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Assessment of radiological levels in soils from Bagega artisanal gold mining exercises at Bagega Zamfara State, Nigeria

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ABSTRACT

The research consists of assessments of radiological levels from Bagega artisanal gold mining exercises in Zamfara State of Nigeria. Results show mean values of activities in the order $^{40}K > ^{226}Ra > ^{232}Th$ gives 370.79±7.98 Bq kg $^{-1}$, 18.3 ± 1.77 Bq kg $^{-1}$, 16.86 ± 0.94 Bq kg $^{-1}$. The mean value of outdoor gamma dose rate is 27.25 nGy h $^{-1}$ which is well below the global average values. The mean annual effective dose rate is 33.44 μSv y $^{-1}$ (= 0.033mSv y^{-1}), which is correspondingly much lower compare to 0.07 mSv y $^{-1}$ UNSCEAR base line. This value are low radiological speaking and should not cause health concerns, however the unprofessional practices of the miners which included non-usage of gas mask puts them at risk of exposure to respiratory crystalline silica as well as exposure to radon gas inhalation.

Key words: Bagega, Artisanal Mining Activity Concentration, Health Effect.

INTRODUCTION

Ionizing radiation is energy in the form of waves or particles that has enough force to remove electrons from atoms. One source of radiation is the nuclei of unstable atoms. As these radioactive atoms (also referred to as radionuclides or radioisotopes) seek to become more stable, their nuclei eject or emit particles and high-energy waves. This process is known as radioactive decay. Some radionuclides, such as radium, uranium, and thorium, have existed since the formation of the earth. The radioactive gas radon is one type of radioactive material produced as these naturally-occurring radioisotopes decay. Human activities, such as the splitting of atoms in a nuclear reactor, can also produce radionuclides. Regardless of how they are produced, all radionuclides release radiation. Humans are primarily exposed to natural radiation from the sun, cosmic rays, and naturally-occurring radioactive elements found in the earth's crust. Cosmic rays from space include energetic protons, electrons, gamma rays, and x-rays. Radon gas, which emanates from the ground, comes from the decay of naturally-occurring radium and is a major source of radiation exposure (1). Ionizing radiation and the possible proliferation of its release due to human activities into the environment is the concern of this work with a particular focus on radiation issues that could be associated with mining in Bagega, Zamfara State of Nigeria. Natural environmental radioactivity and the associated external exposure due to gamma radiation depend primarily on the geological and geographical conditions, and appear at different levels in the soils of each region in the world (2).

Research Area

Bagega exists on the longitude 6°.00' east of the prime meridian and latitudes 11°43' to 11°50' North of the equator. Half of Nigeria, land area of 923,768 km^2 is underlain by crystalline rocks or basement complex and the remaining half, by sedimentary rocks which is dominated by schist, phyllites, quartzite and marble. The study area falls into the sedimentary half of the land area.

Assessment of radionuclides in soils and rocks in many parts of the world has been on the increase in the past two decades because of their hazard on the health of the populace (3). While this is the case, the research into natural radionuclide in the soils and rocks of North-western Nigeria is yet to receive the much needed attention compared to the rate of mineral mining and processing being done in the region. As a contribution to focus on this area, a number of radiological indices were measured from on samples taken from mining field of Bagega.

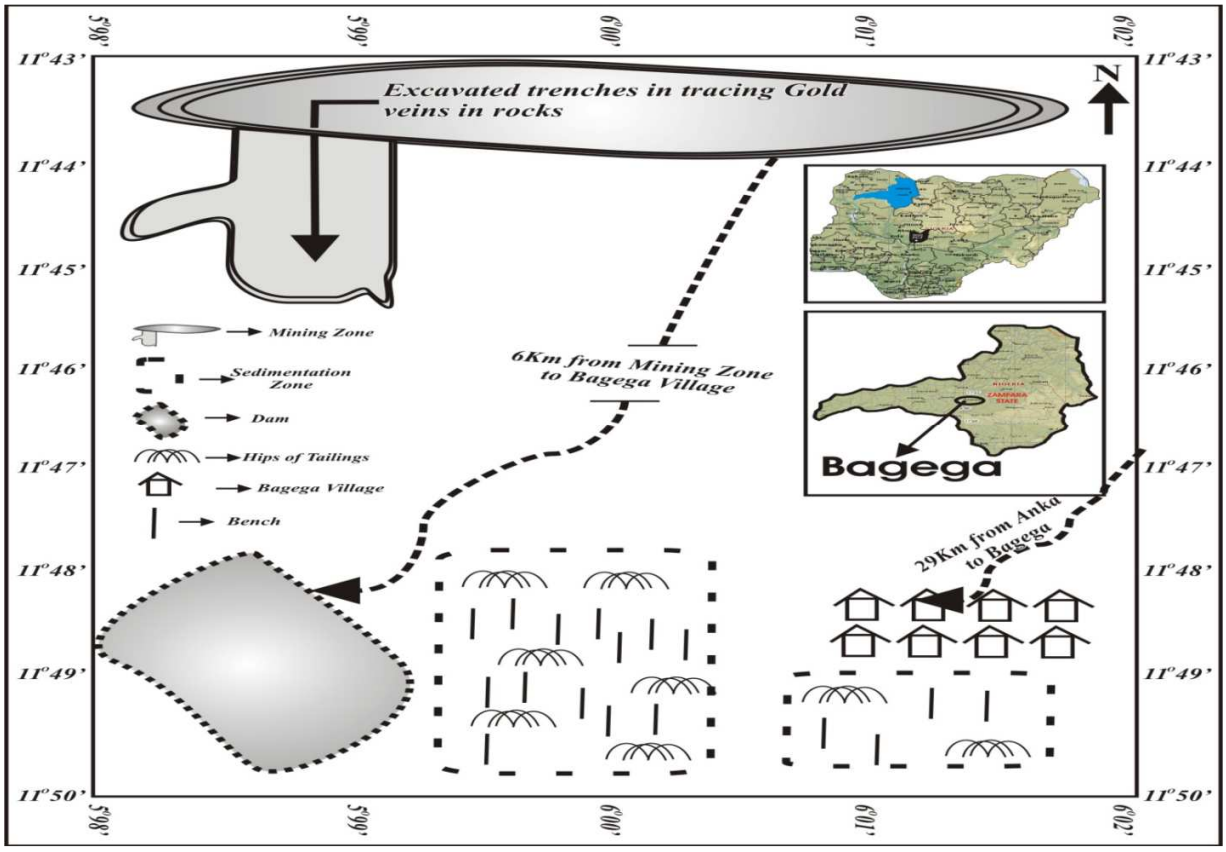

Figure 1. Site map of the research area in Bagega

MATERIALS AND METHODS

2.1 Soil sample collection

A pre-survey was carried out on the mine sites to map out the three mining stages where radiation measurements will be carried out. This was followed by field measurements during which In-situ radiation readings were carried out as well as collection of soil samples. Approximately 500 g of soil from each spot was collected from the marked locations all the samples were mixed thoroughly so as to form composites which are sample representative of the sampling stages. These samples were transferred into polythene bag, labeled and double–bagged to avoid cross-contamination in each case.

2.2 Soil sample preparation

Each of the soil/tailing samples collected were dried and crushed to fine powder with the use of a pulverizer. Packaging of samples into radon-impermeable cylindrical plastic containers which were selected based on the space

allocation of the detector vessel which measures 7.6cm by 7.6cm in dimension was also carried out. To prevent radon-222 escape, the packaging in each case were triple –sealed. The sealing process included smearing of the inner rims of each container lid with Vaseline jelly, filling the lid assembly gap with candle wax to block the gaps between lid and container, and tight- sealing lid-container with a masking adhesive tape. Radon and its short-lined progenies were allowed to reach secular radioactive equilibrium by storing the samples for 30 days prior to gamma spectroscopy.

2.3 Evaluation of Radioactivity of Samples

The analysis was carried out using a 76 × 76 mm NaI(TI) detector crystal optically coupled to a photomultiplier tube(PMT). The assembly has a preamplifier incorporated into it and a 1kilovolt external source. The detector, which is enclosed in a 6cm Lead shield lined with cadmium and copper sheets. The above arrangement is aimed at minimizing the effects of background and scattered radiation. The data acquisition software is Maestro by Camberra Nuclear Products and its 1990 version, the samples were measured for a period of 29000seconds, for each sample. The peak area of each energy in the spectrum was used to compute the activity concentrations in each sample by the use of equation (4).

$C\ (Bg.Kg^{-1}) = \frac{c_n}{C_{fk}}$ …….....(4)

Where,

C = activity concentration of the radionuclide in the sample given in Bq kg–1

c_n = count rate (counts per second)

C_{fk} = Calibration factor of the detecting system

2.4 Standards

The standards used in this work are the IAEA gamma spectrometric reference materials RGK-1 for k-40, RGU-1 for Ra-226(Bi-214 peak) and RTG-1 for Th-212(Ti-208)

2.5 Background

The background count rate for 5hours count time was 0.3 cps for Ra-226, 0.16cps for Th-232 and 0.25cps for K-40.

2.6 Calibration and Efficiency Determinations

Calibrations for energy and efficiency were done with two calibration sources; Cs-137 and Co-60.These were done with the amplifier gain that gives 72% energy resolution for the 66.16keV of Cs-137 and counted for 30 minutes.

Table1. Spectra energy windows, Calibration factors and Detection limits

Element	Gamma Energy (KeV)	Energy Window (KeV)	Calibration Factor (cps/Bq.kg-1)	Detection Limit (Bq/kg)
Ra-226	1764.0	1620-1820	8.632	3.84
Th-232	2614.5	2480-2820	8.768	9.08
K-40	1460.0	1380-1550	6.430	14.54

RESULTS AND DISCUSSION

3.1 Specific radioactivity

Radionuclide concentration for the collected surface soil samples indicates the nature of geological formation for the area studied. Table2 summarizes the specific activity of ^{226}Ra, ^{232} Th, and ^{40} K, air absorbed dose rates as well as their corresponding effective dose rates in the soils/tailings of the research area. In each of the tables, the associated uncertainties, mean values and the ranges as it relates to each column were entered. Table 3 showed a compacted radiological result. The ^{40}K activity is distinctly higher than the ^{232} Th and ^{226}Ra for the two sites studied, this can be adduced to fact that potassium is usually the most abundant element in the soil (5). Being a major element in rock-forming minerals, it occurs mainly in alumino silicates such as feldspar and micas. Figures 1 and 2 show Activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th as a function of samples for the sites. The activity concentration of ^{40} K in Awwal declines with processing stages, while Bagega reveals mean raised values throughout the three stages (mining, milling and sedimentation). ^{226}Ra and ^{232}Th are essentially not soluble in normal surface waters and so its transport is within particulate matter (dust) rather than by solution. (6) With reference to the study site in question, the heavy dust and windy atmosphere at the period of study could have explained thorium transportation. Thorium is

usually more abundant in the suspended load than in the bottom sediments (6) resulting in its near absolute zero detection in the product of the sedimentation zone.

Table 2. The activity concentrations due to 226Ra, 232Th and 40K and gamma dose rates in the Three stages of Bagega mining exercises

Sample Code	^{40}K (Bq/Kg)	^{226}Ra (Bq/Kg)	^{232}Th (Bq/Kg)	DOSE RATES (nGy/h)	EFFECT.DOSERATES (µSv/y)
C1S1	518.82±3.06	43.92±0.57	N.D	41.92±0.39	51.45
C1S2	94.17±4.99	N.D	N.D	3.93±0.21	4.82
C1S3	229.06±4.48	18.27±0.08	N.D	17.99±0.23	22.08
C2S1	580.47±6.66	0.76±2.76	N.D	24.56±1.55	30.14
C2S2	541.22±4.40	N.D	N.D	26.87±0.18	32.97
C3S1	182.32±2.91	29.44±0.44	N.D	21.20±0.32	26.02
C3S2	390.67±24.29	25.93±1.09	10.01±1.64	34.48±11.92	42.32
C3S2	206.84±4.90	20.64±0.00	N.D	18.16±0.20	22.29
C4S1	641.04±7.03	15.58±2.04	N.D	33.92±1.23	41.64
C4S2	262.21±3.28	20.46±0.83	N.D	20.39±0.53	25.02
C5S1	307.68±57.38	22.49±1.40	N.D	23.22±3.04	28.5
C5S2	775.56±8.43	N.D	N.D	40.13±0.35	49.25
C5S3	352.98±9.50	17.09±0.96	18.99±0.24	34.41±0.99	42.22
C5S1	118.18±3.42	16.33±3.01	N.D	12.47±1.53	15.31
C5S2	690.50±7.96	9.77±1.10	N.D	33.31±0.84	40.87
E1S1	202.25±5.04	10.46±0.47	N.D	13.27±0.43	16.28
E1S2	453.52±3.11	N.D	N.D	18.91±0.13	23.21
E2S2	480.07±7.84	18.70±0.00	N.D	28.66±0.33	35.17
E3S1	456.26±6.33	17.70±2.04	N.D	27.20±1.20	33.39
E3S2	193.75±4.68	27.37±1.01	N.D	20.73±0.67	25.44
E4S1	503.17±7.03	17.49±12.62	21.75±1.65	42.57±1.32	52.24
E4S2	386.67±5.63	17.70±2.04	N.D	24.30±1.17	29.82
E5S1	503.50±7.95	13.10±0.24	N.D	27.05±0.44	33.2
E5S2	406.24±3.98	1.16±0.80	16.70±0.24	119.75±0.69	146.97
M1S1	178.31±5.21	3.59±0.28	N.D	9.09±0.35	11.16
M1S2	314.17±9.87	21.49±0.03	N.D	23.02±0.43	28.26
M1S3	910.48±7.09	N.D	N.D	44.67±0.30	54.82
M1S4	151.92±6.19	13.83±1.75	N.D	12.73±1.07	15.62
M2S1	112.28±7.67	47.06±3.56	N.D	26.42±0.45	32.43
M2S3	862.84±6.98	16.14±0.28	N.D	43.43±0.81	53.31
MS1	439.37±4.14	15.89±1.12	N.D	38.16±0.39	46.83
MS2	656.54±6.87	16.74±0.47	N.D	35.11±1.19	43.09
TS1S1	197.12±6.44	26.68±1.96	N.D	20.55±0.51	25.22
TS1S3	197.01±5.54	15.58±0.52	N.D	15.41±0.47	18.92
TS2S1	171.48±7.66	12.72±0.52	N.D	13.03±1.71	15.99
TS2S3	118.18±3.42	16.33±3.01	N.D	12.47±0.62	15.31
TS3S1	141.28±13.40	19.27±1.03	N.D	14.79±1.04	18.15
TS4S2	161.72±7.84	22.47±3.20	N.D	17.13±1.81	21.02
Mean	**370.79±7.98**	**18.33±1.77**	**16.86±0.94**	**27.25 1.08**	**33.44**
Range	**94.17- 775.56**	**0.76 – 47.06**	**10.01 – 18.99**	**0.13-11.92**	**4.82-146.97**

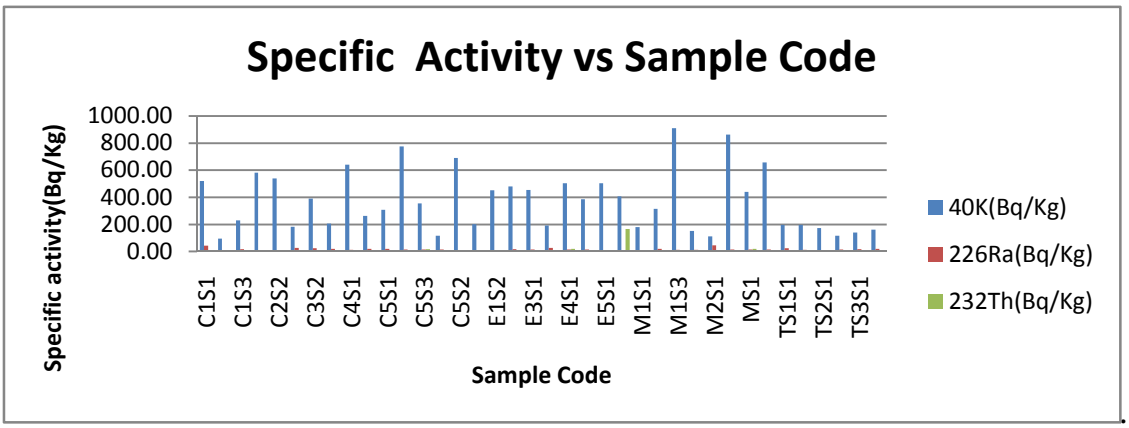

Figure 2 Activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th as a function of sample for Bagega measurement

3.2 Radiological assessments

3.2.1 External absorbed dose rates and Outdoor effective dose

The absorbed dose rates (*D*) due to gamma radiations in air at 1m above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) were calculated based on guidelines provided by UNSCEAR 2000, by the use of the following equation,

$$D\ (nGy.h^{-1}) = 0.462\ ARa + 0.621\ ATh + 0.0417\ AK \quad \text{….....(2)}$$

Where, D represents air absorbed dose rates, A represents activities of the radionuclides.

Table 3 comparison of the mean concentrations in soils of the studied area with some world values and world average

Regions	^{40}K(Bq.kg^{-1})	^{226}Ra(bq.kg^{-1})	^{40}K(Bq.kg^{-1})	references
Agaba-Amunan, Highway, Jordan	208	44.4	36.3	(7)
Taiwan	794	54	32.4	(8)
Rajasthan, India	50.0 - 137.0	30.0 - 78.0	43.0 - 105.0	(9)
Abeokuta, Nigeria	51.81 - 82.80	4 - 11.5	7.62 - 22.8	(10)
Bagega, Nigeria	370.79	18.38	16.86	The present study
World Average	140.0 - 850.0	17.0 - 60.0	11.0 - 64.0	(2),

The calculated results of the dose rates are entered as shown in tables 2 and 3. To estimate the mean annual effective dose rates which is sometimes referred to as Outdoor annual effective dose equivalent, the conversion coefficient from absorbed dose in air to effective dose (0.7Sv.Gy^{-1}) and outdoor occupancy factor (0.2) proposed by UNSCEAR 2000 were used. Therefore, the mean annual effective dose rate (mSv.yr^{-1}) was calculated by the following formula:

$$D\ \text{eff.}\ (\mu Sv.y^{-1}) = \text{Dose rate}\ (nGy.h^{-1}) \times 24h \times 365.25 \times 0.2 \times 0.7\ Sv.Gy^{-1} \times 10^{-3}\ Sv.Gy^{-1} \quad \text{..... (3)}$$

The results obtained from the present study were compared to the world average values shown in Table 3.

3.22 Radium equivalent activity

To compare the specific activities of the samples, the radium equivalent activity (Ra_{eq}) can be used as a common index. It is the sum of the weighted activities of 226Ra, 232Th and 40K based on the estimation that 10 Bq kg–1 of 226Ra, 7 Bq kg–1 of 232Th and 130 Bq kg–1 of 40K will deliver an equal or the same gamma dose rate (11, 12, 13, 14). According to (15), this index is mathematically defined by UNSCEAR, 2000 as:

$$Ra_{eq}\ (Bq.kg^{-1}) = A_{Ra} + 1.43A_{Th} + 0.077\ A_K \quad \text{……..…..…..... (4)}$$

Where A_{Ra}, A_{Th} and A_K are activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, respectively. The mean values of radium equivalent calculated and entered into the table below along with the mean values of associated hazard indices. The radium equivalent of 370 Bq kg–1 corresponds to the dose limit of 1 mSv for the general population. (16)

3.2.3 Radiation hazard indices

External hazard index is a relation that quantifies the exposure factor. According to UNSCEAR, 2000 it is defined as follows:

Eternal hazard index (H_{ex})

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} = \leq 1 \quad \text{..... (5)}$$

Internal hazard index (H_{in})

The hazardous effect of radon and its short-lived products to the respiratory organs need be taken into consideration. The internal exposure to radon and its daughter products is quantified by the internal hazard index Hin, which is given by the equation

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} = \leq 1 \quad \text{..... (6)}$$

For brevity, only the mean values of the calculated radium equivalent, external and internal hazards based on equations 4, 5 and 6 which were used with data in tables 2 and 3 and are subsequently entered into the table of summary

Table 4. Radium Equivalent and Related Hazard indices

Sample Code	Ra_{eq}(Bq/kg)	H_{ex}(Bq/kg)	H_{in}(Bq/kg)
C1S1	158.83	0.43	0.54
C1S2	18.07	0.05	0.06
C1S3	67.84	0.18	0.23
C2S1	112.41	0.3	0.37
C2S2	115.69	0.31	0.39
C3S1	74.72	0.2	0.26
C3S2	127.84	0.35	0.44
C3S2	67.55	0.18	0.23
C4S1	144.03	0.39	0.48
C4S2	77.93	0.21	0.27
C5S1	89.39	0.24	0.3
C5S2	170.27	0.46	0.57
C5S3	124.75	0.34	0.43
C5S1	44.72	0.12	0.15
C5S2	145.68	0.39	0.48
E1S1	52.93	0.14	0.18
E1S2	87.02	0.24	0.28
E2S2	117.36	0.32	0.39
E3S1	111.44	0.3	0.37
E3S2	74.13	0.2	0.26
E4S1	159.04	0.43	0.54
E4S2	98.09	0.26	0.33
E5S1	114.3	0.31	0.38
E5S2	362.57	0.98	1.3
M1S1	39.06	0.11	0.13
M1S2	89.28	0.24	0.3
M1S3	193.17	0.52	0.64
M1S4	47.83	0.13	0.16
M2S1	85.06	0.23	0.3
M2S3	187.34	0.51	0.62
MS1	140.18	0.38	0.48
MS2	148.57	0.4	0.5
TS1S1	73.84	0.2	0.25
TS1S3	58.83	0.16	0.2
TS2S1	50.08	0.14	0.17
TS2S3	44.72	0.12	0.15
TS3S1	53.11	0.14	0.18
TS4S2	61.37	0.17	0.21
Mean	**104.97**	**0.28**	**0.36**
Range	**18.07-362.57**	**0.05-0.98**	**0.06-1.30**

3.4 Radiological Assessment Summary

The resulting picture of the radiological events as related to the mine site is captured in Table 5. It can be seen at a glance that the specific activities of the radionuclides are all within regulatory benchmarks. Correspondingly, the mean annual dose rates and related hazard indices are all within the regulatory benchmarks. These levels of outcomes are consistent to expected results for schist belts based on their sedimentary nature.

Table5. Radiological Summary

S/N	Radiological Indices	Research site (Bagega)	Benchmarks	References
1	Activity Conc.(Bq/Kg)			
	K-40	370.79	140.0 - 850.0	2
	Ra-226	18.33	17.0 - 60.0	2
	Th-232	16.86	11.0 - 64.0	2
2	Dose Rates(nGy/h)	27.25	56	17
3	Effect. Dose Rates(μSv/y)	33.44	70	17
4	Ra_{eq}(Bq/kg)	104.97	370(Max.)	18
5	H_{ex}(Bq/kg)	0.28	<1	2
6	H_{in}(Bq/kg)	0.36	< 1	2

CONCLUSION

Radiologically, the obtained values are low and do not imply any significant concerns on the health effects of the local population and the values form radiological baseline data for Bagega. However This outcome on the general view does not translate to acceptable health safety levels when the present unprofessional practices of the miners are integrated into the evaluation; the lack of usage of face mask against inhalation of high density dust generated from the mining processes and other related practices raises the question of possibility of exposure to radon gas as well as respiratory crystalline silica from the environment. In view of the present observed practices involved with the mining exercises in the zone, as thought based on radiological levels safe but the exercises as unsafe health wise. The miners should be educated on safe mining practice and seen to be inculcate safety culture in their practice. Mining activities should be organized, the miners activities supervised and regulated by appropriate agency.

REFERENCES

[1] EPA (**2007**). Environmental protection Agency, United States. Ionizing Radiation Fact book. Office of Radiation and Indoor Air. EPA-402-F-06-061
[2] United Nations Scientific Committee on the Effects of Atomic Radiation. (**2000**). "Sources, effects and risks of ionization radiation", United Nations Scientific Committee on the Effects of Atomic Radiation, Report to the General assembly, with Annexes, New York
[3] Belivermis, M., Onder, K., Yavuz C. & Sayhan, T. (**2009**). The effects of physicochemical properties on gamma emitting natural radionuclide levels in the soil profile of Istanbul. Environmental Monitoring Assessment. 10.1007/s10661-009-0812-1
[4] Ibeanu, I.G.E. (**1999**). Assessment of radiological effects of Tin mining activities in Jos and its Environs. A Theses (Unpublished) submitted to the Post-Graduate School of Ahmadu Bello University, Zaria,Nigeria.
[5] Abbady, A. (**2005**). *Indian Journal of pure and applied physics.* Vol.43, pp.489-493.
[6] Al-Jundi, J., B.A. Al-Bataina, Y. Abu-Rukah and H.M. Shehadeh, (**2003**). *Radiat. Meas*., 36: 555-560.
[7] Wang, C.J., S.Y. Lai, J.J. Wang and Y.M. Lin, (**1997**). *Applied Radiation Isotopes*, 48: 301-303.
[8] Nageswara Rao MV, Bhatti SS, Rama Seshu P, Reddy AR (**1996**) *Radiat Prot Dosim* 63:207–216
[9] Gbadebo, A.M., (**2011**). *Asian J. Applied Sci*., 4: 176-185.
[10] Tufail, M., Akhtar, N., Javied, S. and Hamid, T. (**2007**) *Journal of Radiological Protection*, Vol. 27, pp.481–492.
[11] Ademola, J.A. (**2008**). Exposure to high background radiation level in the tin mining area of Jos Plateau, Nigeria. National Center for Biotechnology Information, U.S. National Library of Medicine 8600 Rockville Pike, Bethesda MD, 20894. USA.
[12] Ademola, J.A. (**2008b**) *Journal of Radiological Protection*, Vol. 28, pp.93–99.
[13] Shiva Prasad, N.G., Nagaiah, N., Ashok, G.V. and Karunakara, N. (**2008**) *Health Physics*, Vol. 94, pp.264–271.
[14] Diab, H.M., Nouh, S.A., Hamdy, A. & EL-Fiki, S.A. (**2008**). *Journal of Nuclear and Radiation Physics*, Vol. 3, No. 1, pp. 53-62
[15] Jibiri, N.N., Alausa, S.K., & Farai, I.P. (**2008**). I*nt. Journal of Low Radiation*.
[16] United Nations (**1993**). Sources and Effects of Ionizing Radiation. United Nations Scientific Committee on the Effects of Atomic Radiation, .Report to the General Assembly, with scientific annexes. United Nations sales publication E.94.IX.2.United Nations, New York.