ENVIRONMENTAL RADIOACTIVITY MEASUREMENTS IN THE PHILIPPINES

ABSTRACT

Monitoring of terrestrial and marine environment for radioactivity arising from natural and artificial sources were conducted regularly as part of the environmental radiation surveillance program of the Institute. External gamma radiation in ambient air was measured in established monitoring stations surrounding PRR-1 facility using a High Pressure Ion Chamber. Samples of fish and seawater were collected from the coasts of Surigao City, Surigao, Borongan, Eastern Samar and Basco, Batanes and were analyzed for ^{137}Cs. The average ambient gamma dose rate observed around PRR-1 facility was 49 nGy h^{-1} which falls closely with the average ambient gamma dose rate of 45 nGy h^{-1} observed over the entire Philippines (Duran *et.al.*, 1996). The average ^{137}Cs activity concentration of 4 Bq m^{-3} measured in seawater falls within the range of values (2 to 13 Bq m^{-3}) reported for seawater collected from the Pacific Ocean (Duran *et.al.*, 1996) and those reported in FAO Area 61 (Aarkrog *et.al.*, 1996). The average ^{137}Cs activity concentration of 4 Bq kg^{-1} dry (3 Bq kg^{-1} wet) observed in fish samples falls within the reported range of values (0.1 to 3 Bq kg^{-1} wet) for fish (Duran *et.al.*, 1996, Aarkrog *et.al.*, 1996).

OBJECTIVES

The project deals mainly with the determination of natural radioactivity levels in the Philippines and with environmental surveillance for radioactive fallout. Natural radioactivity measurements consists of two phases, namely: (1) measurement of exposure dose in the ambient environment due to cosmic radiation and naturally deposited radioactive ores and substances; (2) measurement of absorbed dose due to ingested radioactive substances (through diet and drinking water) which occur in nature. Environmental surveillance for global fallout due to nuclear accidents or nuclear weapons tests abroad is a continuing activity to provide radiological protection to the Filipino people from man-made sources of radiation.

Specific objectives are as follows:

1. To determine the average annual absorbed dose rate received by Filipinos from the ambient environment due to cosmic and terrestrial sources of radiation.
2. To determine the external radiation dose rate around PRR-1 facility as part of environmental radiation surveillance program of PNRI.
3. To collect seawater and fish samples from the Pacific Coast in order to determine the concentration of artificially-produced ^{137}Cs as part of the surveillance work on the French nuclear testings in the Pacific.
4. To estimate external radiation dose rate due to cosmic sources by measuring the dose rate at sea level using High Pressure Ion Chamber.
5. To conduct environmental radiation surveillance activities in specific areas as per

request by the proper authority.

6. To prepare technical paper for possible publication in local and international journals.

METHODS

A. EXTERNAL RADIATION MEASUREMENTS

Total exposure dose rate in the environment was measured using a High Pressure Ion Chamber (HPIC) RSS-112 equipped with a spherical ionization chamber and an electrometer complete with a tripod and data recorder/reader. The HPIC has an energy response ranging from 7 keV to 10 MeV and is capable of measuring dose rates from 0-100 mR h^{-1}. Radiation data were stored in the RSS-112 micro-computer section which can either be manipulated manually or stored in a computer interface software package. The HPIC was set-up in a tripod at a distance of 1 meter above the ground. Radiation readings were recorded at 10 seconds interval for a total of twenty data points. Additional information such as time, weather conditions, etc. were also noted during radiation measurements. Exposure dose rates measured per sampling station were reported in nanoGray per hour (nGy h^{-1}).

B. SAMPLE COLLECTION AND ANALYSIS

Samples of seawater were collected at about 5-km away from the coastline. Collection of seawater was performed by dipping a water bucket and transferring the sample into plastic carboy containers. A total of about 160 liters surface seawater sample was collected per sampling site. Seawater sample was brought to the shore and transferred to a plastic container calibrated to contain 150 liters volume. The pH of sample was adjusted to pH 2-3 with hydrochloric acid and stable cesium carrier was added. The sample solution was mixed by stirring manually. Ammonium molybdophosphate (AMP) was added to complex the cesium in solution. Once equilibrated, the CsAMP complex was collected in a small polyethylene bottle and brought to the laboratory for analysis. The sample was dried at 105°C oven to constant weight and set aside for gamma counting of ^{137}Cs.

About five kilogram sample of fish were collected and kept frozen on ice during transport to the laboratory for processing. The edible portions of fish or the flesh were separated from the inedible portions by filleting and weighed. The edible parts of the sample were dried at 105°C oven to constant weight, pulverized and well mixed thoroughly to homogeneity. About 200 gram of the dried material was placed in a small polyethylene bottle for measurement of ^{137}Cs.

The seawater CsAMP complex powder and the edible dried portion of fish samples were analyzed for ^{137}Cs using an ORTEC High Purity Germanium detector set-up at the AMR laboratory. The HPGe detector was equipped with an MCA card for gamma spectral analysis and was calibrated against a laboratory prepared ^{137}Cs WHO standard for counting efficiency. Counting time was 180 minutes per sample. Activity concentrations of ^{137}Cs were calculated using the photopeak numerical integration of counts and were reported in becquerel per cubic meter (Bq m^{-3}) for seawater and becquerel per kilogram dry weight (Bq kg^{-1} dry) for fish.

RESULTS AND DISCUSSION

1. ENVIRONMENTAL RADIATION SURVEILLANCE

1.a. Around PNRI (PRR-1) facility and its vicinities

External gamma radiation dose rates measured in 18 established monitoring stations around PRR-1 are shown in Table 1 with their corresponding annual average dose rates. One-way ANOVA test for perimeter areas showed gamma dose rates in ONP1, ONP2 and ONP3 significantly different from other stations. The levels observed could be due to enhanced radioactivity from nearby radioactive waste management facility. At one time, a higher gamma dose rate (140 ± 4 nGy h^{-1}) was observed in ONI3 which could have been due to the release of ^{131}I being dispensed at the Irradiation Services at the time of measurement. Based on dose rates measured in 99 sites, the average absorbed dose rate was 49 nGy h^{-1} which fall closely within the range of the average gamma radiation dose rate of 45 nGy h^{-1} observed over the entire Philippines (Duran et.al., 1996).

Table 1. Ambient Gamma Radiation Measurements Around PRR-1

Date	Absorbed Dose Rate, nGy h^{-1}				
PNRI compound	ONI1	ONI2	ONI3	ONI4	ONI5
1-22-96	54 ± 4	53 ± 2	61 ± 4	53 ± 2	42 ± 2
2-06-96	56 ± 2	64 ± 3	64 ± 1	52 ± 3	51 ± 4
6-25-96	44 ± 2	50 ± 3	140 ± 4	36 ± 2	38 ± 3
8-07-96	49 ± 3	48 ± 2	60 ± 3	37 ± 4	44 ± 2
10-02-96	50 ± 2	50 ± 5	58 ± 3	47 ± 3	45 ± 3
Average Dose	51 ± 2	53 ± 3	61 ± 3*	45 ± 2	44 ± 2
PNRI perimeter	ONP1	ONP2	ONP3	ONP4	ONP5
1-24-96	60 ± 2	73 ± 2	73 ± 2	49 ± 3	40 ± 3
2-13-96	71 ± 3	78 ± 3	73 ± 2	47 ± 4	39 ± 2
3-28-96	65 ± 7	69 ± 3	72 ± 4	46 ± 3	36 ± 3
7-11-96	61 ± 3	66 ± 2	73 ± 3	41 ± 3	37 ± 2
9-12-96	50 ± 3	62 ± 3	77 ± 3	42 ± 5	41 ± 6
10-24-96	---	---	61 ± 11	44 ± 3	37 ± 2

Date	Absorbed Dose Rate, nGy h^{-1}				
Average Dose	61 ± 3	69 ± 2	72 ± 4	44 ± 4	38 ± 3
Two-km radius	OFT1	OFT2	OFT3	OFT4	
1-25-96	47 ± 3	62 ± 5	46 ± 3	55 ± 4	
2-14-96	41 ± 4	51 ± 2	44 ± 6	50 ± 4	
3-28-96	38 ± 3	57 ± 5	45 ± 2	47 ± 2	
6-24-96	37 ± 3	46 ± 3	39 ± 4	46 ± 4	
8-14-96	37 ± 3	47 ± 2	34 ± 2	41 ± 3	
11-12-96	41 ± 2	51 ± 2	46 ± 3	44 ± 2	
Average Dose	40 ± 3	52 ± 3	42 ± 3	46 ± 3	
Five-km radius	OFF1	OFF2	OFF3	OFF4	
1-25-96	49 ± 4	56 ± 4	44 ± 3	47 ± 4	
2-14-96	40 ± 2	43 ± 3	35 ± 4	40 ± 4	
3-28-96	38 ± 3	48 ± 4	42 ± 4	38 ± 4	
6-24-96	32 ± 3	39 ± 2	37 ± 2	32 ± 2	
8-15-96	32 ± 2	—	39 ± 3	34 ± 3	
11-12-96	42 ± 3	43 ± 4	43 ± 2	40 ± 2	
Average Dose	38 ± 2	45 ± 3	40 ± 3	39 ± 3	

*Average dose rate does not include 140 ± 4 nGy h^{1}.

1.b. PNRI Grid Sites

Table 2 showed external gamma radiation dose rates measured in 22 grid sites within the PNRI compound. Absorbed dose rate ranges from 27 to 84 nGy h^{-1} with an average dose rate of 41 nGy h^{-1} The observed levels do not differ from the average dose rate of 43 nGy h^{-1} observed last year.

Table 2. External Gamma Radiation Measurements at PNRI Grid Sites

Sample Code	Specific Location	Absorbed Dose Rate nGy h^{-1}
S6	Between storage shed and ^{60}Co gamma garden, near ONI4 site	52 ± 5
S7	Between ^{60} Co Irradn. Bldg. & water tank	42 ± 2
S8	Agri garden (guava & balimbing orchard)	40 ± 2
S9	Agri garden (pineapple, gabi & camote orchard)	34 ± 4
S11	RP garden (back of nipa hut)	84 ± 10
S12	Side of Indust. Appl. Bldg. (back of Irrad. Lab, near ONI3 site)	57 ± 7
S13	Side of Animal Fac. Bldg (near Agric. rice field)	39 ± 3
S14	Between Cyto. Lab & Env. Measurements Lab.	38 ± 3
S15	In front of HP Modular Bldg	42 ± 3
S16	Between Biomed 1 & 2 Bldg (near guava tree)	44 ± 4
S17	In front of new Admin. Bldg (near PNRI symbol)	39 ± 3

Sample Code	Specific Location	Absorbed Dose Rate nGy h^{-1}
S18	Left side of flagpole In front of ARC Bldg (concrete pavement)	37 ± 2
S19	Basketball court (concrete pavement)	28 ± 3
S20	Near guardhouse & PNRI main gate (concrete pavement)	26 ± 2
S21	Back of PNOC-ERDC Bldg.	30 ± 3
S22	Side of new Admin. Bldg near HP Modular Lab.	30 ± 2
S23	Facing poolside area near volleyball court (concrete pavement)	28 ± 6
S24	Back of PNRI canteen and front of Irrad. Lab.	37 ± 2
S27	Near Nuclear Training side entrance	43 ± 3
S28	Corner of PNRI garden near ONI1 site	47 ± 2
S29	In front of ARC main building entrance	27 ± 3
S30	Back of ARC Bldg. near PRR-1 dome structure	49 ± 3

1.c. At Sea Level

To estimate the absorbed dose rate due to cosmic radiation, external radiation measurements were conducted at Bgy. Sineguelasan, Binakayan, Cavite. Radiation measurements were taken from the shore and at several distances from the shore at corresponding water depth. Sufficient shielding of terrestrial components of natural radiation was achieved at about 5 km away from the shore with 6-8 meters water depth. At this level, the cosmic radiation component was estimated to be 21 nGy h^{-1}.

Table 3. External Gamma Radiation Measurements at Sea Level

Sampling Site	Absorbed Dose Rate nGy h^{-1}
along the shore	26.0 ± 2.1
about 1 meter water depth	26.4 ± 3.4
about 3 meter water depth	23.0 ± 2.3
about 4.5 meter water depth (3 km away from shore)	23.5 ± 2.8
about 6 meter water depth	21.0 ± 5.1
about 7.5 meter water depth (5 km away from shore)	21.3 ± 3.0

1.d. Other Related Activities

Radiation monitoring activities were undertaken in San Marcelino, Zambales in response to reports of alleged presence of radiation in lahar-affected areas. San Marcelino, Zambales is a town where vast land masses have been buried with lahar since the eruption of Mt. Pinatubo in 1991. HPIC gamma radiation readings taken from 2 sampling points in Sto. Tomas river area had an average absorbed dose rate of 48.9 ± 3.1 nGy h^{-1}. Samples of

lahar and riverwater were also collected for subsequent analysis. This activity was organized by the Radiation Health Service of the Department of Health together with four sections of PNRI represented by HPR, RP, AMR and NMR.

2. DETERMINATION OF ^{137}Cs

Environmental surveillance work in connection with the French nuclear weapons tests in the Pacific was conducted in some coastal areas of the Pacific Ocean. Based on current data on water movement, samples of seawater samples were collected off the coast of Surigao City and Borongan, Eastern Samar. Samples of fish caught in these waters were also collected. As part of the HP surveillance program for artificial sources of radiation that may arise from nuclear power generating plants in neighboring countries like Taiwan, seawater and fish samples were also collected in Basco, Batanes.

Tables 4 and 5 showed activity concentrations of ^{137}Cs in samples of seawater and fish. The average ^{137}Cs activity concentration in seawater was 4 Bq m^{3} which falls within the range of values (2 to 13 Bq m^{-3}) reported for seawater in the Pacific Ocean (Duran et.al., 1996). Activity concentration of ^{137}Cs in fish ranges from 2 to 7 Bq kg^{-1} dry, with an average of 4 Bq kg^{-1} dry (or 3 Bq kg^{-1} wet) which falls within the reported range of values (0.1 to 3 Bq kg^{-1} wet) reported for fish (Duran et.al., 1996). Based on these concentrations, no increase in the levels of ^{137}Cs in Philippines Pacific coastal waters and in fish samples were observed. Likewise, no significant increase in the level of ^{137}Cs in seawater and fish samples were also observed in Basco, Batanes.

Table 4. Activity Concentration of ^{137}Cs in Seawater Samples

Location	Date Collected	Activity concentration Bq m^{-3}	LLD
Surigao City, Surigao	2-21-96	5.0 ± 0.9	2.1
Basco, Batanes	6-06-96	3.5 ± 0.8	2.1
NP Borongan, E. Samar	10-10-96	4.3 ± 0.9	2.2
SP Borongan, E. Samar	10-10-96	3.0 ± 0.9	2.3

Table 5. Activity Concentration of ^{137}Cs in Fish Samples

Sample	Location	Date Collected	Activity concentration Bq kg^{-1} dry	LLD
Tambakol	Rizal, Surigao City	2-22-96	4.8 ± 1.1	2.6
Alumahan	Rizal, Surigao City	2-22-96	2.5 ± 0.7	1.7

Sample	Location	Date Collected	Activity concentration Bq kg^{-1} dry	LLD
Dalagang bukid	Tabuk, Surigao City	2-22-96	3.8 ± 1.0	2.6
Samaral	Uyugan, Batanes	6-07-96	2.1 ± 0.9	2.8
Flying fish	Basco, Batanes	6-09-96	3.1 ± 0.8	2.2
Matangbaka	Borongan, E. Samar	10-11-96	5.6 ± 1.1	2.7
Talakitok	Borongan, E. Samar	10-10-96	7.2 ± 1.6	4.0
Salmon	Borongan, E. Samar	10-11-96	4.0 ± 1.0	2.4

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