Radiation dose map at the Peruvian Antarctic Station

José Osores*, Susana Gonzáles

Instituto Peruano de Energía Nuclear, Av. Canadá 1470, Lima 41, Perú.

Abstract

During January 2015, gamma-absorbed dose rates of natural radionuclides above ground were calculated throughout different areas of the Peruvian Antarctic Station “Machu Picchu”. The median outdoor gamma dose rate in air was determined as 43 ± 5 nGy/h. Using the data obtained in this study the median annual dose was found to be about 376 ± 44 μGy. These dose values are far below the doses reported in Peruvian territory due to the geographical location of the station.

Key words: Antarctic; Natural radioactivity; Dose rates

Mapa de dosis de radiación en la Estación Antártica Peruana

Resumen

Durante enero de 2015, tasas de dosis gamma absorbidas debido a radionúclidos naturales por encima del suelo fueron calculadas a través de diferentes áreas de la Estación Antártica Peruana “Machu Picchu”. La tasa de dosis gamma media al aire libre en el aire fue 43 ± 5 nGy/h. Utilizando los datos obtenidos en este estudio la dosis anual promedio se encontró que era aproximadamente de 376 ± 44 μGy. Estos valores de dosis se encuentran muy por debajo de las dosis reportadas en el territorio peruano debido a la ubicación geográfica de la estación.

Palabras clave: Antártica; Radiactividad natural; Tasas de dosis

1. Introduction

Soils of Antarctica are widely regarded as poor regarding nutrients, places for plants and habitats for organisms. Some authors described them as young soils without horizons and raw in terms of their functions for soil processes [1]. King George Island has an ice-free area of about 8 %, weathered soils derived mainly from volcanic rock (andesite basalts and theirs pyroclastics), however, sedimentary rock may be also important in few sites. The periglacial condition with cryoturbation widely prevents active plant growth. Nevertheless, a great variety of soils has been described for Arctowski region, such as Haplorthels, Umbriturbels, Umbriorthels, Aquiturbels, Haploturbels, Sapristels, Mollorthels, and Psammorthels as determined according to Soil Survey Stuff 1998 [2]. Cryosols, Leptosols, Regosols and Fluvisols (WRB taxonomy) are described as main types for the Keller Peninsula region [3].

Ongoing climate warming affects Antarctic environments like others in the world. Several indicators show these effects which can be seen in ecological studies. For example the spread of the endemic higher plants to new places, so far only covered by lichens or mosses, leading to new environments with higher trophic relationships, followed by significant changes in the soil environment. Natural radioactivity is wide spread in the earth’s environment; it exists in biotic and abiotic components. Environmental natural gamma radiation is formed from natural radionuclides include the primordial radioactive elements in the earth's crust, their radioactive decay products, and radionuclides produced by cosmic-radiation interactions. Low levels of uranium, thorium, and their decay products are found everywhere; however, locations with higher concentrations of these radionuclides in their soil have higher dose levels. Natural radionuclides in soil generate a significant component of the background radiation exposure of the population [4].

Gamma radiation intensity in a region depends on soil and geographic structure. The natural radioactivity in soil comes mainly from the ^{238}U, ^{232}Th decay series and natural ^{40}K, respectively [5].

Perú has been a State Party to the Antarctic Treaty since 1981, and has been accepted as a Consultative Party in 1989. In order to

* Corresponding author: josores@ipen.gob.pe

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develop scientific studies in situ Perú established a Scientific Station, named Machu Picchu (ECAMP), located at King George Island in Admiralty Bay, which is used as a summer station [6]. The main objective of this study was to evaluate the annual absorbed dose from outdoor terrestrial radiation. This study would be useful for establishing base line data on the gamma background radiation levels in different areas of the ECAMP for assessment of radiation exposures to the environment and possible variations due to climate change.

2. Material and methods

The Machu Picchu Scientific Station (62°5´ S, 58°28´W) is a Peruvian polar scientific research facility in Antarctica (Fig. 1), established to conduct Antarctic research on environmental chemistry, physics, climatology and biology. The surface area of study is about 0.2 km^2. Influence area cover 0.38 km distance from the Station (Table 1, Fig. 2). During January 2015, gamma dose rates were measured on the surface using a portable digital personal radiation detector RadEye PRD Thermo Scientific.

3. Results and discussion

The contribution of natural radionuclides to the absorbed dose rate in air (ADRA) depends on the concentrations of the radionuclides in the soil. The greatest part of the gamma radiation comes from terrestrial radionuclides. There is a direct connection between terrestrial gamma radiation and radionuclide concentrations in soil.

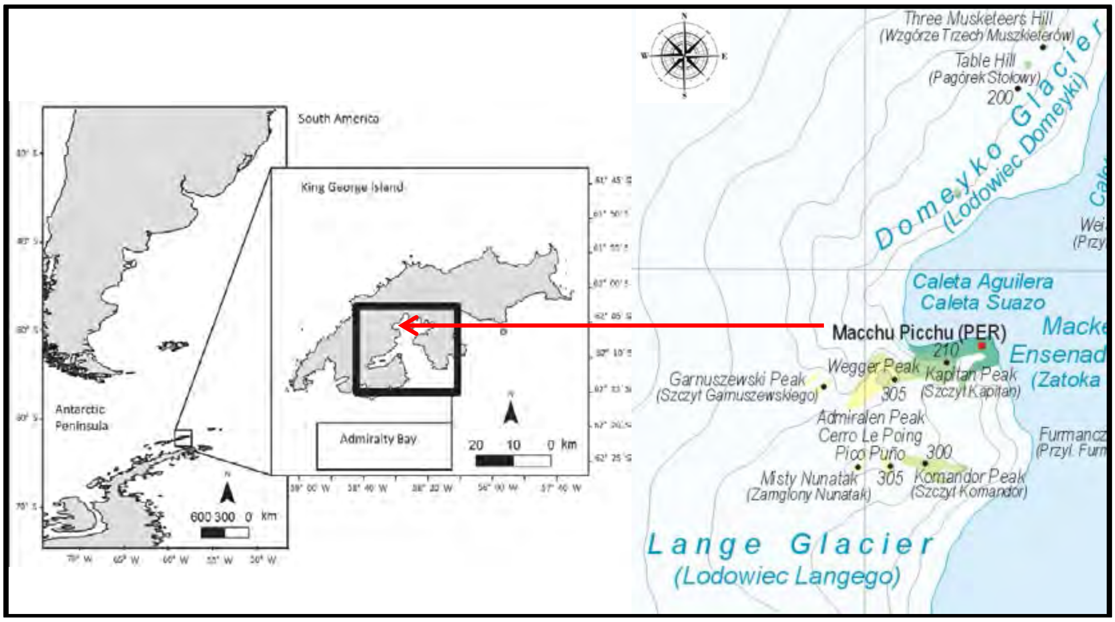

Figure 1. Admiralty Bay, King George Island –Makellar Inlet. Peruvian Antarctic Station "Machu Picchu".

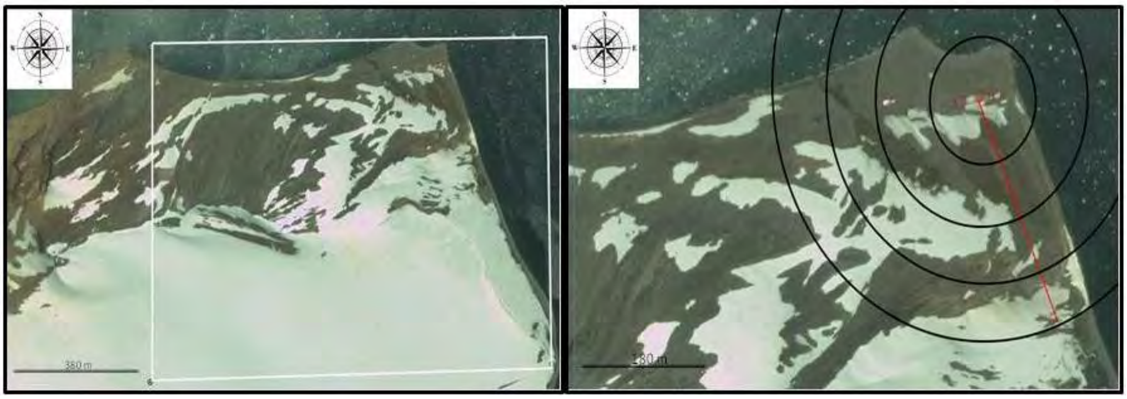

Figure 2. Surface area of study and influence area of the Peruvian Antarctic Station.

Outdoor gamma dose rates were determined in 140 sampling areas. Total outdoor gamma dose rates are presented in Table 1.

The Kolmogorov–Smirnov statistic quantifies a distance between the empirical distribution function of the sample and the cumulative distribution function of the reference distribution. The frequency Table and Kolmogorof-Smirnov Test show that the dose distribution is not homogeneous in the area (Fig. 3). Therefore the values of radioactivity in the area of estuary do not follow a normal distribution. The data has a value ranged between 31.5 and 71.1 nGy/h, it has a median value of 42.95 nGy/h and the median absolute deviation (MAD) for this data is 5.03 nGy/h with a variability of 14.58 %. Annual gamma dose was calculated as 376 ± 44 μGy.

Table 1. Absorbed dose rates above soil in the Peruvian Antarctic Station (2014).

#	Latitude	Longitude	nGy/h	#	Latitude	Longitude	nGy/h	#	Latitude	Longitude	nGy/h	#	Latitude	Longitude	nGy/h
1	-62.0915	-58.4711	46.0	36	-62.0914	-58.4706	39.9	71	-62.0919	-58.4684	39.3	106	-62.0917	-58.4691	40.6
2	-62.0911	-58.4713	48.6	37	-62.0912	-58.4695	43.3	72	-62.0917	-58.4687	37.2	107	-62.0911	-58.4689	42.9
3	-62.0908	-58.4714	44.3	38	-62.0914	-58.4692	48.3	73	-62.0996	-58.4616	33.9	108	-62.0915	-58.4688	41.6
4	-62.0908	-58.4720	44.3	39	-62.0914	-58.4691	46.0	74	-62.0992	-58.4617	38.2	109	-62.0919	-58.4684	41.9
5	-62.0910	-58.4720	43.6	40	-62.0916	-58.4698	42.6	75	-62.0992	-58.4617	38.2	110	-62.0923	-58.4680	41.9
6	-62.0912	-58.4717	40.9	41	-62.0917	-58.4691	42.3	76	-62.0988	-58.4618	35.2	111	-62.0928	-58.4676	40.3
7	-62.0911	-58.4723	50.3	42	-62.0919	-58.4690	42.9	77	-62.0983	-58.4622	36.6	112	-62.0932	-58.4674	47.0
8	-62.0910	-58.4731	48.0	43	-62.0921	-58.4688	45.3	78	-62.0979	-58.4626	37.9	113	-62.0917	-58.4896	47.6
9	-62.0913	-58.4734	44.6	44	-62.0924	-58.4686	47.0	79	-62.0975	-58.4632	34.2	114	-62.0914	-58.4735	49.3
10	-62.0912	-58.4740	35.9	45	-62.0926	-58.4683	44.3	80	-62.0971	-58.4637	35.2	115	-62.0918	-58.4887	47.0
11	-62.0911	-58.4736	37.9	46	-62.0928	-58.4680	42.9	81	-62.0967	-58.4642	38.2	116	-62.0920	-58.4873	44.0
12	-62.0913	-58.4739	47.0	47	-62.0932	-58.4677	43.3	82	-62.0967	-58.4642	38.2	117	-62.0920	-58.4854	44.6
13	-62.0914	-58.4744	44.6	48	-62.0930	-58.4687	47.0	83	-62.0964	-58.4648	33.9	118	-62.0920	-58.4829	46.3
14	-62.0914	-58.4754	37.9	49	-62.0934	-58.4679	51.0	84	-62.0959	-58.4652	36.6	119	-62.0918	-58.4787	49.3
15	-62.0915	-58.4769	35.9	50	-62.0936	-58.4678	49.3	85	-62.0955	-58.4656	44.0	120	-62.0915	-58.4754	42.3
16	-62.0916	-58.4778	40.3	51	-62.0936	-58.4684	56.0	86	-62.0943	-58.4667	48.0	121	-62.0924	-58.4793	47.3
17	-62.0917	-58.4787	34.9	52	-62.0932	-58.4675	42.9	87	-62.0933	-58.4680	48.6	122	-62.0926	-58.4806	39.3
18	-62.0918	-58.4792	36.9	53	-62.0942	-58.4670	47.3	88	-62.0934	-58.4679	53.3	123	-62.0922	-58.4815	39.3
19	-62.0918	-58.4797	37.6	54	-62.0942	-58.4681	45.0	89	-62.0934	-58.4679	50.3	124	-62.0922	-58.4764	47.0
20	-62.0919	-58.4806	35.9	55	-62.0951	-58.4662	52.3	90	-62.0936	-58.4678	50.3	125	-62.0917	-58.4748	44.6
21	-62.0918	-58.4786	36.6	56	-62.0955	-58.4656	37.6	91	-62.0936	-58.4684	47.3	126	-62.0928	-58.4727	44.0
22	-62.0920	-58.4790	37.9	57	-62.0959	-58.4653	36.9	92	-62.0951	-58.4702	41.9	127	-62.0922	-58.4718	49.3
23	-62.0921	-58.4795	33.9	58	-62.0963	-58.4646	37.2	93	-62.0954	-58.4702	42.9	128	-62.0930	-58.4677	53.3
24	-62.0922	-58.4805	31.5	59	-62.0970	-58.4640	34.9	94	-62.0936	-58.4695	55.0	129	-62.0927	-58.4682	48.3
25	-62.0922	-58.4812	35.2	60	-62.0975	-58.4633	32.2	95	-62.0936	-58.4695	55.0	130	-62.0925	-58.4683	56.7
26	-62.0921	-58.4774	40.9	61	-62.0978	-58.4628	37.9	96	-62.0938	-58.4705	42.3	131	-62.0920	-58.4688	55.0
27	-62.0922	-58.4761	45.6	62	-62.0982	-58.4622	38.2	97	-62.0938	-58.4723	50.0	132	-62.0917	-58.4690	42.3
28	-62.0923	-58.4764	41.3	63	-62.0986	-58.4618	34.6	98	-62.0950	-58.4738	49.3	133	-62.0919	-58.4696	48.0
29	-62.0920	-58.4757	48.6	64	-62.0990	-58.4617	37.2	99	-62.0944	-58.4745	47.6	134	-62.0919	-58.4697	71.1
30	-62.0917	-58.4748	40.6	65	-62.0996	-58.4616	38.6	100	-62.0940	-58.4745	36.2	135	-62.0924	-58.4695	49.7
31	-62.0920	-58.4745	37.6	66	-62.0995	-58.4614	33.9	101	-62.0939	-58.4734	49.7	136	-62.0914	-58.4701	51.0
32	-62.0921	-58.4739	35.9	67	-62.0989	-58.4617	35.6	102	-62.0931	-58.4688	51.7	137	-62.0912	-58.4709	49.3
33	-62.0927	-58.4735	35.6	68	-62.0986	-58.4617	38.9	103	-62.0929	-58.4678	45.6	138	-62.0914	-58.4715	52.0
34	-62.0915	-58.4736	38.6	69	-62.0925	-58.4679	37.2	104	-62.0925	-58.4682	49.0	139	-62.0912	-58.4724	48.6
35	-62.0916	-58.4724	39.9	70	-62.0922	-58.4681	38.6	105	-62.0921	-58.4687	46.0	140	-62.0925	-58.4683	45.6

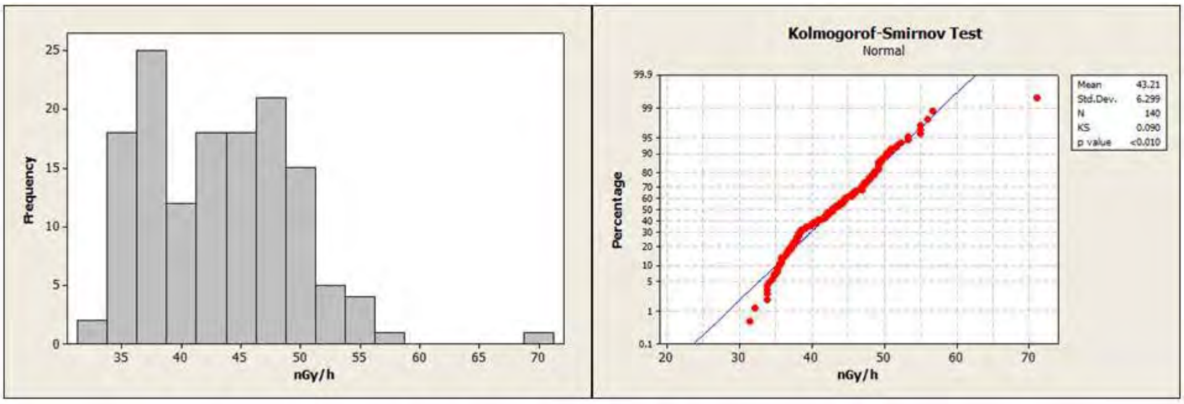

Figure 3. Frequency table and Kolmogorof-Smirnov test.

The contour map of the dose rate shows that the highest levels are found in the area of the scientific station site (Figure 4). The dose values are far below the doses reported in the Peruvian territory due to the geographical location of the statio, Benavente, Celedonio and Manosalva report on Peruvian territory, depending on the height above sea level, environmental effective dose values above 100 nSv/h [7, 8, 9, 10]. On the other hand, the average outdoor gamma dose rate in air of Turkey was 118 nGy/h [11].

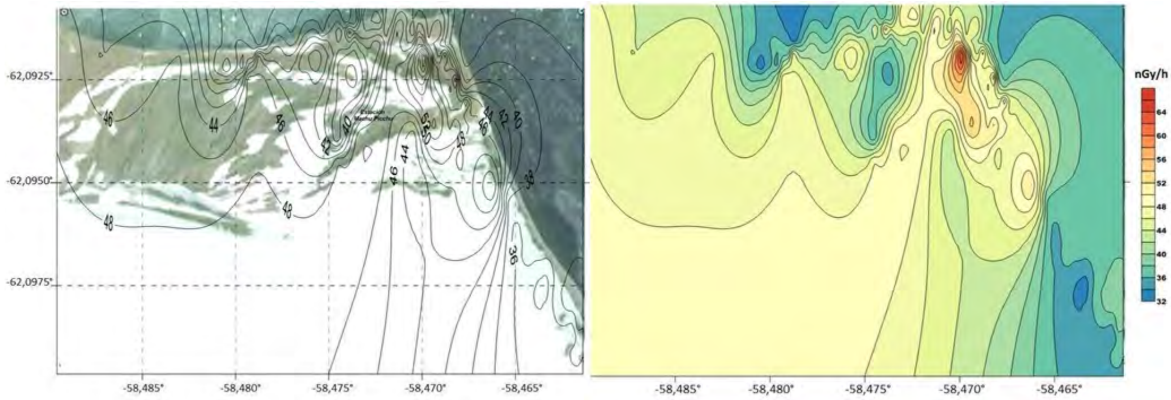

Figure 4. Distribution of absorbed dose in the study area.

4. Conclusions

A total of 140 measurements were made covering the area of the Peruvian Antarctic Station "Machu Picchu". From the measurements made here, the average outdoor gamma dose rate in air due to terrestrial and cosmic radiations was found to be about 43 nGy/h and the median annual dose was found to be about 376 μGy.

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