South Asian Research Journal of Natural Products

Volume 6, Issue 3, Page 118-128, 2023; Article no.SARJNP.98324

Determination of Naturally Occurring Radionuclides and Heavy metals in Pegmatite Rock Using Energy Dispersive X-ray Fluorescence (EDXRF)

Taiwo Bukola Fasiku [a*], Musbau Kewulere Fasasi [b] and Adebimpe Amos Amosun [b]

[a] *Department of Physics, Ajayi Crowther University, Oyo, Nigeria.*
[b] *Center for Energy and Research Development, Obafemi Awolowo University, Ile- Ife, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/98324

Original Research Article

Received: 08/03/2023
Accepted: 11/05/2023
Published: 20/05/2023

ABSTRACT

Aims: This study was to analyse pegmatite rock samples in order to determine the concentrations of naturally occurring radionuclides and heavy metals present in the samples.
Study Design: The samples were analysed using non-destructive Energy Dispersive X-ray fluorescence (EDXRF) spectrometer.
Place and Duration of Study: This work was carried out at the Centre for Energy and Research Development (CERD), Obafemi Awolowo University, Ile- Ife, Osun State, Nigeria between September 2016 and June 2017.

**Corresponding author: Email: ayenitaiwobukola@gmail.com;*

Methodology: In this study, analysis of ten randomly selected rock samples were carried out using EDXRF to determine the concentrations of the naturally occurring radionuclides and heavy metals presence. The elements detected were divided into three groups which include: radionuclides, major and minor elements which were related together using the Pearson correlation coefficient.
Results: The EDXRF analysis confirmed the presence of U (1.54 %), Th (0.40 %), and K (7.85 %) with concentrations higher than their permissible world values of 0.0002.8 %, 0.0007.4 %, and 1.3 %, respectively. The samples contained seven major elements (Fe, Mn, Pb, Ti, La, Ca, and Ta) and fourteen minor elements including some heavy metals (Zn, Sr, Zr, Cr, Nb, Mg, Ce, Re, Hf, V, Al, Nd, Sc, and Y). The results showed a large quantity of Fe with an average value of 37.67 %.
Conclusion: The presence of natural radionuclides and toxic metals like Cr, Pb, and Mn in significant quantity in some of the samples is of serious environmental and public concern. There is an absolute possibility that the heavy metal and the radionuclides find their ways into the natural ecosystem as a result of anthropogenic activities such as mining. This could pose miners, dwellers, and the general populace to a serious health risk.

Keywords: Elemental analysis; energy dispersive x-ray fluorescence; heavy metals; pegmatite; radionuclides.

1. INTRODUCTION

Mining of minerals is of high interest including pegmatites rock because it is associated with rare metals, gemstones, and industrial minerals [1-3]. The characterization of pegmatites is mainly based on the differences in the size of their grains and these are mostly found in ordinary igneous rocks [4]. Pegmatites are associated with diverse rock types, including migmatites, metamorphic rocks ranging from granulites to greenschists, and igneous rocks [4]. Pegmatites exhibit chemical interactions with wall rocks [4]. The earlier initiated and known classification was the one by Ferman [5] who used estimated temperature of crystallization to classify pegmatites. According to Ginsburg and Rodionov [6], a depth zone was used to classify pegmatites and this has been generally applied even in the classification by Cern'y and Ercit [7]. The trace element content of major pegmatite-forming minerals, including feldspar, mica, and quartz, has potential for chemical classification, even though these minerals commonly show a strong chemical zonation within one pegmatite body. Other accessories and valuable minerals that can be found in pegmatites include beryl, tourmaline, spodumene, garnet, uranium, and topaz while rare minerals that can also be formed in them include columbite and tantalite. Pegmatite also serves as a host rock for many rare mineral deposits such as beryllium, bismuth, boron, cesium, lithium, molybdenum, niobium, tantalum, tin, titanium, tungsten, and other elements [8]. The research discoveries revealed that some pegmatites contain high-grade uranium resources that can perhaps be profitably exploited [9-11].

In Nigeria, pegmatite rocks are generally mined by artisan miners who are only interested in their economic value and others from the communities around the mines use the tailings for domestic use such as landfilling and building construction without considering its elemental composition. Most times these rocks are composed of heavy metals that can endanger human lives. Heavy metals are regarded as metals or metal compounds that are toxic to the human body which could later harm human health. Due to an increase in urbanization and industrial activities, heavy metals found their ways into the environment and this may affect human well-being [12-15]. Recent research revealed that nickel, zinc, and copper aid human well-being and can be found everywhere [16]. The use of chromium element in commercial industries can be carcinogenic [17]. These elements contaminate the air, water bodies, and the food ingested by the people in such polluted environments [18-20].

Naturally occurring radionuclides in our immediate ecosystem are of great concern due to its hazardous effect on human’s well-being through ionizing radiation. The concentrations of these elements is peculiar to the geology of the environment either from natural and anthropogenic sources [21]. These radionuclides are present in rock, soils, waterways which may contaminate plants and may be passed on to humans through food chains [22-24]. Every rock is characterized by its chemical composition. A quantitative and qualitative analysis must be carried out in order to identify the contents in minerals such as rocks, [25,26]. The elemental compositions of elements in environmental samples had been carried out by authors using atomic absorption spectrometry (AAS) [27-29]. Other research studies used X-ray Fluorescence (XRF) in determining their elements [30-32]. The analysis of the rock samples in this study was carried out using x-ray fluorescence (XRF) techniques. This technique has been considered the most common and widely used in terms of its sensitivity, rapid detection of elements present in samples without a long process of preparation in ppm or %, and accuracy [33,34]. It can be used to analyze multi- elements. In Energy Dispersive X-ray Fluorescence spectrometry, the sample is bombarded with X-rays from the x-ray tube and generated characteristics X-rays and these are sent to the detector. The characteristics of X-rays interact with the detector and release pulses, proportional to the energy deposited. The total charge of the pulses is measured and the concentration of each element in the sample is determined. This research aimed to ascertain the radioactive elements and heavy metals present in the rock samples in order to identify their possible implications to both the miners and the general populace. The data obtained in this study will also provide information on the radiation level from the naturally occurring radionuclides in the rocks as well as the heavy metals.

2. MATERIALS AND METHODS

2.1 Study Area

A total of ten pegmatite rock samples were randomly collected from the Wamba area of Nasarawa State, Nigeria, as shown in Fig. 1. The study location falls within the Nigeria 400 km coverage ‘pegmatite belt’ between Longitudes 8º 30'E and 8º 40'E and Latitudes 9º 00'N and 9º 07' N which run between northwest to the central north of the country. According to research, it was revealed that Wamba pegmatite is the third largest pegmatite field after Jema’a and Egbe-Ijero pegmatite according to Matheis and Vachette [35]. The area can be assessed through the Jos – Fadan Karshi and then enter into Wamba. This cut across the central pegmatite zone of Nigeria. Other minor roads connect (Gwon-Gwon) pegmatite at Wamba with settlements like Kuraga, Rimi, and Kejeri all within the study area. The area is majorly dominated by vegetation and thick forest and this made their main occupation to be farming.

2.2 Sampling

After the collection of the rock samples, they were transported and prepared for analysis. The samples collected were crushed and then ground in a ball milling machine. Each ground sample was packed in a drug dispensable nylon and transferred to the energy-dispersive x-ray fluorescence (EDXRF) laboratory for analysis. The samples were further pulverized manually to a very fine powder with an agate mortar and pestle. Pellets of 13 mm diameter were made from 0.4 g powder without binder with an 8 - tons hydraulic press (CARVER INC. Model M, Serial no. 12000-270). The pellets were in new drug dispensable nylons to avoid contamination and kept in a polypropylene container until analysis. The EDXRF spectrometer at the Centre for Energy and Research and Development in Obafemi Awolowo University Ile-Ife was used to determine the elemental compositions in the pegmatite rock samples.

2.3 Instrumentations

The spectrometer used in this study was an XR-100CR detector with its in-built preamplifier. The MINI-X consists of the X-ray tube which irradiates the sample before the rays were sent to the detector with voltage and current, 25 kV/50 µA. The detector has a silicon thickness of 300 µm and 500 µm and a multilayer collimator. The setting used for the measurements in this study is the peak of the K-line of ^{55}Fe at 5.9 eV with a full width at half maximum (FWHM) of 186 eV for a shaping time constant of 20 µs. The energy calibration for the spectrometer was carried out using the K-lines of five standard sources with their energies and channels. These standards are Ca, Fe, Zn, Zr, and Sr. The standards and samples were irradiated for the same duration of 1000 s. The settings of each of the units of the spectrometer remain constant. The spectra obtained were stored for qualitative and quantitative analysis.

In this work, the quantitative analysis of samples was carried out using the Fundamental Parameter (FP) method in the Quantitative Analysis Software package. The software identifies and measures the concentrations depending on the sample. Each of the peaks in the spectrum corresponding to an element can be identified using the element library on the personal computer (PC) thereby giving a qualitative analysis. Quantitative analysis was carried out by obtaining the concentrations of the elements from the area under the peaks.

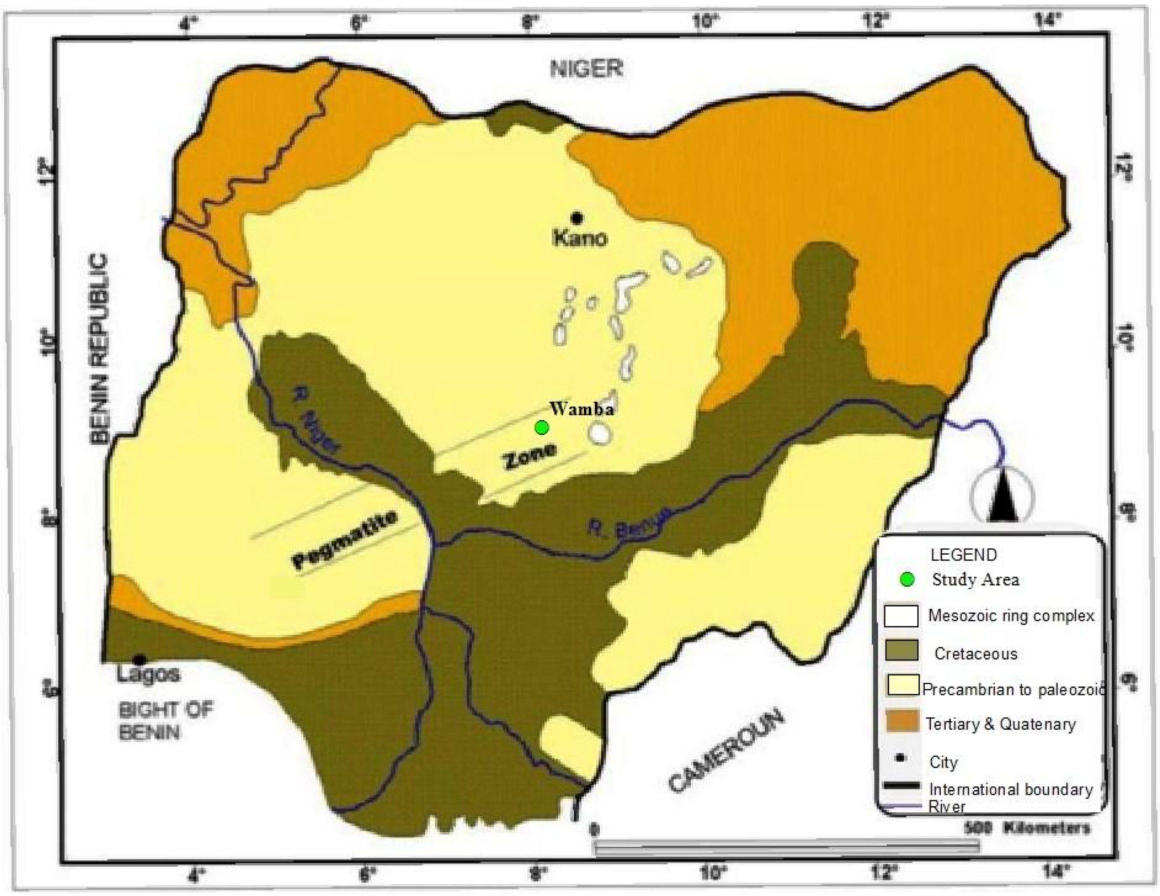

Fig. 1. Map of Nigeria showing the study area [36,37]

2.4 Statistical Analysis

In this research, a correlation between the naturally occurring radionuclides, major and minor elements was done. This was carried out by Statistical Package for Social Sciences (SPSS) version 20. It helps to know the relationship between the elements present in samples under study.

3. RESULTS AND DISCUSSION

The concentrations of 24 elements were identified using the EDXRF technique from the ten rock samples from the aforementioned mining site. These elements are divided into three (3) groups which are radioactive, major, and minor elements. Radioactive elements such as U, Th, and K are referred to as naturally occurring radioisotopes (radioelements). The concentrations of the radioactive elements are presented in Table 1. Table 2 showed major elements whose concentrations are greater than 1% by weight. These elements are Fe, Ti, Ca, Pb, La, Ta, and Mn. In Table 3, elements with concentrations less than 1% by weight are presented. These are regarded as minor elements which include 14 elements in number.

In the first group presented in Table 1, Uranium was observed to have the highest concentration in sample WB3 followed by sample WB6, with the lowest concentration in sample WB4. The concentrations of Uranium ranged from 0.35 ± 0.02 to 4.27 ± 0.10 % with a mean concentration of 1.54 ± 0.10 %. Large quantities of thorium were obtained both in samples WB7 and WB1. Thorium concentration varied from 0.08 ± 0.03 to 1.36 ± 0.01 % with an average value of 0.40 ± 0.10 %. The proportion of uranium and thorium in this study needed to be taken as a serious concern for both occupational and public exposure to radiation. Due to the significance of these radioelements (thorium and uranium) most importantly uranium, the miner may not be aware of the aftermath of overtime exposure to these two elements to their health. Uranium can be used to power nuclear reactors to generate electricity. Also, it is used for other purposes such as the production of isotopes which can be used in medical, industrial, agricultural purposes, and defense. Significant concentrations of Potassium were obtained in all the samples which had the highest concentrations in sample WB1 and ranged from 1.01 ± 0.05 to 21.13 ± 0.44 % with an average concentration of 7.85 ± 0.20 %.

In Table 2, Fe and other major elements obtained from the samples are presented. Fe had the highest concentration in the rock samples which varied from 16.59 ± 0.19 to 49.72 ± 0.12% with a mean value of 37.66 ± 0.20 %. Fe has been the most abundant element on earth and the tenth position in the universe with a mass of 34.6 % [30]. It is an essential element in plant nutrition. It has been useful in all sectors in particular construction of the building and other materials that are significant to human existence. Titanium concentration ranged from 0.88 ± 0.05 to 5.93 ± 0.10 % with an average mean of 4.15 ± 0.10 %. According to Olabanji [38], it was revealed that a large quantity of titanium in minerals may not expose people to severe health risks in the sense that its absorption by plants is poor. Lead was found to be high in sample WB7 with 1.87±0.10 and the lowest values in samples WB4 and WB9 with a concentration of 0.24 ± 0.01. The average value of Pb was obtained to be 0.89 ± 0.04 %. The lead element can be regarded as a harmful pollutant that is very hazardous to human body organs. Pb could be absorbed by the skin and also by the respiratory and digestive systems.

Over time exposure to Pb can lead to cardiovascular disorders due to immune modulation, it can also disrupt the balance oxidant-antioxidant system and cause alteration in physiological functions of the body which is associated with many diseases [39-41]. It is used in the production of weapons, in battery cells, and in devices used in shielding X-rays to avoid direct contact with the human body. La was not detected in sample WB1 and it has a mean value of 1.20 ± 0.10 %. It can be found in modern television sets, energy-saving lamps, and fluorescent tubes. It is used as a catalyst in the petrochemical industries. It has its side effects, especially in the petroleum-producing industry when it is not well disposed of, it could cause severe damage to plants and animals which may later cause nervous system disorders in human beings. Ta concentration varied from 0.43 ± 0.02 to 4.04 ± 0.16 with an average value of 1.55 ± 0.10 %. Tantalum oxide is found to be insoluble which made it impossible to be detected in the waters and it is also poorly absorbed by plants. This metal can be of advantage in various commercial high-temperature applications e.g. aircraft engines, electrical devices such as capacitors, and surgical implants. It can be harmful when inhaled or ingested. Also when it is absorbed by the skin, it could cause eye or skin irritation. According to research, low adverse effects of tantalum were observed in industrially exposed workers. Ca and Mn ranged between 0.57 ± 0.04 to 4.58±0.28, and 0.64 ± 0.03 to 2.12 ± 0.05 with mean values of 1.30 ± 0.10 and 1.10 ± 0.03 %, respectively. Manganese is abundant in nature and about 0.1 % of the earth's crust. According to Calabrese [42], elements like Fe, Mn, Zn, and Ca are regarded as essential and beneficial elements to the human body but if they continue to mount up in the body, they could bring about the metabolism of harmful elements such as Cd and Pb. Therefore, the mining of minerals like iron ore can lead to pollution or contamination of the environment as dust with enhanced radioactivity [43]. This can be inhaled or ingested by the miners or people living in the environment which might pose health risks. Also unknowingly to the public these tailings are bought and used in the construction of buildings which could lead to indoor radiation exposure.

The concentrations of minor elements present in the rock samples were shown in Table 3. Nb has its highest concentration in sample WB3 with 0.12 %. It was not detected in sample WB1. A large concentration of Y was observed in sample WB7 with a value of 0.21 %. Zinc has the highest concentration in sample WB8 which ranged between 0.10±0.01 to 1.21±0.02 % with an average value of 0.54 ± 0.01 %. Zinc has been of various importance, especially in the body. Zn can be regarded as the oldest of all metals. The hazardous impact of Zinc on humans depends on the interaction and the quantity of exposure. The major sources of zinc are industrial activities like the smelting of iron and the mining of mineral resources. Zr varies from 0.07 to 0.13 % and its highest values were obtained in WB2, WB6, and WB10. Sr has the highest concentration in sample WB3 and ranged between 0.03 to 0.19%. Cr has its highest concentration in sample WB7 (0.36 %) followed by 0.21 % in sample WB1 with an average value of 0.09 ± 0.01 %. Chromium element is a naturally occurring heavy metal that can be found in the earth's crust, water bodies, and industrial environments but an increase in body load may result in allergic reactions [30,44]. According to International Agency for Research on Cancer (IARC) report, group 1 carcinogen diseases were traced to be associated with hexavalent chromium element [45]. The easiest way to expose the general populace to chromium is the intake of food, water containing chromium, and skin contact with products that contain the element [46,48]. Magnesium was not detected in samples WB1, WB3, WB4, WB6, WB7, WB8, and WB10 but was present in samples WB2, WB5, and WB9 with a concentration value of 0.33 ± 0.00 %. Both Hf and Re were detected in all the samples with the values ranging between 0.04 to 0.75% and 0.40 to 2.10 % respectively. Vanadium was detected in samples WB5 and WB7. It is relatively a toxic element and a tiny quantity in the diet can lead to a pharmacological effect on the organism [49]. Al was detected in samples WB2, WB5, and WB9 with a value of 0.25 %. There was significant proportion of aluminum in the samples which revealed that in the course of weathering process of the rock, aluminum can be replaced by strontium and then calcium. However, if plant absorbs strontium instead of calcium and animal ingest these plants, this may cause poor bone formation in an animal. Nd was observed in samples WB1, WB7, and WB10. Sc was obtained in WB2 only with a concentration value of 0.0001 %.

The comparison of minor elements in this study and other locations were presented in Table 4. The results of the Pearson correlation coefficients between the naturally occurring radionuclides, major and minor elements are presented in Table 5. The elemental compositions obtained from the rocks samples include the radionuclides, major and minor elements from the area under study were related together to establish the relationship between them. In Table 5, U showed a weak negative correlation to all elements except Ti, Nb, and Sr. Both the Th and K have a strong positive

Table 1. Concentration of radioelements in the pegmatite rock samples [wt. (%)]

Samples	**Elements**		
	U	**Th**	**K**
WB1	0.99±0.06	1.15±0.01	21.13±0.44
WB2	1.28±0.07	0.54±0.15	2.09±0.12
WB3	4.27±0.10	0.70±0.01	3.06±0.12
WB4	0.35±0.02	0.09±0.01	1.01±0.05
WB5	0.82±0.05	0.55±0.14	12.56±0.29
WB6	2.39±0.07	0.18±0.01	1.97±0.09
WB7	0.88±0.08	1.36±0.01	21.28±0.64
WB8	1.06±0.05	0.22±0.01	11.72±0.22
WB9	1.27±0.04	0.08±0.03	1.49±0.06
WB10	2.04±0.06	0.14±0.01	2.16±0.09
Min.	0.35±0.02	0.08±0.03	1.01±0.05
Max.	4.27±0.10	1.36±0.01	21.13±0.44
Mean value	1.54±0.10	0.40±0.10	7.85±0.20

Table 2. Concentration of major elements in the pegmatite rock in wt. (%)

Elements Samples	**Fe**	**Ti**	**Pb**	**La**	**Ta**	**Ca**	**Mn**
WB1	23.57±0.16	0.88±0.05	1.48±0.06	**ND**	3.04±0.09	1.72±0.12	2.11±0.05
WB2	42.86±0.19	5.93±0.10	1.21±0.06	1.95±0.20	1.05±0.06	0.72±0.05	0.64±0.03
WB3	33.39±0.15	11.70±0.13	0.77±0.04	0.49±0.09	1.04±0.05	1.11±0.06	1.11±0.03
WB4	47.82±0.13	4.57±0.05	0.24±0.02	3.01±0.15	0.60±0.03	0.39±0.02	0.84±0.02
WB5	35.42±0.17	1.56±0.06	0.59±0.04	0.52±0.10	1.82±0.07	1.66±0.09	1.54±0.04
WB6	43.14±0.15	5.44±0.07	0.39±0.02	2.36±0.16	1.13±0.05	0.77±0.04	0.83±0.02
WB7	16.59±0.19	2.03±0.11	1.87±0.10	1.27±0.29	4.04±0.16	4.58±0.28	0.87±0.05
WB8	38.29±0.14	1.47±0.04	1.53±0.05	0.04±0.02	1.42±0.05	0.74±0.04	0.76±0.02
WB9	49.72±0.12	3.54±0.04	0.24±0.01	0.32±0.04	0.43±0.02	0.72±0.03	1.07±0.02
WB10	45.85±0.15	4.41±0.06	0.54±0.03	1.36±0.12	0.97±0.04	0.57±0.03	0.87±0.02
Min.	16.59±0.19	0.88±0.05	0.24±0.01	ND	0.43±0.02	0.39±0.02	0.64±0.03
Max.	49.72±0.12	5.93±0.10	1.87±0.10	3.01±0.15	4.04±0.16	4.58±0.28	2.11±0.05
Mean	37.67±0.20	4.15±0.10	0.89±0.00	1.20±0.10	1.55±0.10	1.30±0.10	1.10±0.03

Table 3. Concentration of minor elements in the pegmatite rock in wt. (%), $\pm \leq$ 0.02 concentration error

No.	Elements	WB1	WB2	WB3	WB4	WB5	WB6	WB7	WB8	WB9	WB10
1	Zn	0.10	0.46	0.72	0.61	0.40	0.44	0.51	1.21	0.54	0.39
2	Nb	ND	0.03	0.12	0.02	0.07	0.09	0.02	0.01	0.03	0.05
3	Zr	0.11	0.13	0.12	0.07	0.10	0.13	0.20	0.11	0.08	0.13
4	Sr	0.09	0.14	0.19	0.03	0.06	0.07	0.10	0.04	0.04	0.06
5	Y	0.11	0.01	0.06	0.003	0.06	0.04	0.21	0.02	0.01	0.02
6	Cr	0.21	ND	ND	ND	0.17	ND	0.36	0.06	0.14	ND
7	Mg	ND	0.33	ND	ND	0.33	ND	ND	ND	0.33	ND
8	Ce	0.17	ND	ND	ND	ND	ND	0.44	0.12	ND	ND
9	Re	2.05	0.72	1.16	0.40	1.63	0.58	2.10	1.14	0.41	0.50
10	Hf	0.75	0.40	0.13	0.11	0.17	0.21	0.44	0.20	0.04	0.05
11	V	ND	ND	ND	ND	0.26	ND	0.28	ND	ND	ND
12	Al	ND	0.25	ND	ND	0.25	ND	ND	ND	0.25	ND
13	Nd	0.52	ND	ND	ND	ND	ND	0.75	ND	ND	0.96
14	Sc	ND	0.0001	ND	ND	ND	ND	ND	ND	ND	ND

Table 4. Comparison of minor elements concentrations with other locations around the world

Elements	Karon lake ppm [50]	Wadi El Rayan ppm [50] ppm	Oba Akoko ppm [47]	Bayelsa mg/kg [51]	Kabba mg/kg [30]	Gezira ppm [52]	Suki ppm [52]	Nyala ppm [53]	Ado Ekiti mg/kg [34]	Romania mg/kg [53]	Present Study %
Zn	27-33	25-90	138-593	18.3-77.8	-	68.96	54.8	0.001-0.1670	90-246	34.07-100.2	0.10-0.72
Nb	22-32	27-32	-	-	-	-	-	-	35-120	-	ND-0.09
Sr	33-85	17-137	237-1025	-	-	-	-	-	13-89	-	0.03-0.19
Zr	79-231	98-737	173-1737	116.2-1483	5930	-	-	105.5-858.9	151-953	-	0.07-0.20
Y	11-34	9-38	-	-	-	-	-	9.7-31.2	-	-	0.003-0.21
Cr	26-98	23-203	ND-11	7.8-80.8	340	77.21	123.33	0.012-9.726	-	52.91-101.26	ND-0.21
Mg		-	-	-	-	-	-	-	-	-	ND-0.33
Ce	-	-	-	-	-	-	-	-	-		ND-0.44
Re	-	-	-	-	-	-	-	-	-		0.40-2.10
Hf	-	-	-	-		-	-	-	-		0.04-0.75
V	7-57	11-17	357-1178	70-1495.8	1030	-	-	27.7-70.6	-	59.50-110.74	ND-0.28
Al	-	-	-	-	-	-	-	-	-	-	ND-0.25
Nd	-	-	-	-	-	-	-	-	-	-	ND-0.96
Sc	-	-	-	-	-	-	-	-	-	-	ND-0.0001

Table 5. Pearson correlation coefficient between natural radionuclides, major and minor elements present in the rock samples

Variable	U	Th	K	Fe	Ti	Pb	La	Ta	Ca	Mn	Zn	Nb	Zr	Sr	Y	Re	Hf
U	1																
Th	-.031	1															
K	-.372	.822**	1														
Fe	.031	-.958**	-900**	1													
Ti	.845**	-1.66	-6.33	.2.53	1												
Pb	-1.87	.764	.787**	-801	-.348	1											
La	-210	-.155	-.369	.254	.130	-.283	1										
Ta	-265	.909**	.937**	-.951**	-.478	.794**	-.126	1									
Ca	-.186	.842	.775	-.867	-.314	.658	-.143	.909**	1								
Mn	-.097	.467	.566	-.451	-.336	.116	-.459	.406	.172	1							
Zn	.106	-3.55	-.178	.192	.140	.126	-.436	-.287	-.188	-.564	1						
Nb	.844**	.055	-283	-.050	.710*	-.366	-.078	-.179	-.138	.448	-.264	1					
Zr	.147	.653*	.470	-.672	-.021	.663*	-.011	.707*	.777**	-.211	-.095	.008	1				
Sr	.688*	.515	.013	-393	.697*	.308	-.098	.168	.211	.030	-.104	.568	.419	1			
Y	-.078	.905**	.823**	-.937**	-.270	.674*	-.121	.949**	.967**	.320	-.276	-.006	.763*	.280	1		
Re	-.156	.907**	.950**	-.957**	-.403	.755*	-.402	.917**	.792**	.604	-.213	.019	.505	.273	.851**	1	
Hf	-.266	.788**	.738*	-.724*	-.375	.728*	.179	.748*	.484	.536	-.453	-.249	.380	.281	.596	.718*	1

*** Correlation is significant at the 0.01 level*
**Correlation is significant at the 0.05 level*

correlation with the following elements Ta, Y, Re, Hf, and a strong negative correlation with Fe. Iron and Titanium have a strong negative linear relationship with some of the elements like Pb, Ta, Ca, and others. La has negative correlations with the major and minor elements present in the sample. Pb has a strong correlation with Ta, Zr, Y, Re, and Hf. Mn, Zn, and Nb showed a weak negative correlation with all the minor elements in the study. Ta correlates strongly with Ca, Y, and Re. Ca has a significant linear relationship with Zr, Y, and Re. Mn, Zn, and Nb have weak negatives with most minor elements in the sample. Y has a strong linear correlation with Re and Sr has a weak correlation with the three following minor elements; Y, Re, and Hf. All three radionuclides obtained in this study are poorly correlated especially with major elements in the sample. This showed that the rock samples have uncommon geochemical behavior which means they are derived from different origins and do not interact with each other.

4. CONCLUSION

The EDXRF spectrometry techniques used in this study showed the presence of radioelements with the mean values of U, (1.54±0.10 %) Th, (0.40±0.10 %) and K (7.85±0.20 %) major (Fe, Mn, Pb, Ti, La, Ca, and Ta), and minor (Zn, Sr, Zr, Cr, Nb, Mg, Ce, Re, Hf, V, Al, Nd, Sc, and Y) elements (including heavy metals). The concentration of naturally occurring radionuclides was higher than the world-recommended values. The presence of heavy metals like Mn, Cr, and Pb in the soil could contaminate the farm products from this area due to the weathering of the rock being washed down to the parent soil including toxic substances. However, these toxic substances will also be taken by plants and then ingested into human bodies and this could be hazardous to humans.

The Pearson correlation analysis showed strong linear relationship between radionuclides and some elements. Also strong positive correlations were observed in most of the elemental pairs in the samples. This study will serve as a piece of baseline information to know the level of exposure to radiation and other harmful elements via water and food ingested into the body of the miners and the people around the area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Glover AS, Rogers WZ, Barton JE. Granitic pegmatites: Storehouses of industrial minerals. Elements. 2012;8(4):269-73.
2. Simmons WB, Pezzotta F, Shigley JE, Beurlen H. Granitic pegmatites as sources of coloured gemstones. Elements. 2012; 8(4):281-7.
3. London D, Verplanck PL, Hitzman MW. Rare – element granitic pegmatites. Rare earth and critical elements in ore deposits. Rev Econ Geol. 2016;18:165-94.
4. Müller A, Simmons W, Wise M, Thomas R, Martin R, Beurlen H et al. Initiative of a new classification of pegmatites – A review of initial thoughts. Abstract Volume of the 21st General Meeting of the International Mineralogical Association 1, Johannesburg, South Africa. 2014;260.
5. Fersman A. A geochemical genetic classification of pegmatites. Monograph Akademiia Nauli SSSR. (in Russian); 1930. p. 85-9.
6. Ginsburg AI, Rodionov GG. On the depths of the granitic pegmatite formation. Gearogiya Rudnykh Mestorozhdenyi Lzd Nab Moskva. 1960;1:45-54.
7. Cern'y P, Ercit TS. The Classification of Granitic pegmatites revisited. Earth Sci. 1981;2(2):81-90.
8. Tanko IY, Chime P. Geochemistry and mineralization of some selected pegmatite deposits in panda North Central, Nigeria, EJERS, European. J Eng Technol Res. 2021;6(2):58-66.
9. Mawdsley JB. Uraninite-bearing deposits, Charlebois Lake area, Northeastern, Saskatchewan, Canad, Inst Min Metal. Bull. 1952;482:66-375.
10. International Atomic Energy Agency (IAEA) geological classification of uranium deposits and selected examples. TecDoc. Vienna, 2018.
11. Association WN. World uranium mining production; 2020.
Available: https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production.aspx
12. Salonen V, Korkka-Niemi K. Influence of parent sediments on the concentration of heavy metals in urban and suburban soils in Turku, Finland. Finl Appl Eochemisty. 2007;22(5):906-18.
13. Sodango TH, Li X, Sha J, Bao Z. Review of the spatial distribution, source and

extent of heavy metal pollution of soil China: impacts and mitigation approaches. J Health Pollut. 2018;8(17):53-70.

14. Timothy N, Tagui Williams E. Environmental pollution by heavy metal: an overview. Environ Chem. 2019;3(2):72-82.
15. Sharma P, Kumar S, Pandey A. Bioremediated techniques for remediation of metal pollutants using metagenomics approaches: A review. J Environ Chem Eng. 2021;9(4):105684.
16. Azeh Engwa G, Udoka PF, Nweke FN, Unachukwu NM. Mechanism and health effects of heavy metal toxicity in humans poisoning mod. world. New Tricks Old Dog. 2019;82511.
17. Coetzee JJ, Bansal N, Chirwa EMN. Chromium in environment, its toxic effect from chromite- mining and ferrochrome industries and its possible bioremediation. Expo Health. 2020;12(1):51-62.
18. Zhao Y, Fang X, Mu Y, Cheng Y, Ma Q, Nian H et al. Metal pollution (Cd, Pb, Zn and As) in agricultural soils and soybean, glycine max, in southern China. Bull Environ Contam Toxicol. 2014;92(4):427-32.
19. Emurotu JE, Onianwa PC. Bioaccumulation of heavy metals in soil and selected food crops cultivated in Kogi State, North Central Nigeria. Environ Syst Res. 2017;6(1):1-9.
20. Hasan AB, Reza AHMS, Kabir S, Siddique MAB, Ahsan MA, Akbor MA. Accumulation and distribution of heavy metals in soil and food crops around the ship breaking area in southern Bangladesh associated health risk assessment. SN Appl Sci. 2020;2(2): 1-18.
21. United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and Effects of Ionizing Radiation, General Assembly with scientific annexes, New York: United Nations Sales Publication. United Nations. 2000;1.
22. Faweya EB, Adesakin GE, Faweya O. X-ray fluorescence (XRF) analysis of rock and soil samples from a magnetic intrusive rock in Oba Akoko, Nigeria. Adv Phys. 2016;11(9):4043-53.
23. Ajayi OS, Dike CG, Balogun KO. Elemental and radioactivity analysis of rocks and soils of some selected sites in southwestern Nigeria. Environmental Forensic. 2018;19(2):87-98.
24. Orosun MM, Usikalu MR, Oyewumi JO, Achuka JA. Radioactivity levels and transfer factor for granite mining field in Asa, North- Central Nigeria. J Heliyon. 2020;6(6):e04240: 1-6.
25. Harvey B, Robert JT. Petrology. 2nd Ed. New York: Freeman.1997;66.
26. Jan S, Victor AD, Douglas KM, Jean CCH, Dennis DE. Quantitative X-ray diffraction analysis of clay- bearing rocks from random preparations. Clays Clay Miner. 2001;49:6 (Galley 59).
27. Isinkaye MO. Distribution of Heavy metals and Natural Radionuclide in Selected Mechanize Agricultural Farmlands within Ekiti State, Nigeria. Arab J Sci Eng. 2012;37(5):1483-90.
28. Kolapo AA, Omoboyede JO. Health Risk Assessment of Natural Radionuclide and Heavy metals in commonly consumed Medicinal plants in South- West Nigeria. IFE J Sci. 2018;20(3):529-37.
29. Okeyode IC, Makinde V, Bada BS, Mustapha AO, Jegede OA, Ajayi OA et al. Concentration of Natural radionuclides and Heavy Metals in Quarry pit soils in Abeokuta, Ogun State, South West Nigeria. Niger J Phys. 2018;27(2): 84-92.
30. Arogunjo AM. Heavy metal composition of some solid minerals in Nigeria and their Health implications to the Environment. Pak J Biol Sci. 2007;10(24): 4438-43.
31. Samia ME, Amany TS, Najat FA, Saher MD. XRF analysis of heavy metals for surface soil of Qarun Lake and wadi el Rayan in Faiyum, Egypt. Open J Met. 2013;3:21-5.
32. Mohammed MS. Chemical and Structural analysis of Rocks using X-ray fluorescence and X-ray diffraction Techniques. 2020; 79-87.
33. Lowemark I, Chen HE, Yang TN, Kylander M, Yu EF, Hsu YW et al. Normalising XRF scanner data; A cautionary note on the on the interpretation of high resolution records from organic – rich lakes. J Asian Earth Sci. 2011;40:1250-6.
34. Isinkaye MO, Shitta MB, Oderinde MO. Determination of radionuclides and elemental composition of clay soils by gamma- and X-ray spectrometry. SpringerPlus. 2013;2(74):2-11.
35. Matheis G, Caen-Vachette M. Rb – Sr Isotopic study of Rare Metal Bearing and Barren pegmatites in the Pan-African Reactivation Zone of Nigeria. J Afr Earth Sci. 1983;1(1):35-40.

36. Kinnaird JA. Contrasting styles of Sn-Nb-Ta-Zn mineralization in Nigeria. J Afr Earth Sci. 1984;2(2):81-90.
37. Fasiku TB, Fasasi MK, Amosun AA. Measurement of Radioactivity concentration in pegmatite Rocks samples and Dose Assessment from Wamba in North Central, Nigeria. AJOPACS. 2022;10(3):45-53.
38. Olabanji SO, Omobuwajo OR, Ceccato D, Buoso MC, De Poli M, Moschini G. Analysis of some medicinal plants in south-western Nigeria using PIXE. J Radioanal Nucl Chem. 2006;270(3):515-21.
39. Joseph CIM, Havstad, Ownby, DR, Peterson EI, Maliarik M, McCabe MJ. Blood lead level and risk of asthma. Environ. Health Perspect. 2005;113(7): 900-904.
40. Jacobs DE, Wilson J, Dixon SL, Smith J, Evens A. The relationship of housing and population health: a 30 – year retrospective analysis. Environ Health Perspect. 2009;117(4):597-604.
41. Kianoush S, Balali-Mood M, Mousavi SR, Moradi V, Sadeghi M, Dadpour B et al. Comparison of therapeutic effects of garlic and d- penicil amine in patients with chronic occupational lead poisoning. Basic Clin Pharmacol Toxicol. 2012;110(5): 476-81.
42. Calabrese E. Nutrition and environmental health: the influence of nutritional status on pollutant toxicity and carcinogenicity. New York: John Wiley & Sons; 1981.
43. Adewale OO, Tubosun IA, Ojo JO. Assessment of Terrestrial naturally occurring radioactive material in soil and mine tailings of Awo Ede, Osun State, Nigeria. IFE J Sci. 2015;17(1):199-209.
44. Tchounwou PB, Yedjou CG, Patlolla AK, Sutton DJ. Heavy metal toxicity and the environment. Mol. Clin. Environ Toxicol. 2012;101:133-64.
45. Loomis D, Guha N, Hall AL, Straif K. Identifying occupational carcinogens: an update from the IARC monographs. Occup Environ Med. 2018;75(8):593-603.
46. Nickens KP, Patierno SR, Ceryak S. Chromium genotoxicity: a double-edged sword. Chem Biol Interact. 2010; 188(2):276-88.
47. Faweya EB, Adesakin GE, Faweya O. X-ray fluorescence (XRF) analysis of rock and soil samples from a magnetic intrusive rock in Oba Akoko, Nigeria. Adv Phys. 2016;1(19):4043-53.
48. Nielsen FH. The importance of diet composition in ultra-trace element. Res. J Nutr. 1985;115(10):1239-47.
49. Wu Y. Element background levels in soils of Liaohe River Plane. J Environ Sci (China). 1990;3(1):55-73.
50. Samia ME, Amany TS, Najat FA, Saher MD. XRF analysis of heavy metals for surface soil of Qarun Lake and wadi el Rayan in Faiyum, Egypt. Open J Met. 2013;3:21-5.
51. Ikoko LAN, Briggs-Kamara MA, Sigalo FB, Ideriah TJ, Ude HN. Elemental composition analysis of soil samples from Bayelsa State in the Niger Delta region of Nigeria. J Appl Sci Environ Manag. 2022;26(4):745-50.
52. Adam MM, Osman MM, Elhag AS, Elsheikh MA. ICP/XRF Analysis fir Trace Elements in Soil Samples from Gezira and Ski Schemes, Sudan. Int J Sci Res Manag. 2021;9(2):32-9.
53. Antoaneta E, Alina BS, Lucian G. Determination of heavy metals in soils using XRF technique. Rom J Phys. 2009;55(7-8):815-20.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/98324