Determination of natural radioactivity in soils of Henties Bay, Namibia

S.A. Shimboyo[1]*, J.A. Oyedele[1]

[1]Department of Physics, University of Namibia

340 Mandume Ndemufayo Avenue, Private Bag 13301, Pionierspark, Windhoek, Namibia.

Received: 17th December, 2014. Accepted: 3rd March, 2015. Published: 6th March, 2015.

Abstract

The concentrations of naturally occurring radionuclides ^{40}K, ^{238}U and ^{232}Th in soil samples collected across the town of Henties Bay in Western Namibia have been determined and used to estimate a baseline natural radiation level in the town. These concentrations were measured using an HPGe detector and found to vary from 790.2±31.6 Bq kg^{-1} to 1039.0±38.7 Bq kg^{-1} with a mean of 936.1±68.5 Bq kg^{-1} for ^{40}K, 36.2±2.6 Bq kg^{-1} to 153.4±4.8 Bq kg^{-1} with a mean of 62.2±20.0 Bq kg^{-1} for ^{238}U and 50.4±4.5 Bq kg^{-1} to 323.6±12.7 Bq kg^{-1} with a mean of 97.1±44.7 Bq kg^{-1} for ^{232}Th. The corresponding effective dose rate obtained from the radionuclides is 0.16±0.04 mSv y^{-1}. This dose rate is well below the limit of 1.0 mSv y^{-1} recommended for the public by the International Commission on Radiological Protection (ICRP) and indicates that the town has a normal background radiation.

Keywords: Natural radioactivity; Soil; Gamma spectroscopy; Henties Bay; Namibia.

ISTJN 2015; 5:104-110.

1 Introduction

Naturally occurring radionuclides such as ^{40}K, ^{238}U and ^{232}Th are present in the soil where they disintegrate spontaneously releasing ionizing radiation which could pose health prob-

*Corresponding author - E-mail: sshimboyo@unam.na; Phone:+(264-61)206-3373; Fax:+(264-61)206-3427.

ISSN: 2026-7673

lems to the inhabitants of a given location especially when the concentrations of the radionuclides are high (Arogunjo et al. 2004; Dabayneh et al. 2008; Beyala et al. 2010; Canbaz et al. 2010). Consequently, there is increasing interest in many countries to study the radioactivity in different towns or areas (Sroor et al. 2001; Hashim et al. 2004; Tahir et al. 2005). Namibia is one such country where there is interest in environmental. The western part of the country is known to have many mineral resources including uranium and therefore the concentrations of radionuclides and the associated radiation or the natural radioactivity in the soils may be high. Furthermore, the country is considering acquiring nuclear reactors for power generation so that it is important to obtain a baseline data of environmental radioactivity that will serve as a reference in future. Henties Bay is an important town in Western Namibia and one of the research centers of the University of Namibia, the Sam Nujoma Marine & Coastal Resources Research Centre, is located there. There is therefore interest in the determination of the natural radioactivity in the soils of Henties Bay.

Henties Bay is located in the Erongo Region at latitude 22°7' S and longitude 14°17'. It is about 358 km from Namibia's capital city, Windhoek. The town is a tourist destination and it is about 70 km from another well-known tourist town, Swakopmund. Also, many scientists, both local and international, visit and work at the University of Namibia's Sam Nujoma Marine & Coastal Resources Research Centre at the town.

The aim of this study was to determine the concentrations of the naturally occurring radionuclides ^{40}K, ^{238}U and ^{232}Th in soil samples collected from across Henties Bay and use the data to establish a baseline radiation level due to the radionuclides. These results will reveal whether the town is in an area of normal or high background radiation and will also contribute to the baseline data for the region.

2 Sample collection and measurement procedure

Fifty soil samples with a mass of about 1 kg each were collected from ten different geographical areas (five samples/area) of Henties Bay as shown in Figure 1. The samples were collected from the top layer of the soil (2-5 cm depth) using a spade. Also, the sites chosen were away from buildings, trees, rivers and roads in order to obtain soil samples that are not influenced by human activity. All the samples were dried under laboratory temperature in the nuclear laboratory of the Physics department of the University of Namibia, and were subsequently passed through a 2 mm mesh screen. Samples were mixed thoroughly and 500 g of each sample were carefully weighed and placed in a 500 ml air-tight polythene bottle similar to those of the reference materials and sealed. These were then stored for about a month to ensure radioactive equilibrium between ^{226}Ra and ^{232}Th and their progeny before they were counted in the gamma spectrometry detector system. The gamma-ray spectra for

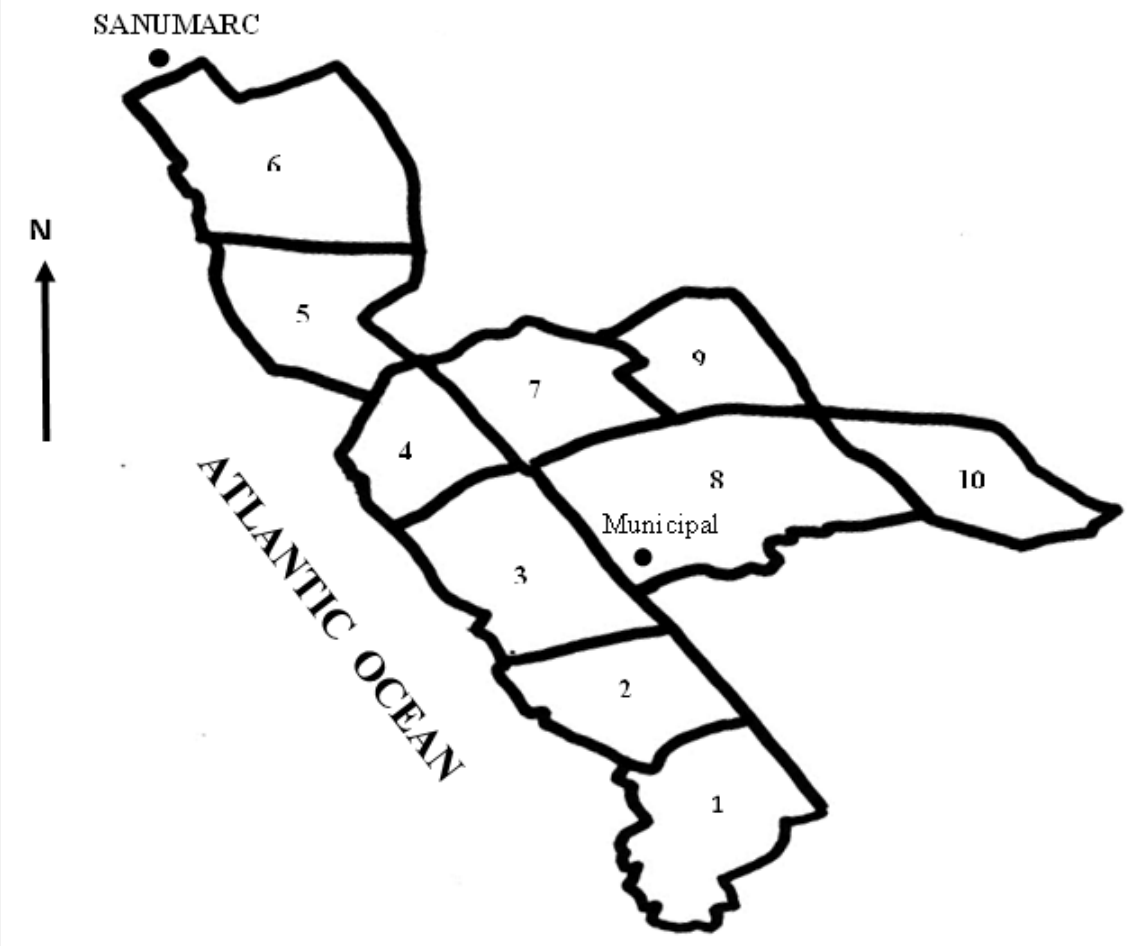

Figure 1: Map showing the areas where soil samples were collected in Henties Bay. 'Municipal' and 'SANUMARC' show the locations of the Municipality and the Marine Research Centre respectively. The ten areas are (1) Brandberg street/Paresis street residential area, (2) Orange street/Kavango street residential area, (3) Duine road/Jakkalsputs road town centre area, (4) Pelikaan street/Kabeljou street residential area, (5) Marsbanker street/Elf street residential area, (6) Kraai street/Omaruru street residential area, (7) Municipality area, (8) Omdel residential area, (9) Brick factory area and (10) Business area.

the soil samples were measured using a vertical well-shielded coaxial high purity germanium (HPGe) p-type detector (Canberra model GC2519) was quoted at 25% relative efficiency with respect to 7.6×7.6 cm NaI(Tl) detector. The energy resolution of the detector is 1.9 keV FWHM for ^{60}Co at 1332 keV and MCA with 8192 channels. Genie 2000 software was used to analyse the spectra of the samples and reference materials. This system was calibrated using reference materials RGU-1, RGTh-1 and RGK-1 provided by the International Atomic Energy Agency (IAEA). Each sample was placed directly on the detector using the same geometry as that used for the reference materials. The activity in each sample was counted for 10800 s and the activity concentrations of ^{40}K, ^{238}U and ^{232}Th were determined respectively from the intensities of the gamma lines at 1.465 MeV of ^{40}K, 0.609 MeV of ^{238}U and 0.911 MeV of ^{232}Th. These concentrations were subsequently used to calculate the average absorbed dose rate and the mean annual effective dose for the town.

3 Results and Discussion

The activity concentrations of ^{40}K, ^{238}U and ^{232}Th calculated from the different spectra and their average values for the different areas are summarized in Table 1. As could be observed in the Table (values in parentheses), the concentrations of ^{40}K varied from 790.2 ± 31.6 Bq kg^{-1} (Area 10) to 1039.0 ± 38.7 Bq kg^{-1} (Area 7) with an average (all samples) of 936.1 ± 68.5 Bq kg^{-1}. Similarly, the concentrations of ^{238}U varied from 36.2 ± 2.7 Bq kg^{-1} (Area 6) to 153.4 ± 4.8 Bq kg^{-1} (Area 5) with an average of 62.2 ± 20.0 Bq kg^{-1} while the concentrations of ^{232}Th varied from 50.4 ± 4.5 Bq kg^{-1} (Area 1) to 323.6±12.7 Bq kg^{-1} (Area 5) with an average of 97.1 ± 44.7 Bq kg^{-1}. These results show that there is a wide range of concentrations of each radionuclide in the soils of Henties Bay. The overall average concentration of ^{40}K (936.1 ± 68.5 Bq kg^{-1}) is much higher than those of ^{238}U (62.2 ± 20.0 Bq kg^{-1}) and ^{232}Th (97.1 ± 44.7 Bq kg^{-1}). This relatively high value of ^{40}K has also been observed in other parts of Africa (Hashim et al. 2004; Tahir et al. 2005). In contrast to ^{40}K, ^{238}U has the lowest overall average concentration (62.2 ± 20.0 Bq kg^{-1}). This low value of ^{238}U indicates that there is no large deposit of uranium in the town. A comparison of the average concentrations of each radionuclide in the different areas shows that the average concentrations also vary from one area to another. However, the average concentrations in the different areas as well as the overall average concentration in the town are higher than the world-wide average values (400 Bq kg^{-1}, 35 Bq kg^{-1} and 30 Bq kg^{-1} for ^{40}K, ^{238}U and ^{232}Th respectively) (UNSCEAR 2000).

The absorbed dose rate, D, in air due to radionuclides at each of the 50 sites were calculated using the equation (UNSCEAR 2000),

$$D = 0.0417A_K + 0.462A_U + 0.604A_{Th}$$

Table 1: Average (± standard deviation) radionuclide concentrations, absorbed dose rates and annual effective dose in ten areas of Henties Bay. The corresponding range of values are given in parentheses.

Area	Radionuclides concentration (Bq/kg)			Absorbed dose rate (nGy h^{-1})	Annual effective Dose (mSv)
	^{40}K	^{238}U	^{232}Th		
1	959.0 ± 87.7 (853.7-1029.3)	56.0± 12.7 (45.7-72.1)	70.6 ± 14.0 (50.4-84.6)	108.5 ±10.4 (95.0-119.1)	0.13 ± 0.01 (0.12-0. 15)
2	949.3 ± 59.3 (868.3-1014.6)	52.3 ± 6.8 (41.3-57.9)	82.2 ± 20.8 (65.1-112.3)	113.4 ± 17.2 (98.2-136.3)	0.14 ±0.02 (0.12-0.17)
3	925.9 ± 34.0 (892.7-970.7)	53.1 ± 6.7 (44.0-61.2)	81.1 ± 20.9 (52.3-102.5)	112.1 ± 14.5 (92.4-128.8)	0.14± 0.02 (0.11-0.16)
4	893.7 ± 47.5 (819.5-946.3)	53.2 ± 6.4 (46.4-60.4)	76.5 ± 9.9 (66.2-88.2)	108.1 ± 8.2 (99.3-116.3)	0.13 ± 0.01 (0.12-0.14)
5	917.1± 63.8 (819.5-990.2)	83.4 ± 40.4 (58.3-153.4)	143.1 ± 103.1 (68.6-323.6)	163.2 ± 80.1 (106.8-304.0)	0.20 ± 0.10 (0.13-0.37)
6	933.7 ± 78.9 (809.8-1019.5)	54.3 ±16.2 (36.2-79.4)	70.3 ± 12.1 (53.0-82.6)	106.5 ± 11.7 (91.2-117.6)	0.13 ±0.01 (0.11-0.14)
7	969.8± 83.7 (824.4-1039.0)	60.1± 26.7 (43.6-107.1)	98.3 ± 51.1 (64.4-187.6)	127.6 ± 44.1 (95.8-203.9)	0.16 ±0.05 (0.12-0.25)
8	963.9 ± 56.5 (907.3-1024.4)	66.2± 8.5 (52.0-73.4)	111.4 ± 23.9 (71.3-133.6)	138.1 ± 19.1 (104.9-152.4)	0.17 ±0.02 (0.13-0.19)
9	935.6 ±61.3 (868.3-1009.8)	75.1 ± 15.9 (61.8-102.5)	124.3 ± 28.7 (101.7-170.4)	148.8 ± 23.5 (129.5-186.5)	0.18 ± 0.03 (0.16-0.23)
10	913.2 ± 109.0 (790.2-1024.4)	68.0 ± 19.3 (46.2-97.9)	113.1 ± 38.5 (68.0-171.9)	137.8 ± 32.8 (96.4-187.4)	0.17 ±0.04 (0.12-0.23)
All samples	**936.1 ± 68.5 (790.2-1039.0)**	**62.2 ± 20.0 (36.2-153.4)**	**97.1 ± 44.7 (50.4-323.6)**	**126.4 ± 35.7 (91.2-304.0)**	**0.16 ± 0.04 (0.11-0.37)**

where A_K is the activity concentration of ^{40}K, A_U is the activity concentration of ^{238}U and A_{Th} is the activity concentration of ^{232}Th in each sample. The activity concentration is in Bq kg^{-1} while the absorbed dose rate is in nGy h^{-1}. The absorbed dose rates obtained varied from 91.2 ± 3.7 nGy h^{-1} (Area 6) to 304.0 ± 8.8 nGy h^{-1} (Area 5) with an overall average of 126.4 ± 35.7 nGy h^{-1} as shown in Table 1 (values in parenthesis). As could be expected, the average absorbed dose rates varied from one area to another. The absorbed dose rates were used to calculate the annual effective dose at each site and an average annual effective dose for the town using a conversion factor 0.7 Sv Gy^{-1} and an occupancy factor 0.2 (Arogunjo et al. 2004; UNSCEAR 2000). As shown in Table 1, the effective dose varied from 0.11 ± 0.01 mSv (Area 6) to 0.37 ± 0.01 mSv (Area 5) with an overall average of 0.16 ± 0.04 mSv. These values and the average value of 0.16 ± 0.04 mSv for the town are less than the maximum permissible dose rate of 1 mSv y^{-1} recommended for the public by the International Commission on Radiological Protection (ICRP) (Wrixon 2008). Therefore, the results indicate that the town of Henties Bay has a normal background radiation.

4 Conclusion

The concentrations of the radioisotopes ^{40}K, ^{238}U and ^{232}Th in soil samples collected across the town of Henties Bay vary from sample to sample and are generally higher than the world-wide average values. ^{40}K has the highest average concentration while ^{238}U has the lowest average concentration. The corresponding annual effective dose is 0.16 ± 0.04 mSv which is much below the limit of 1.0 mSv recommended by the International Commission on Radiological Protection, ICRP (Wrixon 2008) for the public, thus indicating that the town has an acceptable background radiation.

Acknowledgements

The authors will like to thank the University of Namibia, the Municipality of Henties Bay, Ministry of Health and Social Services (MHSS) and the Ministry of Mines and Energy (MME) for supporting the project. Also, the authors are grateful to the International Atomic Energy Agency (IAEA) for providing the equipment and reference materials used in the project.

References

[1] Arogunjo AM, Farai IP, Fuwape IA. Dose rate assesment of terrestrial gamma radiation in the Delta region of Nigeria. Radiat. Prot. Dosim. 108, 73-77 (2004).

[2] Beyala Ateba JF, Owono Ateba P, Ben-Bolie GH, Abiama PE, Abega CR, Mvondo S. Natural background dose measurements in south Cameroon. Radiat. Prot. Dosim. 140, 81-88 (2010).

[3] Canbaz B, Cam FN, Yapark G, Candan O. Natural radioactivity (226Ra,232Th and 40K) and assesment of radiological hazards in the Kestanbol granitoid, Turkey. Radiat. Prot. Dosim. 141,192-198 (2010).

[4] Dabayneh KM, Mashal LA, Hasan FI. Radioactivity concentration in soil samples in the southern part of the West Bank, Palestine. Radiat. Prot. Dosim. 131, 265-271 (2008).

[5] Hashim NO, Rathore IVS, Kinyua AM, Mustapha AO. Natural and artificial radioactivity levels in sediments along the Kenyan coast. Radiat. Phys. Chem. 71, 805-806 (2004).

[6] Sroor A, El-Bahi SM, Ahmed F, Abdel-Haleem AS. Natural radioactivity and radon exhalation rate of soil in southern Egypt. Appl. Radiat. Isot. 55, 873-879 (2001).

[7] Tahir SNA, Jamil K, Zaidi JH, Arif M, Ahmed N, Ahmad SA. Measurements of activity concentrations of naturally occuring radionuclides in soil samples from Punjab province of Pakistan and assessment of radiological hazards. 113, 421-427 (2005).

[8] United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Sources of ionizing radiation (Annex B). Report to the General Assembly, New York, (2000).

[9] Wrixon, A. D. New ICRP recommendations. J. Radiol. Prot. 28, 161-168 (2008).