A comparative analysis of radioactive material concentrations in natural sources linked to mining in Niger using two measurement methods

Abstract

In the present work, we report the results of radioactivity measurements carried out in soils from the COMINAK and SOMAIR mining areas, using normal mode gamma-ray spectroscopy (NMGS) and thermal neutron activation analysis (TNAA). Radio activities were determined for two series radionuclides (U-238 and Th-232) and one non-series radionuclide (K-40) from measured gamma-ray spectra. The activity concentrations of U-238 and Th-232were respectively determined from the average nuclide concentration [Pb-214 (295.2keV ; 19.20%), Pb-214(351.9keV ; 37.10%), Bi-214 (609.3keV ; 46.90%), Bi-214 (1120.2keV; 15.04%) and Bi-214 (1764.49 keV; 15.90%)] and [Pb-212 (238.6keV; 43.6%), Pb-212 (300.09 keV; 3.18%), andAc-228 (911.2keV; 25.8%), Ac-228 (968.9keV; 15.8%), Ac-228 (338.32 keV; 11.27%)]. The activity concentrations of K-40 are determined directly by measuring gamma-ray transitions at 1460.8keV (100%) using a high-resolution pure germanium detector with good efficiency from the Egyptian Atomic Energy Authority. We find that the result found in NMGS technique and TNAA technique for COMINAK soil sample for U-238 and Th-232 are 2.32mg/Kg, 2.36mg/Kg and 11.67mg/Kg, 11.72mg/Kg respectively the results are getting closer. In SOMAIR soil sample the result found for U-238 is getting closer 1.35mg/Kg and 1.34mg/Kg respectively for NMGS and TNAA and also for Th-232 the result is close 7.2mg/Kg and 7.87mg/Kg respectively for NMGS and TNAA. The results obtained confirm that one of the samples (COMINAK soil) is more radioactive than the SOMAIR soil samples, and the results are similar for both NMGS and TNAA techniques, with the exception of thorium in the SOMAIR soil sample. This study will help to assess the environmental impact around the mining areas.

*Keywords: [*NORM, gamma-ray spectrometry, neutron activation, uranium mines*}*

1. Introduction

Uranium mining began in the Republic of Niger in the Monts Aériens region in 1968, with SOMAIR, a 50-70 m-deep open-pit mine located 7 km northwest of the mining town of Arlit. And the second, underground mine, located near the town of Akokan, and was created in 1974: COMINAK, with a depth of 250 m and over 250 km of galleries, is one of the largest underground mines in the world. The environmental impacts of uranium mining are as follows: Depletion of fossil aquifers, disappearance of vegetation cover, disturbance of flora and fauna, deformation of the landscape due to tailings formed by extracted materials, and deposition of radioactive waste and other radioactive materials. It is therefore clear that uranium mining in Niger over the past fifty years has had serious consequences for the environment and human health [1]. In order to properly assess the impact of uranium mining activities in Niger, an on-site mission was organized to gather the necessary information and carry out sampling at the COMINAK and SOMAIR sites [9,10]. The aim of this work is to measure natural radioactive materials in the Agadez region, Republic of Niger, and to compare the results of two methods: normal mode gamma spectroscopy and thermal neutron activation analysis. The activity concentrations of U-238, Th-

232and K-40 are determined. Multi-element analysis two soils sample of Niger republic namely: COMINAK and SOMAIR for soil series taken from 7km of two uranium site mining in Niger and using TNAA technique and NMGS technique at the Egypt Training Research Reactor-2. The analysis was done using the ETRR-2 and a PC based gamma spectroscopy system. A Reference Material, SOIL-7 supplied by the International Atomic Energy Commission (IAEA) was used to validate the methodology used Specific activitiesand mass concentrations in mg/kg.

2. Methodology

Several techniques for measuring radioactivity, particularly uranium, have been developed in nuclear physics and radiochemistry laboratories around the world. Among these techniques are those developed at the Nuclear Physics Laboratory of the Faculty of Sciences in Rabat since 1977: gamma spectrometry using either a Ge(Li) or a NaI (Tl) well detector, X-ray fluorescence spectrometry, solid nuclear trace detectors and neutron activation [6]. In this work, we used two methods to measure natural radioactivity: the normal mode gamma-ray spectrometry technique and neutron activation analysis. The activity of a radionuclide is determined from the number of events contributing to the total absorption peak per unit time. The corresponding count rate represents, to within a multiplicative factor, the radionuclide's activity. To do this, it is necessary to subtract the contribution of the continuum background, created by the interaction of higher-energy photons and ambient radiation. This operation constitutes the measurement of the net peak area; this net peak area is calculated by subtracting the background counts from the total counts in a peak on a gamma spectrum. The background counts are typically determined by measuring the counts in a region adjacent to the peak and extrapolating to the peak region. GENIE 2000 software is used to process spectra, from radionuclide identification to the calculation of characteristic γ-activities [4].

2.1 Sample collection and preparation

The samples were taken at Arlit and Akokan in the north-east of the Republic of Niger. A 1 kg soil sample was also taken from the Arlit garden, and another 1 kg soil sample was taken from the Akokan garden. Once the samples had been collected from the sites, they were taken to the National Centerof Radioprotection (CNRP) in Niger for physical preparation.The samples were then dried in the oven at around 100 degrees Celsius for around a day. Then they were ground and sifted to obtain a powder. Powdered samples were weighed and stored in sterilized plastics to avoid contamination, then stored for at least 28 days to allow for a secular balance between U-238, Th-232 and their progenies. These samples were packaged in plastics and transported on the plane to Egypt for analyzes. Analysis of the samples was carried out in Egypt at the laboratory of the Egyptian Atomic Energy Authority. The reference which is the IAEA-soil-7 was collected near Ebensee in Upper Austria at an altitude of 1100 m above sea level. The material was sieved through a 1 cm sieve, and then heated at 450^{o} C for 24 hours to destroy organic matter. This sample is intended to be used as a reference material for the measurement of trace elements in the soil samples. The details concerning the criteria for qualification as a recommended value can be found in the report (IAEA/RL/112) “Report on the Inter-comparison Run IAEA-Soil-7; trace elements in soil [7]

2.1 .1 Preparation of samples for gamma spectroscopy measurement

A soil sample from the COMINAK region and another from SOMAIR, each weighing 0.5 kg, were placed in two cylindrical plastic bottles 11.5 cm high and 5.5 cm in diameter. For gamma-ray measurements, each of the two samples was placed in direct contact with the detector and counted for around 72,000 seconds (20 hours). The gamma-ray counting time was set at 72,000 seconds for both counting modes. A long counting time was used because the samples had very low activities and the measurements therefore required very slow counting. The analysis software is then able to match the energy of the spectrum peaks to the radionuclides potentially present from a library that references all known X and γ lines. Once the peaks have been identified, quantitative analysis can begin. The radionuclides contained in the samples were identified and the areas under the peaks were used to determine the activity concentrations of each nuclide. The activity concentrations of U-238 and Th-232 were determined from the average nuclide concentration [Pb-214 (295.2keV; 19.20%), Pb-214 (351. 9keV; 37.10%), Bi-214 (609.3keV; 46.90%), Bi-214 (1120.2keV; 15.04%) and Bi-214 (1764.49KeV; 15.90%)] and [Pb-212 (238.6keV;43.6%), Pb-212 (300.09 keV; 15.90%)] and [Pb-212 (238.6keV;43.6%), Pb-212 (300.09 keV; 15.90%)]. 3.18%), and Ac-228 (911.2keV;25.8%), Ac-228 (968.9keV; 15.8%),Ac-228 (338.32keV; 11.27%)] respectively. Activity concentrations of K-40 were determined directly by measuring gamma-ray transitions at 1460.8keV (100%).The gamma spectrometry system of Egypt Training Research Reactor-2 was a Compton Suppression Spectrometry system with a main (primary) detector of Hyper Pure Germanium (HPGe) and secondary detectors of five NaI (TI) detectors was used. The system is used for double purpose; the first is the normal Gamma ray spectrometry mode: this is done by switching off the High Voltage Power Supply of the secondary detectors and working only with the main HPGe. And the second is theComptonsuppression mode; by utilizing the entire main as well as secondary detectors. Inthis work the Normal Gamma ray spectrometry mode is used. The specification of the detector is as follows; a high

resolution gamma ray spectrometry, it uses n-type HPGe detector Model 6MP-100250-S and Serial No. 38-N31278A. The detector has a relative efficiency of 100% and energy resolution of 2.1 keV at 1.33 MeV of Co-60 line and a peak-toCompton ratio (P/C) of 64: Energy calibration was performed using the standard Gamma ray point sources of Eu-152, Ba-133, Co-60, Cs-136 and Cs-137. Energy calibration was performed every time before measuring the irradiated samples. Energy calibration was carried out using option of Genie software.

2.1.2 Sample preparation for neutron activation analysis (NAA) measurement

The measurement of this quantity, commonly practiced in the past on activation detectors placed between two fuel pellets, was then developed on fuel rods from 1995 onwards. The γ spectrometry bench equipped with a planar-type detector was specially designed to measure γ lines at 277.6 keV, emitted by neptunium 239 (produced by neutron capture on uranium 238), and at 293.3 keV, emitted by cerium 143 for normalization to the total fission rate. If the uranium and thorium content of the sample is low, determining the concentration of U-238 and Th-232 is difficult. Soil samples have low concentrations, so a conventional long irradiation NAA can be used to determine their uranium and thorium nuclide content by measuring the radioactivity of the Np-239 and Pa-233 wires respectively. In fact, the first results of neutron capture are U-239and Th-233, which have short half-lives. It is therefore impossible to use the relative method, as they would disintegrate in subsequent measurements of the gamma rays they emit. Four soil samples were prepared. Two samples from the Republic of Niger, an IAEA standard sample (IAEA-313) in which the activities are known, and a blank (IAEA Soil-7). Two measurements were made for each sample, one for a short irradiation time of 60 seconds and the second for a long irradiation time of 3600 seconds. The irradiation process was managed in accordance with the procedure that follows radiological safety rules, in which the samples to be irradiated were stored in an irradiation bar that was located inside an irradiation isolation room or cobalt room using robotic arms. At the end of each irradiation, the capsule was removed from the reactor and allowed to cool (decay) until the activity level was within acceptable limits for handling. The samples were then removed from the capsule for counting. Each sample was placed at the appropriate position on the detector and counts were accumulated over a predetermined time to obtain spectral intensities. For short irradiation, a count time of 600 seconds proved adequate, and for long irradiation, the count time was 3600 seconds.

2.1 .3 Measuring activity in the context of low-noise counting

The sensitivity of a system is defined as a detection limit at or close to background level. This is a useful benchmark, not an absolute level. The critical level (Lc), detection limits (DL) and minimum detectable activity (MDA) is three benchmarks. The critical level (Lc) is the net count rate that must be exceeded for the sample to present measurable radioactivity above background with a certain degree of confidence. The critical level values were compared with the corrected net counts recorded in the photographic peaks for each nuclide. If the number of counts exceeds the critical level value, it is assumed that this line is emitted by the sample and the activity of this line has been determined; otherwise, it means that there is no measurable activity in the sample. The detection limit is based on the uncertainty of the results. In this work, the detection limit is calculated by Curie's formula of equation (1)

$$Dl = 2.71 + 4.65\sqrt{NB} \quad (1)$$

Where

N is the number of channels in the peak region of background,

Bis the continuum subtracted from the gross counts to produce the net area

If the result is below the decision threshold, the radionuclide is not detected. This does not mean that the radionuclide is absent, but that the measurement method guarantees with a high probability (1-β) that if it were present, its activity would not exceed the detection limit. The result is expressed as < LD.

If the result is above the decision threshold, the probability that the radionuclide is present is high (greater than 1-α). The most probable result is A, and the probability is high (equal to 1-γ) that the result lies between the lower and upper limits of the confidence interval. The result is expressed as A ± b, where b is the expanded uncertainty. It is an exact value when the standard uncertainty exceeds 25% (because in this case the confidence interval is symmetrical), and an approximate value when the standard uncertainty does not exceed 25% (because in this case the confidence interval is not exactly symmetrical).

The MDA is the minimum quantity of radioactive nuclide that we can be sure of detecting. It is often equated with the activity equivalent to the detection limit, DL. From DL in equation (1), we can deduce the MDA, which then becomes the activity we can expect to detect in 95% of cases.

$$MDA = \frac{DL}{\varepsilon . T_L . I_\gamma} \quad (2)$$

Where Iγ is the gamma emission probability, T_L is the counting lifetime; ε is the photo peak efficiency.

The MDA per sample mass can be calculated using equation (3):

$$MDA = \frac{DL}{\varepsilon.T_L.I_\gamma.m} \quad (3)$$

Where m is the sample mass in kg.

2.1 .4 ***Specific activity***

The activity per unit mass, i.e. the specific activity in Bq.kg-1, or the radiological concentration for each nuclide detected, is calculated by expressing Ai, for a nuclide i and for a peak at energy E, by equation (4). This expression ignores the limitations of both instrumentation and data analysis.

$$A_i = \frac{N_{in} - N_B}{\varepsilon_E.T_L.I_\gamma.m} \quad (4)$$

Where, N_{int} - N_B is the net area of a peak at energy E, ε_E is the detection efficiency at energy E, T_L is the live counting time, $I_\gamma$is the gamma emission probability at energy E, and m is the sample mass in kg. If there is more than one peak in the energy analysis range for a certain nuclide, an attempt is made to average the activities of the peaks. The result is then the weighted average of the specific activity of the nuclide. On the basis of the measured photo γ peaks emitted by specific radionuclides in the Th-232 and U-238 decay series and in K-40, their radiological concentrations in the samples taken were determined. The calculations are based on the establishment of a secular equilibrium in the samples, due to the much shorter lifetimes of the daughter radionuclides in the Th-232 and U-238 decay series. Specifically, the concentration of Th-232 was determined from the average concentrations of Pb-212 and Ac-228 in the samples, and that of U-238 from the average concentrations of the decay products Pb-214 and Bi-214. Thus, an accurate measurement of the radiological concentrations of Th-232 and U-238 was made, while an actual measurement of the K-40 concentration was carried out [2]. The radiological concentrations of Th-232, U-238 and K-40 were then converted to total elemental concentrations of thorium, uranium and potassium, respectively, according to the following equation (5):

$$F_E = \frac{M_E.C}{\lambda_E.N_A.I_\gamma.f.n}.\sum_{i=1}^{n} A_i \quad (5)$$

where F_E is the fraction of element E in the sample or the concentration of the element, M_E is the atomic mass (g.mol-1), λ_E is the decay constant (s-1) of the parent radioisotope, N_A is the Avogadro number (6.023×10^{23} atoms. mol-1), f is the fractional atomic abundance of Th-232, U-238 or K-40 in nature, C is a constant (with a value of 100 or 1,000) that converts the ratio of element mass to soil mass into percent or ppm, and A_i is the radiological concentration of radionuclide i .

3. RESULTS AND DISCUSSION

3.1 Gamma spectrometry in normal mode

3.1.1 Critical level and detection limit:

The critical level and detection limit for the normal mode gamma-ray spectrometry method are, as shown in Table 1, between 20 ± 12 and 126 ± 20 counts and between 42 ± 27 and 254 ± 44for Bi-214 (1764.49keV) and Pb-212 (238.63keV) respectively. This means that the soil sample must record values higher than these to be considered active. Analysis of the samples showed high concentrations recorded at COMINAK such as thorium (Th), Uranium (U) and Potassium (K). The present study has shown that the samples taken at the COMINAK site have high concentrations (see Table 2). This high concentration is thought to be due to the intensive uranium exploration carried out on the site over the years. The high presence of lead in the samples is certainly due to the use of fertilizers and household waste to improve market garden produce.

Table 1 Detection limits for gamma-ray spectrometry in normal mode

Radionuclides	Critical level(counts)	Detection limit(counts)
Pb-212	126±20	254±44
Pb-214	46±19	95±41
Ac-228	95±19	192±40
Pb-214	81±18	165±40
Pb-212	105±26	212±55
Bi-214	85±13	172±28

Ac-228	63±17	128±36
Ac-228	53±16	108±35
Bi-214	48±21	99±45
Bi-214	20±12	42±27
K-40	59 ±17	120±36

Table 2 activity concentration in the soil sample

Sample	Activity concentration in Bq/kg			Concentration in mg/kg		
	U-238	Th-232	K-40	U-238	Th-232	K-40
COMINAK	27.36± 0.02	47.21± 0.01	619.87± 0.01	2.32± 0.002	11.67± 0.001	19822± 0.001
SOMAIR1	15.7 ± 0.03	29.14± 0.02	542.48± 0.01	1.35± 0.003	7.2± 0.002	17350± 0.002

3.1.2 Estimating the accuracy and precision of NMGS measurements

Improving the quality of calculation forms therefore necessarily involves the use of controlled experiments and reduced uncertainties. However, given the harsh environment in which these measurement techniques are used, limiting phenomena are likely to introduce systematic errors that need to be assessed and quantified. Moreover, since the physical quantities of interest are never obtained directly, corrective factors must be applied to the raw measurement results. These are tainted by uncertainties that need to be assessed and propagated.

The precision and accuracy of the method are determined by the percentage, %P and En-score. Equations (6) and (7) were used to calculate the results shown in Table 5. A comparison was made between the U-238, Th-232 and K-40 activity concentration results obtained from samples from the Republic of Niger and the values specified by the IAEA for the IAEA-SOIL-7 reference sample. A certified reference material (IAEA-SOIL-7) was analyzed to confirm the accuracy of the methods. Results for all elements except K were within the certified concentration range.

$$\%P = \frac{x - X}{X}.100 \qquad (6)$$

$$E_n = \frac{x - X}{\sqrt{U_x{}^2 + U_X{}^2}} \qquad (7)$$

With x_ measured value for the sample, X _ IAEA certificate value, Ux-expanded uncertainty of the measured value and UX_ expanded uncertainty associated with the IAEA value. An En-score ≤1 indicates that x and X are in agreement within their respective uncertainties. An En-score>1 indicates that x is different from X and therefore that the uncertainty associated with the result has been underestimated. The performance criteria for En-scores are therefore as follows:

If En ≤1 satisfactory (in line with IAEA value).

If En ≥ 1 unsatisfactory (disagrees with IAEA value

3.1.3 **Concentration of activity**

Equation (6) was used to calculate the radionuclide activity concentration in mg/kg for the soil sample. The results are presented in Table 2. We conclude that Pb-212, Pb-214 and Bi-214 exist in measurable quantities only in the background environment of the detector and do not originate from the samples themselves.

Table 3 Minimum detectable activity for nuclides present in the background

Radionuclide	Pb-212	Pb-214	Ac-228	Pb-214	Pb-212	Bi-214	Ac-228	Ac-228	Bi-214	Bi-214	K-40
MDA(Bq/kg) COMI Soil	0.026	0.055	0.145	0.031	0.356	0.022	0.042	0.064	0.123	0.11	0.123
MDA(Bq/kg) SOMAIR	0.0224	0.0487	0.123	0.0322	0.308	0.0244	0.0400	0.0562	0.0656	0.0902	0.121

Soil											

Table 4 precision and accuracy for NMGS technique

Radionuclides	U-238	Th-232	K-40
COMINAK soil x(mg/kg)	2.32± 0.002	11.67± 0.001	19822 ± 0.001
SOMAIR soil x(mg/kg)	1.35 ± 0.003	7.2 ± 0.002	17350 ± 0.002
IAEA Sample 7, x (mg/kg)	2.6 ± 0.7	8.2± 0.5	12100± 600
%P COMINAK	10.8	18	63
In COMINAK	0.199	0.73	4.21
%P SOMAIR	43	12	85
In SOMAIR	0.45	0.999	8.63

When we consider each sample individually, looking at Table 4 considering each measurement for the COMINAK soil sample and the SOMAIR soil sample, it was found that the deviations of the uranium concentration results from the mean value of the IAEA certificate for uranium in the IAEA reference sample sol-7 are very high 48% and 10.8% in the SOMAIR soil sample and the COMINAK soil sample respectively for the normal mode Gamma Spectrometry Technique. The respective En-score results are 0.42 and 0.199. As these results is less than 1: indicates that x and X are in agreement with their respective uncertainties. Also for thorium, the deviations are 12% and 18% respectively for the SOMAIR soil sample and the COMINAK soil sample for the normal mode gamma-ray spectrometry technique. The respective En-score results are 0.99 and 0.73. As these results is less than 1: indicates that x and X are in agreement with their respective uncertainties. We note that the maximum deviations of the IAEA soil potassium results are 85% and 63%, ~En=8.63 and En=4.21 in this method, indicating that the uncertainty associated with the measured value has been underestimated.

3.2 Thermal neutron activation analysis

3.2.1. Minimum detectable activity

The activities of U-238 and Th-232 (in Bq/kg) in the samples were estimated from the activities of Np-237 and Pa-233 formed after long irradiation. The samples were co-irradiated with the IAEA standard sample. Potassium K-40 activity was estimated from K-42 activity after short irradiation.

Table 5 Minimum Detectable Activity

Radionuclide	MDA for COMINAK soil on Bq/kg	MDA for SOMAIR Soil on Bq/kg	Probability of emission
Np-239	0.73	0.51	0.1438
Pa-233	0.43	0.27	0.386
K-42	1.7	1.36	0.18

3.2.2.Activity concentrations of radionuclides U-238, Th-232 and K-40

Measurements were taken from environmental samples where uranium and thorium are present in trace amounts (mg/kg). Equation (8) was used to calculate the activity concentration. The results are shown in Table 7.

$$C_{samp} = C_{st} \frac{W_{st}.A_{sampl}}{W_{sampl}.A_{st}} \quad (8)$$

Where "samp" and "st" refer to the Republic of Niger sample and the standard sample respectively

Table (6) Activity concentration for TNAA

Name of sample		COMINAK	SOMAIR	IAEA-soil 313
Activity	U-238 (Np-239)	14138±0.06	6598.3±0.01	96154±0.02

concentration in Bq/kg	Th-232 (Pa-232)	206.6± 0.23	114.09± 1.3	1200± 0.01
	K-40 (K-42)	10925±0.06	6857.8±0.08	11942±0.04
Activity concentration in mg/kg	U-238	2.36 ± 0.03	1.34± 0.01	NA
	Th-232	11.72 ±0.13	7.87± 0.12	NA
	K-40	NA	NA	NA

NA: Not Applicable

All deviations are less than 50% the method is therefore accurate.

Table 7 compares the activity concentration results for U-238, Th-232 and K-40 between those obtained from sample measurements and the values specified by the IAEA for the IAEA-SOIL-7 reference sample.

Table 7 Precision and accuracy for NAA technique

Radionuclides	U-238	Th-233	K-40
COMINAK soil x(mg/kg)	2.36 ± 0.03	11.72± 0.13	NA
SOMAIR soil x(mg/kg)	1.34 ± 0.01	7.87 ± 0.12	NA
IAEA-Soil 7 x (mg/kg)	2.6± 0.7	8.2± 0.5	12100 ± 600
%P COMINAK (%)	9.2	42.9	NA
In COMINAK	0.17	0.34	NA
%P SOMAIR	48.5	4.02	NA
In SOMAIR	0.89	0.35	NA

NA: Not Applicable

4. Comparative assessment: Thermal Neutron Activation Analysis (TNAA) and Normal Mode Gamma Spectrometry (NMGS)

4.2 Normal mode gamma-ray spectrometry offers the best detection capability and the lowest minimum detection limit.

For individual isotopes, when using NMGS, Th-233 is better detected than K-40, and U-238 is better detected with NMGS than with TNAA. This may be explained by the fact that uranium 238 has a higher radioactivity than thorium 232. On the other hand, Th-232 is better detected by the TNAA measurement technique than U-238. This may be explained by the fact that Th-232 has a high relative neutron activation property.

Table 8 - Comparison between MDA for NMGS and technical TNAA

Radionuclides	MDA (Bq/Kg) COMINAK with NMGS	MDA (Bq/Kg) SOMAIR with NMGS	MDA (Bq/Kg) COMINAK with TNAA	MDA (Bq/Kg) SOMAIR with TNAA
U-238	0.07	0.052	0.73	0.51
Th-233	0.13	0.11	0.43	0.27
K-40	0.121	0.123	1.7	1.36

The results obtained with NMGS for U-238 and Th-233 are less than one (En ≤1), which is satisfactory (in agreement with the results obtained with TNAA for U-238 and Th-232 are smaller than 1 in the SOMAIR and COMINAK samples. This method is therefore satisfactory for these isotopes.

Table 9 Comparison between %P, E_n for NMGS and TNAA techniques

Radionuclides	En-score COMINAK with NMGS	En-score SOMAIR with NMGS	En-score COMINAK with TNAA	En-score SOMAIR with TNAA
U-238	0.199	0.45	0.17	0.89
Th-233	0.73	0.999	0.34	0.32
K-40	4.21	8.63	NA	NA

5. CONCLUSION

In present study, levels of natural radioactivity in soil samples collected from Akokon and Arlit, Niger Republic is determined using an HPGe detector and NAA. Comparison of the results obtained using TNAA and NMGS at the ETRR-2 and the certified known concentration of SOIL-7 showed that NMGS technique has good accuracy than TNAA. For the

cost and availability the Neutron Activation Analysis method is more expensive and less available than Gamma-rays Spectrometry method. The activity of the sample is low, longer count periods may be required to get statistically significant results. We find that the result found in NMGS technique and TNAA technique for COMINAK soil sample for U-238 and Th-232 are 2.32mg/Kg, 2.36mg/Kg and 11.67mg/Kg, 11.72mg/Kg respectively the results are getting closer. In SOMAIR soil sample the result found for U-238 is getting closer 1.35mg/Kg and 1.34mg/Kg respectively for NMGS and TNAA and also for Th-232 the result is close 7.2mg/Kg and 7.87mg/Kg respectively for NMGS and TNAA. In conclusion, it is appears that naturally occurring radioactive materials can be found almost everywhere. This leads to humans being regularly exposed to the ionization radiation from these nuclides. The activity concentrations of U-238 and K-40 are lower than the world wide average, but the activity of Th-232 is higher than the world wide average[8]. The results obtained confirm that the soil sample for COMINAK is relatively more radioactive than the soil samples of SOMAIR. Furthermore, comparison of the results obtained with the known standard concentration of U-238 and Th-232 in the IAEA SOIL-7 sample shows that the NMGS technique is more accurate than the TNAA method. These results show that γ-spectrometry is a powerful, multidisciplinary measurement technique. Its practical implementation is straightforward, which explains its universal use for characterizing nuclear materials and irradiating objects. It does, however, require a good understanding of the main limiting phenomena that users are likely to encounter.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

[1] Frank Winde, Doug Brugge, Andreas Nidecker, Urs Ruegg, and Uranium from Africa – An overview on past and current mining activities: Re-appraising associated risks and chances in a global context, Journal of African Earth Sciences, Volume 129, 2017, Pages 759-778, ISSN 1464-343X, https://doi.org/10.1016/j.jafrearsci.2016.12.004.

[2] Malcolm B. Cooper, Naturally Occurring Radioactive Materials (NORM) in Australian Industries - Review of Current Inventories and Future Generation, A Report prepared for the Radiation Health and Safety Advisory Council, ERS-006, 2005, EnviroRad Services Pty. Ltd.

[3] Raghunath, B. and P. Kotrappa, Diffusion coefficients of decay products of radon and thoron,*Journal of Aerosol Science* 10 (2): 133-138, 1979.

[4] NOTICE CANBERRA. "Genie 2000 Customization Tool Manual, 1997.

[5]. B. LAVENIR, "Measurement of the 242Pu capture rate", ENSPG internship report, June 1999.

[6]. O. Hakam et al "Impact of phosphate deposits on radioactivity in natural water and air samples in Morocco. Journal Afrique SCIENCE 01(2) (2005) 253 – 259 ISSN 1813-548X page 255

[7]. PszonickiL.,Hanna A. N. And Suschny o. , Report on the Intercomparison Run IAEA-Soil-7: Trace Elements in Soil.

[8]. United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and Effects of Ionizing Radiation. New York;. (United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes). Report No. 2000;I.

9. Kadiri MK, Muhammad A, Bashir M, Suleiman IK. Evaluation of Radiological Hazards Associated with Some Selected Mining Sites in Niger State, Nigeria. Current Journal of Applied Science and Technology. 2022 Sep 26:25-36.

10. Faweya EB, Ayeni MJ, Adewumi T, Faweya O. Environmental and Health Impacts: Presence of Radionuclides and Toxic Metals in Mining Areas in Niger State, Nigeria. Journal of Environmental Science and Management. 2023 Jul 8;26(1).