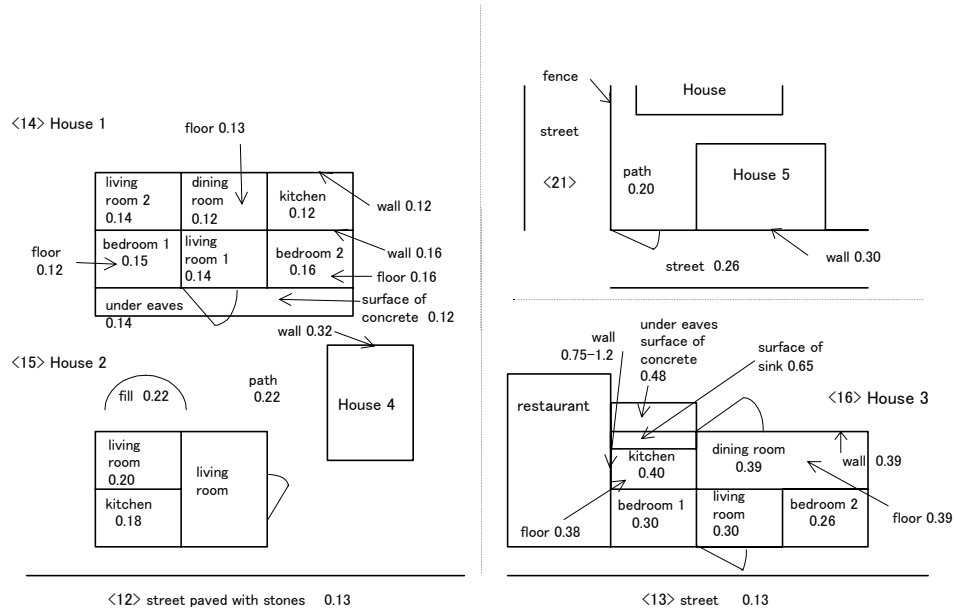


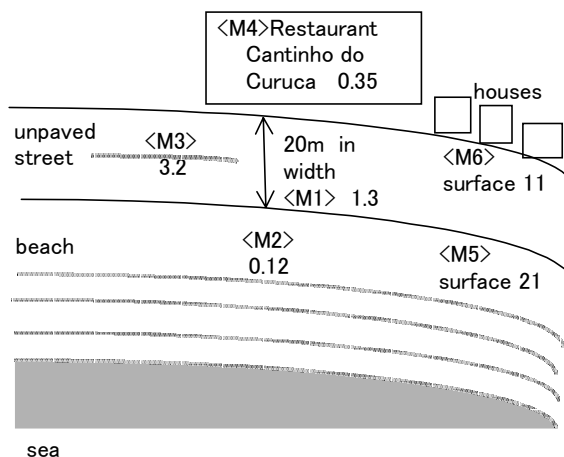
Fig.5 Absorbed dose rate in air inside houses along the Pedro Caetano Street in Guarapari. (unit : $\mu\text{Gy/h}$)

Table 4 Absorbed dose rate in air inside houses in Guarapari. (on the surface)

Place	Point No.	Dose rate ($\mu\text{Gy/h}$)	Range ($\mu\text{Gy/h}$)	Remarks	Measuring condition
House 1	14	bedroom 1 : tiled floor	0.12	Pedro Caetano St. built about 45 years ago surveyed by PUC-RJ	↑ surface ↓
		bedroom 2 : concrete floor	0.16		
		bedroom 2 : wall	0.16		
		dining room : tiled floor	0.13		
		kitchen : wall	0.12		
House 3	16	dining room : floor	0.39	0.75-1.20 Pedro Caetano St.	↑ surface ↓
		dining room : wall	0.39		
		kitchen : wall	0.98		
		kitchen : floor	0.38		
		kitchen : sink	0.65		
Room 24 Hotel Porto do Sol	31	floor	0.11	near door to the porch center near entrance bathroom shower room porch inner wall near porch near desk near entrance near bed between bedroom and bathroom near washstand inner wall of bathroom inside wardrobe	↑ surface ↓
		floor	0.09		
		floor	0.09		
		floor	0.11		
		washstand	0.12		
		floor	0.10		
		floor	0.10		
		wall	0.11		
		wall	0.11		
		wall	0.13		
		wall	0.11		
		wall	0.09		
wall	0.12				
wall	0.11				
wall	0.10				

Tables 3 and 4 indicate absorbed dose rates at one meter height and on the surface, respectively, which were observed inside houses in Guarapari. Figure 5 reveals dose rates inside houses along the Pedro Caetano

Street. Although a dose rate of 0.4 $\mu\text{Gy/h}$ was observed inside house 3, those inside the other houses did not exceed 0.2 $\mu\text{Gy/h}$, which includes the house where the Pontifical Catholic University, Rio de Janeiro surveyed in



the 1960s, and the Centro Post Office, in the street in front of which a dose rate attained 0.6 $\mu\text{Gy/h}$.
 Fig.6 Absorbed dose rate in air around the Meaie Beach. (unit : $\mu\text{Gy/h}$)

Table 5 Absorbed dose rate in air in Meaiepe.

Place	Point No.	Dose rate ($\mu\text{Gy/h}$)	Range ($\mu\text{Gy/h}$)	Remarks	Measuring condition
Street Centro	M7	0.13	0.12-0.13	paved with stones, 5m in width	↑ at 1m height ↓
	M8	0.35			
	M9	0.12	unpaved		
Street unpaved Beach St. 20m in width, red soil	M3	3.2	1.2-5.2	center along the beach	
	M1	1.6	1.6-1.9	5m from Restaurant Cantinho do Curuca	
		1.8		10m from the Restaurant	
1.4		15m from the Restaurant			
		0.36		20m from the Restaurant	
Beach	M2	0.12		in front of the Restaurant	
Unoccupied Centro ground	M7	0.13		soil	
Restaurant indoor	M4	0.40		covered with sand	↓
Restaurant indoor	M4	0.30		bricked floor	
Street unpaved Beach St.	M1	3.9	3.3-4.4	10m from the Restaurant	↑
Verge unpaved Beach St.	M6	11		sand	
Restaurant inside floor	M4	0.40		covered with sand	surface
Restaurant inside floor		0.50		under a 10cm-thick sand cover	
House outer wall	M7	0.13		Centro	↓
Beach hot spot	M5	21	10-32		

The absorbed dose rate inside room 24 of Hotel Porto do Sol on the Morro Beach was about 0.1 $\mu\text{Gy/h}$, and the spectrum of the indoor gamma-rays, which is illustrated in Fig.4a, indicated a dull peak from potassium-40 alone.

As shown in Table 4, the highest absorbed dose rate on the surface was observed on the wall of the kitchen in house 3, whose value was 1.2 $\mu\text{Gy/h}$, while those in the other houses were below 0.2 $\mu\text{Gy/h}$.

3. Absorbed dose rate in air in Meaiepe

Table 5 and Fig.6 indicate absorbed dose rates observed in Meaiepe. The Meaie Beach Street was an unpaved road along the beach, which was about 20 m wide. Dose rates were high along the center of the street, whose highest value was 5.2 $\mu\text{Gy/h}$. The highest absorbed dose rate of 32 $\mu\text{Gy/h}$ on the surface was observed on the beach near the breakwater. There was a restaurant along the street, whose floor was covered with beach sand.

The highest absorbed dose rate on the surface inside the restaurant was 0.5 $\mu\text{Gy/h}$. In downtown, absorbed dose rates at one meter height generally ranged from 0.1 to 0.4 $\mu\text{Gy/h}$.

Table 6 Th-232 and Ra-226 concentration in sand and soil sampled around Guarapari.

Sampling place	sample	Point No.	Th-232 (Bq/kg-dry)		Ra-226 (Bq/kg-dry)	
Present Work						
Meaipe Beach (white sand)	sand	M2	57 \pm	2	11 \pm	1
M. Silva St. (under repair)	soil	18	120 \pm	2	15 \pm	1
In front of Matriz N.S. Church	soil	26	174 \pm	4	32 \pm	2
Joaquim A. de Castro St. (under repair)	soil	23	316 \pm	7	47 \pm	2
Meaipe Beach St. (unpaved)	sand	M1	1 070 \pm	13	115 \pm	4
Areia Preta Beach	sand	1	5 320 \pm	112	554 \pm	31
Areia Preta Beach (hot spot)	sand	2	27 500 \pm	592	2 250 \pm	151
Meaipe Beach (hot spot)	sand	M5	41 200 \pm	858	4 070 \pm	246
Sand for filling up a pendant :Sample 1	sand	24	5 730 \pm	154	940 \pm	49
Sand for filling up a pendant :Sample 2	sand	24	113 000 \pm	1 220	14 400 \pm	354
Malanca(1995) ⁹⁾ Concentration range of						
Areia Preta : black sand sampled around Guarapari			190 - 36 600		25 - 2 410	
UNSCEAR(1982) ³⁾						
Typical range of concentration in ordinary soil			7 - 50		10 - 50	

4. Averaged effective dose rate

Our effective dose rate from external terrestrial irradiation (outdoors and indoors) was 0.17 $\mu\text{Sv/h}$ on the average during the period of our three day stay in Guarapari and Meaipe, which was determined with a personal dosimeter. In the same way the effective dose rate during the stay in Rio de Janeiro was found to be 0.15 $\mu\text{Sv/h}$, which was barely different from the former.

5. Th-232 and Ra-226 concentrations in sand and soil

Table 6 indicates Th-232 and Ra-226 concentrations in sand and soil sampled in Guarapari and Meaipe. Th-232 concentrations ranged from 57 to 41200 Bq/kg-dry and Ra-226 concentrations from 11 to 4070 Bq/kg-dry. These results are similar to those of Malanca et al.⁹⁾. They also reveal that Th-232 and Ra-226 concentrations in sand sampled from the white sand part was not so high, compared with the typical range of concentration in ordinary soil³⁾, even if it was from the Meaipe Beach.

A souvenir stand in the Jeronimo Monteiro Plaza sold glass pendants filled up with beach sand, where samples 1 and 2 were given to us. While the concentrations in sand of sample 1 obtained lately from the beach was consistent with those of sand we sampled at point 1 in the Areia Preta Beach, those of sample 2 obtained about 40 years ago were much higher than those of the sample we and Malanca et al.⁹⁾ obtained in the 1990s.

DISCUSSION

From results of the present survey, in Guarapari and Meaipe, absorbed dose rates in the streets ranged from 0.1 to 0.4 $\mu\text{Gy/h}$ except for a few places such as near the Areia Preta Beach and Meaipe Beach. Dose rates inside houses were lower than 0.2 $\mu\text{Gy/h}$ except for two houses where an indoor dose rate attained 0.4 $\mu\text{Gy/h}$. These values are lower than those observed in the 1960s, which were cited in UNSCEAR reports^{3,10,11)}. We have, therefore, searched literature which deals with dose rates around Guarapari after the 1970s.

Pfeiffer et al.¹²⁾ has indicated that considerable changes had taken place in many sites surveyed by Roser and Cullen⁴⁻⁸⁾: dirt streets were paved, new roads were built, and cement floors were laid down inside houses. Their results for those places did not agree with those reported by Roser and Cullen.

The Military Institute of Engineering, Brazil (IME)⁶⁾ has made measurements of environmental gamma radiation in the high background radiation area and the results suggested that there was a reduction in the levels of external exposure rates in the streets and squares in Guarapari because of building materials brought with urbanization.

Oliveira et al.¹³⁾ has described that progress and transformation of Guarapari and Meaipe into beach resorts with paved streets, new highways and intense urbanization brought about sweeping changes in their radiological characteristics.

For verification of these views, Table 7 gives ranges of absorbed dose rate in air at four places where Roser et al.⁶⁾, IME⁶⁾ and we surveyed in common. This table indicates that although there are hardly any gaps in ranges among three results for the unpaved Meaipe Beach Street and the Areia Preta Beach, the maximum dose rates in the 1990s are much lower than those in the 1960s for the Joaquim da Silva Lima Street and the Pedro Caetano Street. This fact means that dose rate levels have decreased clearly in downtown, while the levels have scarcely changed on beaches and unpaved beach streets which have not been developed yet, which is in agreement with the three views.

Table 7 Absorbed dose rate in air, in Guarapari in the 1960s and the 1990s.

Place	(μGy/h)		
	*Roser & Cullen(1962) ⁶⁾	* IME (1993) ⁶⁾	Present work
Joaquim da Silva Lima St.	0.70 - 2.1	0.10 - 0.22	0.10 - 0.17
Pedro Caetano St.	0.17 - 2.2	0.09 - 0.30	0.13
Areia Preta Beach	0.07 - 3.5	0.03 - 10	0.09 - 6.2
Meaipe Beach St.	0.09 - 7.4	0.11 - 6.8	0.36 - 5.2

*: Values of Roser & Cullen and IME were converted from exposure rate (μR/h).

CONCLUSIONS

Our results suggests that the natural radiation environment of Guarapari and Meaipe has varied with urbanization which brought paved streets, and changes in the structure and building materials of houses. The average absorbed dose rate : 0.63 μGy/h³⁾ of inhabitants living in Guarapari from external terrestrial irradiation, which has been cited in the UNSCEAR report, ought to be revised. A detailed survey is necessary in order to evaluate present absorbed dose rates in air in this area.

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