Volume 2 No.3, March 2012 ISSN 2224-3577
International Journal of Science and Technology

http://www.ejournalofsciences.org

Determination of Natural Radioactivity in Saline Water and Salt from Panbros Salt Industry Limited in the Accra Metropolis, Ghana

[1,2]C. Kansaana, [1,2]E. O. Darko, [1]C. Schandorf, [2]O. K. Adukpo,
[1,2]A. Faanu, [2]H. Lawluvi, [2]D. O.Kpeglo
[1]Graduate School of Nuclear and Allied Sciences, University of Ghana
[2]Radiation Protection Institute, Ghana Atomic Energy Commission, Box LG 80, Legon, Ghana.

ABSTRACT

Radioactivity levels in saline water and salt from Panbros Salt Industry Limited in the Greater Accra Region of Ghana have been investigated. Activity concentrations in Bq/l in all samples were measured using gamma spectrometry. The annual effective dose to an adult individual due to intake of natural radionuclides in salt was estimated to be 0.0025 ± 0.00053 $mSvy^{-1}$ and this is far below the average radiation dose of 0.29 $mSvy^{-1}$ received per caput worldwide due to ingestion of natural radionuclides provided in UNSCEAR 2000 report. The results indicate insignificant radiological health hazard to the public due to the consumption of salt. The results provide baseline values which may be useful for the Regulatory Authorities in the country to control the exposure of the public to NORMS due to intake of salt.

Keywords: *Natural Radioactivity, Public Exposure, Saline Water, Salt*

1. INTRODUCTION

The determination of radioactivity in waters of high salt content is of considerable importance. Saline water is a general term for water that contains a significant concentration of dissolved salt (NaCl) and it is used in the production of salt [1]. It is therefore necessary to determine the present levels of radioactivity as part of preoperational surveys and to measure the quantity of radioactivity added to sea water [2].

Humans are continuously exposed to ionizing radiation of natural sources (NORMS) from terrestrial and extraterrestrial origin, and artificial sources used for various applications in medicine, agriculture, industry, research and teaching. The extent of exposure if significant could lead to detrimental health effects. Exposure to high levels above background radiation could lead to somatic and genetic effects that tend to damage critical or radiosensitive organs of the body, which ultimately can lead to death [3].

Salt is being mined in commercial quantities in the Central, Volta and Greater Accra Regions of Ghana for many years. The importance of essential elements to human health has stimulated the analysis of their occurrence in many foods. Salt analysis is very important due to its high consumption by the Ghanaian population and for its medicinal and nutritional use. One of the salt mines in Ghana is Panbros Salt Industry Limited, which extracts salt by solar evaporation of sea water. The salt contains about 98.5 % NaCl and 1.5 % other salts. The salt and its derivatives are used in many industries [4]. Due to the large consumption of salt in Ghana, a study of radionuclides' content in salt is desirable.

Several authors have studied the levels of natural background radiation by analysis of radionuclides concentrations in water and salt samples [2, 4]. Until now, no studies have been carried out on radioactivity levels in salt from the salt mines in Ghana. This situation could pose health problems due to the high salt consumption rate by Ghanaians and as the country makes frantic efforts in promoting its salt industry.

The objectives of this research work are to determine the activity concentrations of NORMS in saline water and salt and to calculate the effective dose in order to assess the exposure of the public to NORMS due to the consumption of salt.

This work, therefore, investigated the extent of the exposure of the general public due to intake of salt as part of the national effort to establish baseline values for the Regulatory Authorities to control the exposure of the public to NORMS due to the consumption of salt in Ghana.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study area is located in Weija, in the Ga South Municipality of the Greater Accra Region of Ghana and is within the Accra-Winneba road. It lies between longitudes 0°17'57.16"W and $0^0$55' 15"W and latitudes 5° 33' 26.27"N and 5^0 35' 30"N. It is bounded on the north and west by McCarty Hills and Tetegu respectively, on the east by Mendskrom-Dansoman and on the south by the Gulf of Guinea (Figure 1).

Volume 2 No.3, March 2012 ISSN 2224-3577
International Journal of Science and Technology

http://www.ejournalofsciences.org

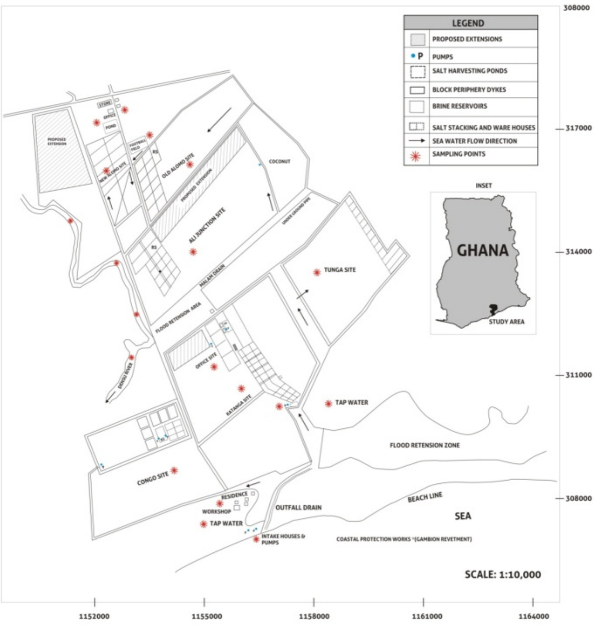

Figure 1: Map of Panbros Salt Industry Limited showing the sampling sites

The study area is generally flat and at an elevation of 70 m above the sea level. The total area of the mine's concession is about 1130 ha of which 784 ha have been developed into pans. The climate is characterized by two rainfall maxima. The major rainy season occurs between May and July with the peak occurring in June while the minor one occurs between September and October with the peak occurring in October. Generally, the rainfall in the area is low with mean annual rainfall of approximately 900 mm per annum. The mean temperature is 26^{0}C. The vegetation is mainly coastal grassland and scrub. The soil is sandy clay with salinity ranging from 6 to 21 desi semin/meter (ds/m) at 1 m depth of soil profile [5].

2.2 Sampling and Sample Preparation

The sampling was carried out in the month of October, 2010 where the weather conditions were fairly stable. A total number of 75 samples were collected for the analysis. They included 50 saline water samples and 25 salt samples.

2.2.1 Saline Water

5 samples were collected from each of the 10 identified sampling sites (Table 1). The samples were collected into 2 liter polyethylene gallons and a few drops of concentrated hydrochloric acid (HCl) were added to bring the pH of the water to less than 2. This was done to prevent the radionuclides present from absorbing on the walls of the gallons and also extend the holding time to about 6 months. Sample containers were properly labelled and tightly covered with the lids immediately prior to collecting the samples. Composite samples were made to represent each sampling site and subsamples taken for analysis in the laboratory. The samples were then measured in 1.0 l Marinelli beakers and then stored prior to measurement.

2.2.2 Salt Samples

5 samples were collected from each of the 5 identified salt production sites (Table 3). The samples were then transferred into polyethylene bags and labeled accordingly. Composite samples were made to represent each sampling site and subsamples taken for analysis in the laboratory.

About 20 g of each sample was dissolved in 1000 ml of deionized and double distilled water in one liter Marinelli beakers and then stored prior to measurement.

2.3 Analysis of Saline Water and Salt Samples

The samples were counted using a gamma spectrometry. The gamma-spectrometry system consists of a high pure germanium detector (HPGe) connected to a desk top computer provided with a Canberra S100 multichannel analyzer (MCA) in conjunction with a Maestro-32 mult-channel buffer (MCB) configuration software for spectrum acquisition and evaluation. The detector crystal has a diameter of about 36 mm and thickness of about 10 mm. The crystal is housed in an aluminium canister with a 0.5 mm thick beryllium entrance window. A lead shield, built with 50 mm thick lead brick surrounds the detector to prevent it from external background radiation reaching the detector. The detector is cooled with liquid nitrogen at 77 K in a 25 L Dewar. The ambient temperature around the detector was relatively stable at 16°C during the period of measurement.

Prior to the analysis of the samples, energy and efficiency calibrations were performed to enable identification and quantification of the radionuclides. The detector system was calibrated using the multinuclide reference standard solution. The calibrations were carried out for Marinelli beaker containing a mixed radionuclide solution supplied by the Dentscher Kalibrierdienst (DKD) of Germany. The standard solution contains the following radionuclides with the corresponding energies; ^{241}Am (59.54 keV), ^{137}Cs (661.6 keV) and ^{60}Co (1172.3 and 1332.5 keV) [6].

A counting time of 36,000 s was used to acquire spectral data for each sample and evaluated. The activity concentrations of ^{238}U, ^{232}Th and ^{40}K were determined after correction for background and inhomogeneities [6, 7].

Volume 2 No.3, March 2012 ISSN 2224-3577
International Journal of Science and Technology

http://www.ejournalofsciences.org

The activity concentration of ^{238}U was calculated from the average of 295.3 keV of ^{214}Pb and 1764.5 keV of ^{214}Bi, ^{232}Th from the average of 2614.0 keV peak of ^{208}Tl and 969.1 keV of ^{228}Ac, and ^{40}K was determined from 1460.0 keV.

The analytical expression used in the calculation of the activity concentrations in Bq/l for the samples is as shown in equation 1.

$$A_{ac} = \frac{N_{sam}\exp(\lambda T_d)}{P_E * \varepsilon(E) * T_c * M} \quad (1)$$

where; A_{ac} is the activity concentration, λ is the decay constant, N_{sam} is total net counts for the sample in the peak range, P_E is the gamma-ray emission probability, T_d is decay time between sampling and counting, T_c is the counting time, $\varepsilon(E)$ is the total counting efficiency of the detector system, M is the mass of sample (kg) and the expression exp (λT_d) is the correction factor for decay between sampling and counting [7].

The dose conversion factors for saline water were not available and it was assumed that density of the dissolved salt was close to that of the water, and therefore the dose conversion factors for both the dissolved salt and the saline water were taken as that of water, i.e. 4.5 x 10^{-5} $mSvBq^{-1}$ for ^{238}U, 2.3 x 10^{-4} $mSvBq^{-1}$ for ^{232}Th and 6.2 x 10^{-6} $mSvBq^{-1}$ for ^{40}K [8].

The annual effective dose, E (mSv/y) to an adult individual due to intake of natural radionuclides in salt was calculated on the basis of the activity concentrations of the radionuclides. The daily salt consumption rate in Ghana was taken to be 10 g per day [9]. The annual effective dose owing to ingestion of ^{238}U, ^{232}Th and ^{40}K in salt was calculated using equation 2.

$$E = \sum A_s \times I_s \times CF_s \quad (2)$$

where; A_s is the activity concentration of radionuclides (Bql^{-1}), I_s is the annual intake of salt (l y^{-1}), CF_s is the dose conversion factor ($SvBq^{-1}$).

3. RESULTS AND DISCUSSION

3.1 Activity Concentrations in Saline Water

Table 1 shows the sample locations with their respective co-ordinates and Table 2 shows the activity concentrations of ^{238}U, ^{232}Th and ^{40}K measured in the saline water samples. The measured activity concentration of ^{238}U for the various locations varied from 1.55 mBq/l at the residential areas to 2.16 mBq/l at the Congo site with an average value of 1.97 ± 0.46 mBq/l. For ^{232}Th, the measured activity concentration also varied from 5.75 mBq/l to 7.39 mBq/l with an average value of 6.48 ± 0.70 mBq/l. The lowest value was recorded at Ali Junction whilst the highest was obtained at the Pump House. The measured activity concentration of ^{40}K also varied from 46.15 mBq/l at the Ali Junction site to 54.05 mBq/l at the Katanga site with an average value of 50.12 ± 5.17 mBq/l.

Table 1: Sample location with co-ordinates for saline water samples

Sample ID	Sampling Site	Co-ordinates	
		Longitude	Latitude
KTW_1	Katanga	5°33'27.27"N	0°17'57.16"W
TGW_2	Tunga	5°33'25.16"N	0°17'52.15"W
AJW_3	Ali Junction	5°35'28.25"N	0°17'55.17"W
CGW_4	Congo	5°32'18.27"N	0°17'34.29"W
PHW_5	Pump House	5°33'26.27"N	0°17'57.16"W
OAW_6	Office Area	5°32'24.20"N	0°17'52.14"W
RAW_7	Residential Area	5°35'17.26"N	0°17'52.14"W
PDW_8	Pond	5°33'25.27"N	0°17'59.16"W
OAW_9	Old Alomo	5°33'04.89"N	0°18'03.38"W
NAW_{10}	New Alomo	5°33'06.14"N	0°18'01.96"W

Table 2: Activity concentrations of ^{238}U, ^{232}Th and ^{40}K in the saline water samples

	Activity Concentration (mBq/l)		
	U-238	Th-232	K-40
Range	1.55- 2.16	5.75-7.39	46.15-54.05
Average	1.97	6.48	50.13
Standard Deviation	0.46	0.70	5.17

Panbros Salt Industry Limited produces salt by pumping sea water into salt pans to be evaporated. It can be seen from Table 2 that the activity concentrations of ^{238}U, ^{232}Th and ^{40}K in the saline water samples are higher than that in the salt samples (Table 4). The low values of the activity concentrations recorded for the salt samples may be attributed to the fact that the daughter products of these radionuclides tend to escape into the air during the evaporation process.

3.2 Activity Concentrations in Salt Samples

Table 3 shows the salt sample locations with their respective co-ordinates. The activity concentrations of ^{238}U, ^{232}Th and ^{40}K measured in the salt samples are shown in Table 4. Activity concentrations of ^{238}U, ^{232}Th and ^{40}K varied from 1.12–1.91, 2.11–3.47 and 30.25–47.65 mBq/l, respectively with mean values of 1.39 ± 0.31, 2.91 ± 0.47 and 37.88 ± 3.10 mBq/L respectively. The lowest value of ^{238}U activity concentration was recorded at the Congo site, whilst the highest was recorded at the Katanga site. It was also realized that the

ISSN 2224-3577
International Journal of Science and Technology

http://www.ejournalofsciences.org

highest value of ^{232}Th activity concentration was found at the Tunga site and the lowest value was obtained at the Alomo site. The lowest and highest values of ^{40}K activity concentrations were recorded at the Katanga and Alomo sites respectively.

Table 3: Sample location with co-ordinates for salt samples

Sample ID	Sampling Site	Co-ordinates	
		Longitude	Latitude
KT-1	Katanga	5°33'26.27"N	0°17'57.16"W
TG-2	Tunga	5°33' 25.16"N	0°17'52.15"W
AJ-3	Ali Junction	5°35' 26.28"N	0°17'34.29"W
CG-4	Congo	5°33' 18.27"N	0°17'54.29"W
AL-5	Alomo	5°33' 06.14"N	0°18'07.96"W

Table 4: Activity concentrations and annual effective doses of ^{238}U, ^{232}Th and ^{40}K in the salt samples

	Activity Concentration (mBq/l)			Annual Effective Dose (μSvy^{-1})
	U-238	Th-232	K-40	
Range	1.12-1.19	2.11-3.47	30.25-47.65	2.02 - 3.05
Average	1.39	2.91	37.88	2.46
Standard Deviation	0.31	0.47	3.10	0.53

The results from this study were compared with published data from some countries. In Egypt, El-Bahi [4] studied the radioactivity levels of ^{238}U, ^{232}Th and ^{40}K in salt samples (dry weight) and obtained the levels as 0.46 ± 0.02 − 32.6 ± 1.6, 0.2 ± 0.0 1− 10.5 ± 0.5, and 0.42 ± 0.02 − 158.6 ± 7.9 Bq/kg respectively. Tahire et al. [10] also measured the mean activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in rock salt samples in Pakistan as 0.5–1.3, 0.4–0.9 and 15.0–34.0 Bqkg^{-1} respectively. The levels obtained are high compared to the levels recorded in this work. The variations of the activity concentrations depend on factors such as the geographical location and the geological structure of the salt mine areas. Figure 2 shows the comparison of the average activity concentrations of ^{238}U, ^{232}Th and ^{40}K in the saline water and salt samples from Panbros Salt Industry Limited.

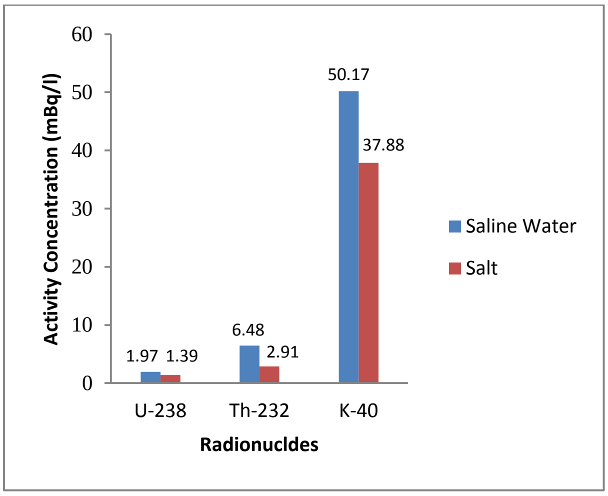

Figure 2: Comparison of the average activity concentrations of ^{238}U, ^{232}Th and ^{40}K in the saline water and salt samples

Assessment of the exposure of ^{238}U, ^{232}Th and ^{40}K to humans from intake of salt was also made. The annual effective dose calculated for the salt samples varied from 0.00202 to 0.00305 mSvy^{-1} with a mean value of 0.0025±0.00053 mSvy^{-1}. The highest annual effective dose was recorded at the Alomo site whilst the lowest value was obtained at the Katanga site. Tahire et al. [10] estimated the mean annual effective dose due to intake of natural radionuclides from rock salt for adults from the Khewera Mines located in Pakistan to be 0.0638±0.015 mSv. The value obtained is much higher than that recorded in this study.

Comparing the value of the annual effective dose from this study with published data for ingestion of natural radionuclides from UNSCEAR 2000 report, it would be seen that the value obtained from this study is much less than that given in the UNSCEAR report and this shows that consumption of the salt does not pose any significant radiological risk to the general public.

4. CONCLUSIONS

Natural radioactivity in saline water and salt from Panbros Salt Industry Limited in the Accra Metropolis of Ghana has been measured using gamma-spectrometry system. The activity concentrations in the saline water samples were found to be higher than that recorded in the salt samples. The annual effective dose to an adult individual due to intake of natural radionuclides in salt was estimated to be 0.0025±0.00053 mSvy^{-1} which is far below the average radiation dose of 0.29 mSvy^{-1} received per caput worldwide due to ingestion of natural radionuclides reported in UNSCEAR [11]. The results indicate that the general public is not exposed to any significant radiological health hazard due to consumption of salt.

Though the salt from the salt mine does not pose any significant radiological health hazard to consumers, the general public is advised to take less salt since there are a lot of other health effects inherent with high salt intake. The results from the study could be used as baseline values for the Regulatory Authorities to control the exposure of the public to NORMS due to the consumption of salt in Ghana.

ACKNOWLEDGEMENTS

The authors would like to acknowledge with thanks the assistance received from the management of Panbros Salt Industry Limited during the period of sampling. The authors are also grateful to the Radiation Protection Institute (RPI) of the Ghana Atomic Energy Commission for making their laboratories available for the research. The authors also appreciate the contribution of Ms. Rita Kpodzro and Mr. Ibrahim Doe Ali of RPI for their assistance in the completion of this work.

REFERENCES

[1] USGS (2011). Uses of saline water. Retrieved May 16, 2011 from the World WideWeb:http://ga.water.ugs.gov/edu/salineuses.

[2] Sodd, V.J., Goldin, A.S. and Velten, R.J. (1960). Determination of radioactivity in saline waters. Vol. 32, No. 1, pp. 25.

[3] Ajayi, I.R., Ajayi, O.S. and Fusuyi, A.S. (1995). The Natural Radioactivity of Surface Soils in Ijero – Ekiti, Nigeria, Nig. Jour. of Phy. Vol. 7, pp 101 – 103.

[4] El-Bahi, S.M. (2003). Radioactivity levels of salt for natural sediments in the northwestern desert and local markets in Egypt. Applied Radiation and Isotopes 58, 143-148.

[5] Dickson, K. B. and Benneh. G. (2004). A New Geography of Ghana, Longmans Group Limited, London.

[6] Gilmore, G. and Hemingway, J. D. (1995). Practical Gamma Spectrometry, John Wiley and Sons, NY, NY.

[7] Oresengun M. O., Decker, K. M. and Sanderson, C. G. (1993). Determination of Self Absorption Correction by Computation in routine Gamma-ray Spectrometry for Typical Environmental Samples, J. Radioactivity and Radiochemistry, Vol. 4, pp. 38 – 45.

[8] ICRP (1991). 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60. Annals of the ICRP 21(1-3). Pergamon Press, Oxford.

[9] Johnston, J. (1996). Projects in Ghana: International Development Research Center; Iodine Deficiency Disorder, Ghana.

[10] Tahir, S.N.A. and Alaamer, A.S. (2008). Determination of natural radioactivity in rock salt and radiation doses due to its ingestion. Journal of Radiological Protection 28, 233-236.

[11] UNSCEAR (2000). Sources and effects of ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation, United Nations, New York.