Journal of
NUCLEAR
Technology in Applied Science
ISSN 2314-8209 e-ISSN 2314-8217

J. Nucl. Tech. Appl. Sci, Vol. 5, No. 4, PP. 215 : 222 (2017)

Evaluation of Natural Radioactivity and Radiological Impact Assessment in theSurrounding Area of Nag-Hammadi City, Qena, Egypt

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Received: 25/09/2017

Accepted: 25/10/2017

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KEYWORDS

Natural Radioactivity;Radiation Hazard Indices; Industry Area.

ABSTRACT

The specific activities of ^{226}Ra (^{38}U series),^{228}Ra(^{232}Th series) and (^{40}K) (Bq/kg dry weight) were measured for the collected Samples from Nag-Hammadi city(bauxite ore, alumina, scrap, soil, plant and water) using high purity germanium (HPGe) gamma ray spectrometry. The measurements were conducted according to ENRRA.The mean values of ^{226}Ra, ^{232}Th and ^{40}K content of the samples are 20 (bauxite), 31(scrap), 16 (alumina), 10 (water) and 20 (soil) $Bq \cdot kg^{-1}$ for ^{226}Ra and 33 (bauxite), 41(scrap), 45(alumina), 20 (soil) $Bq \cdot kg^{-1}$ for ^{232}Th and 965 (bauxite), 354 (scrap), 105 (alumina), 274 (soil) $Bq \cdot kg^{-1}$ for ^{40}K, respectively. The mean activity concentrations of ^{226}Ra, and^{232}Th in all samples are less than the world international recommended limits (for soil 33, 45 $Bq \cdot kg^{-1}$), respectively while ^{40}K is higher than the world average, 420 $Bq \cdot kg^{-1}$, with the exception of Bauxite. The radiation hazard parameters (radium equivalent activities, gamma dose rates, annual effective dose and the annual gonadal dose equivalent) due to the radionuclide at 1 meter above the ground surface were calculated. The radium equivalent activities were 88 (alumina) and 142 (bauxite) $Bq \cdot kg^{-1}$ are within the safety recommended limit of 370 $Bq \cdot kg^{-1}$. The mean annual effective doses calculated from the absorbed dose rates in air were 54 (alumina) and 98 (bauxite) $\mu Sv \cdot y^{-1}$, which is lower than the 1 $mSv \cdot y^{-1}$ recommended for the general public. The annual gonadal dose equivalent of all samples with the exception of scrap was higher than the world average values.

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INTRODUCTION

Natural radioactivity is a common phenomenon that is as old as the age of the planet earth. Radioactive elements occur naturally in rocks, soils and water in varying concentrations. They give rise to a natural radiation back-ground that varies by approximately two orders of magnitude over the surface of the earth, but in most situations this exposure is not amenable to control (**UNSCEAR, 2000**.) Most of the essentials of man come from the earth crust with the exception of air. Dependence on these essentials such as soil, water, rock and minerals poses some natural radiation treats to man.

Enhanced levels of naturally occurring radionuclides may be associated with certain natural materials, minerals and other resources. Exploitation of these resources for the production of consumer items may lead to further enhancement of the radioactivity at concentrations above normal in the products, by-products, residues or waste arising from the industrial process. Raw materials used in industries may contain naturally occurring radioactive materials (NORM)**,**the most important radionuclides are ^{238}U and ^{232}Th and their decay products, as well as ^{40}K (**Beretka*et al.,* 1985;Bruzzi*et al.,* 2000;Karagiannidi*et al.,* 2009 and Fathivand*et al.,* 2009)** The raw materials vary in activity concentrations depending on the region of origin (**Lu *et al.,*2006)**. The mining, transportation and processing of the raw materials may lead to the release of radionuclides into the environment and the distribution of the radionuclides in products and waste thereby giving rise to radiological hazards in workplaces and in the environment**(Hofmann *et al.,* 2000**.)

Study area

Nag-Hammadi area belongs administratively to Qena governorate lyingabout 60 kilometers from the city of Qena South Egypt Fig. (1).It extends for about 271 km^2 inland. The study area has the largest plant for the production of aluminum in the Middle East and the Arab World, largest factories for the production of sugar at the level of the Republic of Egypt.The plant of manufacturing wood particle-board remnants of sugar cane and also it's the promising district for tourism, (**http://www.qena.gov.eg/MainPage/DispProvinceInLines.)**

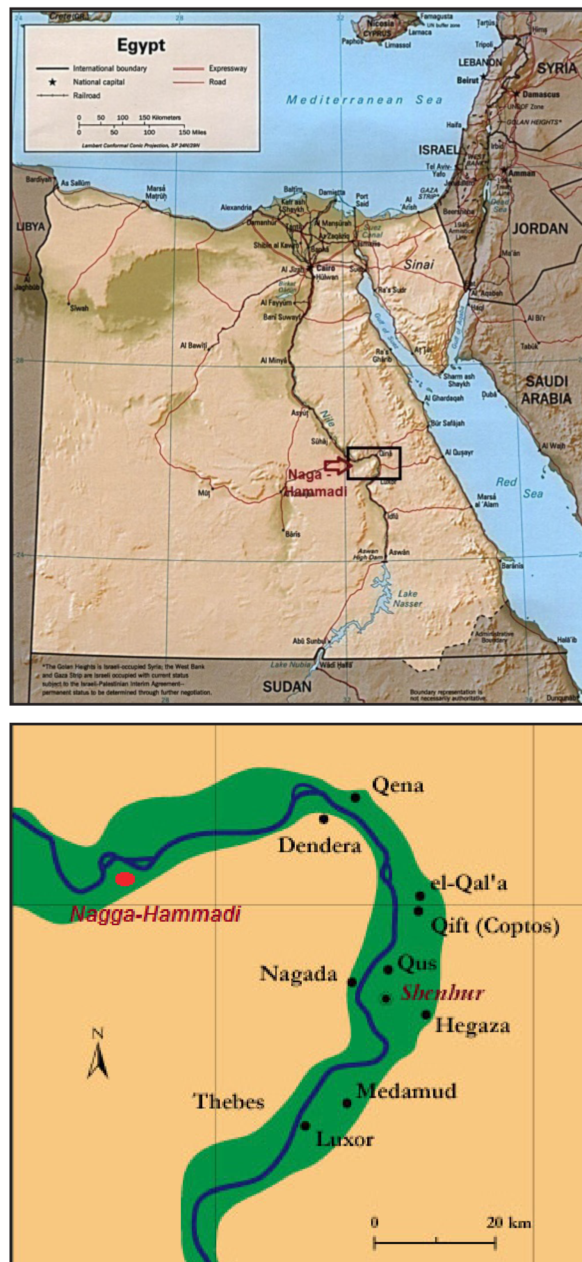

Fig. (1): The map of Egypt showing the Study area.

Work activities in which radiation exposure of workers and members of the public is increased due to the presence of NORM are receiving attention from regulatory authorities. To the best of our knowledge, there is no study on radiological aspect from Nag-Hammadiarea;therefore, the present study seeks to investigate the level ofnatural radionuclides in the environmental samples from the surrounding area of the study area. The health effects that such radionuclides may have on the population are also assessed.

MATERIALS AND METHODS

A total of 25 samples were collected from Naga-Hammadi city for this study. They include bauxite ore (4 samples), scraps (2 samples), alumina (7samples), water after use (4 samples), plant (4 samples) and soil (4 samples). The soil samples were taken around Aluminium Company. The scrap samples were collected from the aluminium scraps obtained during production and processing of aluminium into other products like ingots and billet before it is recycled. Limited number of samples was collected due to restriction by the industry involved. The map of Egypt showing the sampling spot is shown in Figure (1).

All samples were weighed, dried for 24h in an oven at 110 °C, (**Chieco*et al.,* 1992)** The dried samples were grinded in order to achieve homogenization; they were sieved through a 0.8 mm mesh sieve. The sieved samples were weighed and packed into Marinelli-type beaker (100 ml capacities according to the available sample amounts), to be analyzed using gamma spectrometers hermetically sealed and stored for a minimum of 4 weeks before measurement, to prevent the escape of gaseous ^{222}Rn and ^{220}Rn from the samples and to reach secular equilibrium between ^{226}Ra and its progenies (**Mollah*et al.,* 1986.)** Gamma-ray spectrometric measurements were carried out using a hyper pure germanium (HpGe) detector planner configuration CANBERRA Model GC5019, with a relative efficiency of 50% and resolution of 1.95 keV (FWHM) at 1.33 MeV for ^{60}Co gamma line. The detector was calibrated for the efficiency curve followed by standardization using KCl as a standard solution (**El-Tahawy*et al.,* 1992.)**

The gamma energy transition of 295.2 Kev (19.4%) and 351.9 Kev (37.1%) of ^{214}Pb and 609.3 Kev (46.1%), 1120.0 Kev (15.0%) and 1764.5 Kev (15.9%) of ^{214}Bi were used for ^{226}Ra determination; 583.1 Kev(33.2%) of ^{208}Tl,338.3 Kev (13.0%) and 911.2 Kev (30.3%) of ^{228}Ac gamma energy transition for ^{232}Th determination; while energy transitions of 1460.7 Kev (10.8%) were used to determine ^{40}K. Quality control and quality assurance of the measurements using IAEA reference materials (soil-6, IAEA-326). Also duplicate samples were added to insure the analysis consistency of the measurements. Blank samples were added to insure that cross- contamination is not occurring to the samples.

Activity concentration measurements

The activity concentration (A) in Bq gm^{-1} of each radionuclide was determined using the equation

$$A = \frac{C}{\eta . y . m} A = \frac{C}{\eta . y . m} \qquad (1)$$

Where C is the full-energy peak count rate of the measured radionuclide (in counts per second), η is the efficiency of detection for the specific energy, y is the correspondent gamma-ray yield, and m is the mass of the sample, expressed in grams,**Azouazi*et al.,* 2001**.

Radium equivalent

The radium equivalent index is used to represent the sum of activities of ^{226}Ra, ^{232}Th and ^{40}K by single quantity, which takes in account the radiation hazard associated with them. The radium equivalent indexRa$_{eq}$ had been defined assuming that 370 Bq·kg^{-1} of ^{226}Ra, 259 Bq·kg^{-1} of ^{232}Th and 4810 Bq·kg^{-1} of ^{40}K produce the same gamma dose rate and is given as **Beretaka*et al.,* 1985.**

$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.007C_{k}$ (2)

where C_{Ra} , C_{Th} and C_K are the activities (Bq/Kg) of ^{226}Ra(^{238}U series),^{228}Ra(^{232}Th series) and ^{40}K, respectively.

Exposure scenarios

Based on the materials and their mean activities, model calculations have been performed in order to assess the radiological consequence of typical scenarios and to identify the materials most dose relevant. These scenarios include; Dose uptake of operating personnel due to direct gamma radiation, and Dose uptake of operating personnel due to dust inhalation

1- The absorbed dose rate in air at a height of 1 m above the ground due to ^{226}Ra, ^{232}Th and ^{40}K was calculated using the formula (**UNSCEAR, 2000And Krieger, 1985).**

$D\ (nGy \cdot h^{-1}) = 0.462C_{Ra} + 0.604C_{Th} + 0.0417C_{K}$ (3)

Where C_{Ra}, C_{Th} and C_K are the activities (Bq/Kg) of ^{226}Ra(^{238}Useries),^{228}Ra(^{232}Th series) and ^{40}K, respectively.

2- The annual effective doses were calculated using a conversion coefficient of 0.7 $Sv \cdot Gy^{-1}$ for an absorbed dose in air to effective dose in human body, (**UNSCEAR, 2000**). The occupancy time was taken as the normal working hours in Egypt which is 8 hours per day for five days in a week. For 50 working weeks per annum, the occupancy time is 2000 $h \cdot y^{-1}$.Hence, the annual effective dose, AED, is

$AED = D \times 10^{-9}\ (Gy \cdot h^{-1}) \times 0.7\ Sv \cdot Gy^{-1} \times 2000\ h \cdot y^{-1}$ (4)

3- The organs of interest considered by **UNSCEAR, 1988** are the gonads, the active bone marrow and the bone surface cells. Hence the annual gonadal dose equivalent (AGDE), due the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the samples was calculated using the following relation, **Xinwei*et al.*, 2006**

$AGDE\ (\mu Sv \cdot y^{-1}) = 3.09C_{Ra} + 4.18C_{Th} + 0.314C_{K}$ (5)

RESULTS AND DISCUSSION

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were determined in the collected samples were shown in Table 1. The mean activity concentrations of ^{226}Ra in $Bq \cdot kg^{-1}$are (20) for bauxite, (31) for scrap, (16) for alumina, (4)$Bq \cdot L^{-1}$ for water,(20) for soil and <DL for plant, The mean activity concentrations of ^{232}Th in$Bq \cdot kg^{-1}$ are (33) for bauxite, (41) for scrap, (45) for alumina,<DL for water, (20) for soil, <DL for plant and The mean activity concentrations of ^{40}K $Bq \cdot kg^{-1}$(965)for bauxite, (354) for scrap, (105) for alumina,<DL for water,(274) soil, (4.2)

Table (1) *Activity concentrations of natural radionuclides in samples ($Bq \cdot kg^{-1}$ for all samples and $Bq \cdot L^{-1}$ for water).*

Sample	^{226}Ra		^{323}Th		^{40}K	
	Range	Mean	Range	Mean	Range	Mean
Bauxite (4)	12 - 28	20	13-53	33	950-980	965
Scrap (2)	24-38	31	41	41	348-360	354
Alumina (7)	5-23	16	35-50	45	91-137	105
Water (4)	5-15	10	<DL		<DL	
Soil (4)	11-30	20	9-31	20	184 -363	274
plant (4)	<DL		<DL		1.10 -7.30	4.20

<DL: less than detection limit, Detection limit 0.3 Bq/Kg (U-238, Th-232) 0.7 Bq/Kg (K-40)

Bq·kg^{-1}for plant.

The mean activity concentrations of ^{226}Ra, and^{232}Th in all of the samples are less than the world average for soil 33, 45 Bq·kg^{-1} respectively while ^{40}K is higher than the world average, 420 Bq·kg^{-1}, with the exception of Bauxite **UNSCAR, 2000**

Figure(2) presents a bar chats of the mean activity concentrations of the three radionuclides. Some reported concentration ranges of radioactivity in bauxite ore are given as 10 - 900 Bq·kg^{-1} for uranium series radionuclides, 35 - 1400 Bq·kg^{-1} for thorium series radionuclides and 10 - 600 Bq·kg^{-1} for ^{40}K, **IAEA, 2003.**Comparison of these with this study shows that the results obtained are within the lower ranges.

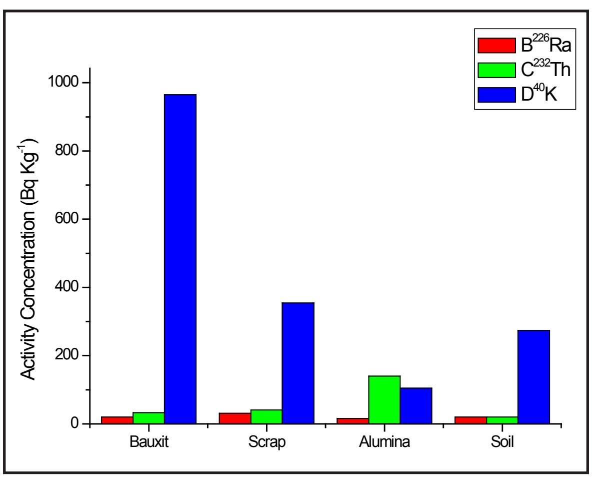

Fig. (2): Mean activity concentrations of natural radionuclides in samples.

RESULTS OF EXPOSURE

Radium equivalent activity (Ra_{eq})

The results obtained for $Ra_{eq}$are presented in Table (2), and the mean values of radium equivalent activity ranges from, 10 to 142 Bq·kg^{-1}. These are within the safety recommended limit of 370 Bq·kg^{-1}

Absorbed dose rate (D)

Radionuclides ranged from 39 nGy·h^{-1} (alumina) to 70 nGy·h^{-1} (bauxite). The mean absorbed dose rate for soil samples in the surroundings of the industry is 26 nGy·h^{-1}, this corresponds to the estimated world average value for soil 60 nGy·h^{-1}**UNSCAR, 2000.** All other samples had a mean value less than the world average except bauxite which had 70 nGy·h^{-1}.

Annual effective dose (AED)

The average annual effective dose are 98, 54, 76, 54 µSv·y^{-1}, respectively for bauxite, alumina, scrap and soil, these are less than the 1 mSv·y^{-1} recommended for the public **ICRP, 1990.**

Annual gonadal dose equivalent (AGDE)

The mean values of the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were used to calculate the AGDE. The results obtained Table (2), show that the AGDE from all samples are less than the world average value of 0.30 mSv·y^{-1},with the exception of scrap (0.4mSv·y^{-1}) (**Xinwei*et al.*, 2006).**

Table (2) *Radium equivalent activity (Ra_{eq}), absorbed dose rate (D), annual effective dose (AED) and annual gonadal dose equivalent (AGDE) of natural radionuclides in samples.*

Sample	Ra_{eq} (Bq·kg^{-1})		D (nGy·h^{-1})		AED (µSv·y^{-1})		AGDE (mSv·y−1)
	Range	Mean	Range	Mean	Range	Mean	Mean
Bauxite	104 – 179	142	53-86	70	74- 120	98	0.005
Scrap	109 – 124	117	50 – 58	54	71 – 81	76	0.4
Alumina	62 – 97	88	27 – 43	39	37 – 60	54	0.27
Water	5-15	10	3-7	5	7-10	9	0.005
Soil	38-102	70	18-33	26	25-64	54	0.23

CONCLUSION

The activity concentrations of natural radionuclides in samples from Naga-Hammadi city had been measured using gamma ray spectroscopy method. The radium equivalent activity (Ra_{eq}), absorbed dose rate in air and the annual effective dose were calculated from the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K. The results of the Ra_{eq} and external hazard index are within the recommended safety limit, the annual effective doses due to the samples are less than the recommended limit of 1 $mSv \cdot y^{-1}$ to the general public. However the annual gonadal dose equivalent was higher than the world average value of Scrap.

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مجـلة
التقنيـات النـوويـة
فى العلوم التطبيقية
مجلد 5 ، عدد 4 ، ص 215 : 222 ، (2017)

تقييم النشاط الإشعاعي الطبيعي وتقييم الأثر الإشعاعى في المنطقة المحيطة بمدينة نجع حمادي، قنا، مصر

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تهدف هذه الدراسه إلي قياس الخلفية الإشعاعية وتقييم الآثار الإشعاعية الناتجة عنها في المنطقة المحيطة بمدينة نجع حمادي - قنا - مصر.لذا فقد تم تجميع عدد خمسة وعشرون من العينات البيئية لمنطقة الدراسة (٤ عينات من البوكسيت الخام ، و ٢ عينه من الخردة و ٧ عينات من الألومينا و٤ عينات من المياه و٤ عينات من النباتات و ٤ عينات من التربة السطحية). وتم إستخدام جهاز الجيرمانيوم عالي النقاوة في قياس النويدات المشعة الطبيعية لعناصر سلسلتي (اليورانيوم-٢٣٨ والثوريوم - ٢٣٢) ونظير البوتاسيوم-٤٠ لهذه العينات وذلك بعامل هيئة الرقابة النووية والإشعاعية- مصر.وكان متوسط النتائج المتحصل عليها لسلسلة اليورانيوم-٢٣٨ مقدرة بالبيكريل - كجم عدا عينات المياه قدرت بالبيكريل - لتر كانت كالتالى ٢٠ لخام البوكسيت و٣١ للخردة و١٦ لخام الألومينا و ٢٠ لعينات التربة و ١٠للمياه.أما بالنسبة لسلسلة الثوريوم كانت كالتالى ٣٣ لخام البوكسيت و٤١ للخردة و٤٥ لخام الألومينا و ٢٠ لعينات التربة كذلك بالنسبة لنظير البوتاسيوم - ٤٠ كانت كالتالى ٩٦٥ لخام البوكسيت و٣٥٤ للخردة و١٠٥ لخام الألومينا و ٢٧٤ لعينات التربة.وبناء علي النتائج المتحصل عليها تم حساب مكافئ الراديوم (بيكريل/كجم) والجرعه الممتصة (نانوسيفرت/ساعة) والجرعة الممتصة السنوية ومكافئ الجرعة السنوية للغدد التناسلية وخلصت هذه الدراسة إلي أن الجرعة الأشعاعية المصاحبة لأشعاعات جاما علي بعد واحد متر أعلي سطح الارض في حدود قيمة المنظومة الدولية لحساب خلفية التعرض الإشعاعي ١ مللى سيفرت /عام فيما عدا الجرعة السنوية للغدد التناسلية لعينات الخردة (٠،٤٠ مللي سيفرت/عام) فهي أعلي من الحدود الموصي بها دوليا(٠،٣٠ مللي سيفرت/عام).

1. قسم المواقع والبيئة- هيئة الرقابة النووية والإشعاعية - ص. ب: 1557- مدينة نصر: 26711- القاهرة - مصر.