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RADIOACTIVE POLLUTION AND EXCESS LIFETIME CANCER RISK DUE TO GAMMA EXPOSURE OF SOIL AND GROUND WATER AROUND OPEN LANDFILLS IN RIVERS STATE, NIGERIA

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ABSTRACT

The objective of present study was to evaluate the activity concentrations of ^{238}U, ^{232}Th and ^{40}K and excess lifetime cancer risk due to gamma exposure of soil and ground water around open landfills in Rivers State, Nigeria. A total of 21 soil and 17 ground water samples were collected around Aluu and Rumuolumeni landfills. Soil and water samples were analyzed using a well calibrated gamma-ray spectrometry (NaI (Tl)) detector system after they have reached radiogenic equilibrium. The mean specific activity concentration of ^{238}U, ^{232}Th and ^{40}K for soil samples were 48.44± 4.08 $Bqkg^{-1}$, 39.68±2.48$Bqkg^{-1}$ and 416.48±11.23$Bqkg^{-1}$ in Aluu landfill and 22.99± 1.04$Bqkg^{-1}$, 12.94± 0.84$Bqkg^{-1}$ and 169.11±5.46$Bqkg^{-1}$ in the Rumuolumeni landfill respectively, while in water they were 10.58± 1.09Bql^{-1}, 10.30±1.02 Bql^{-1} and 173. 78±21.32Bql^{-1} in Aluu landfill and 11.01±3.44Bql^{-1}, 16.26± 3.77Bql^{-1} and 225.88± 36.10Bql^{-1}in Rumuolumeni landfill respectively. The mean activity concentration of ^{238}U, ^{232}Th and ^{40}K around Aluu landfill were higher than the permissible values. The radiation hazard indices calculated for the soil samples around Aluu landfill were higher than their permissible values. All other radiation hazard indices calculated in all the samples (soil and ground water) from both Aluu and Rumuolumeni landfill were below unity. Based on our present study, we concluded that activity concentration of ^{238}U, ^{232}Th and ^{40}K in soil and ground water samples were high and Excess lifetime cancer risk calculated for all the samples analyzed were higher than the safe limits, therefore long term radiation exposure of the residents around Aluu and Rumuolumeni landfill will pose significant health threat, thus the ground water from these study areas should be treated for radionuclide before ingestion to reduce the radiation risk .

Keywords: River State, radioactivity, health impacts, soil and water land filling, spectrometer.

INTRODUCTION

Humans are usually exposed to some levels of environmental radiation of terrestrial origin. Terrestrial radiation mainly originate from radionuclides which exists naturally in air, water , soil, rocks and building materials depending on the geological and geographical features of the region (Avwiri *et al*., 2011). Dumping of industrial, medical and domestic wastes such as phosphogypsum, alum shale, scraps from oil and gas plants and so on can contaminate the soil, surface and underground water resources (Olubosede *et al*., 2012). In Nigeria, landfills are usually an unlined shallow pits (oftennot deeper than 50cm) where wastes are dumped. Another study, Odunaike *et al*. (2008) defined it as dumps which receives solid wastes in an uncontrolled manner and allows free access to scavengers. Studies have shown that soil from landfills and water resources near landfills contains high activity concentration of radionuclides (Oladapo *et al*., 2012; Innocent *et al*., 2013).

Hazards posed by such dumpsites are not only in terms of odour or presence of disease vectors, but can also arise from the radiation exposure (Ojoawo *et al*., 2011). Natural radionuclides constitute a treat to humans when ingested or inhaled in the body, either through drinking water or food chain (Ononugbo *et al*., 2013; Uosif *et al*., 2012). Ingested, radionuclide could be concentrated in certain parts of the body according to the metabolism involved (Ajayi *et al*., 2009). The effect can be chronic such as lung disease, acute leucopenia, anemia or death (Avwiri *et al*., 2013; Ramasamy *et al*., 2009).

Various radioactivity measurements carried out in many countries especially in Nigeria have shown the existence of natural radionuclides in several matrices like soil, water, foods (Jibril *et al*., 2007; Tchokossa *et al*., 2012). All these are contained in the domestic, industrial and medical wastes which are indiscriminately dumped in open pits fields (Ojoawo *et al*., 2011) and farm soils

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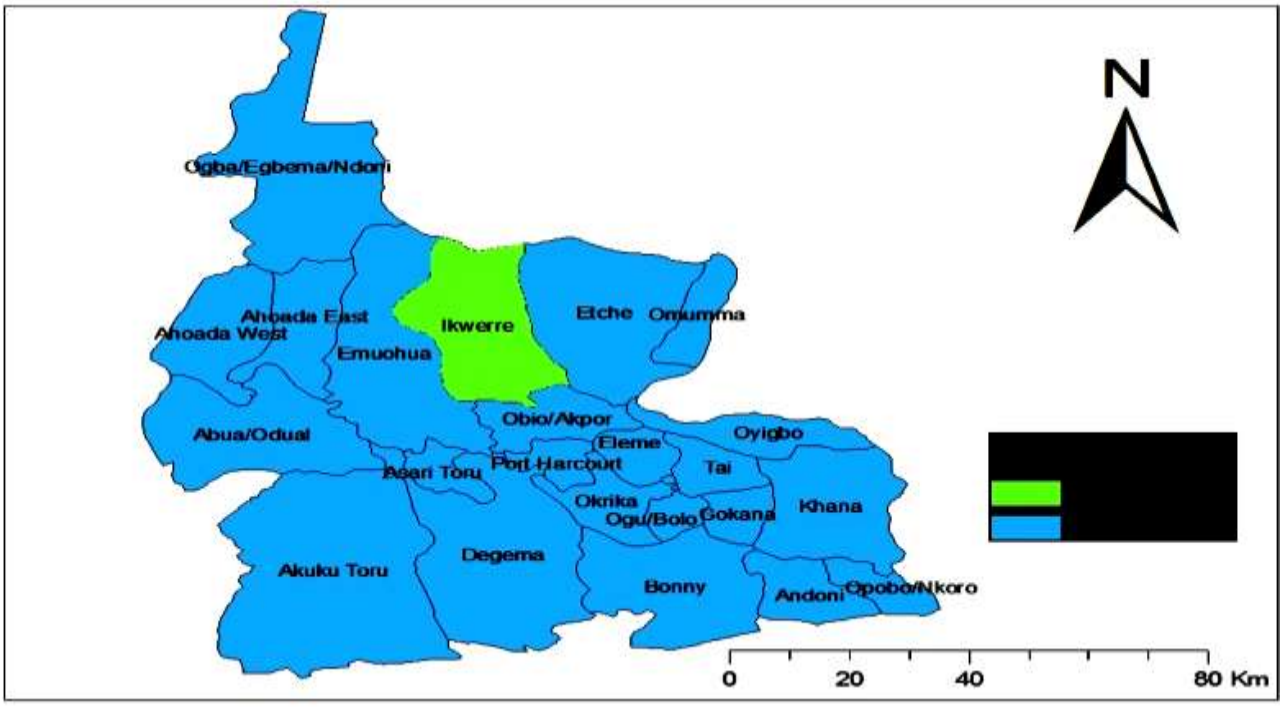

Fig. 1. Rivers State map showing Ikwerre LGA.

(Alatise *et al*., 2008). In Nigeria, unprotected, unlined landfill and open dumping are the available options for solid waste disposal. Aluu and Rumu-olumeni landfills in Rivers state are not exempted from poor environmental management. These wastes range from chemical toxic, hazardous industrial, medical, metal scraps and other debris, which are not separated from the municipal solid wastes disposed of at the Aluu and Rumuolumeni landfills. The potential environmental and health hazards could be deleterious if not properly handled (Eja *et al*., 2010; Longe and Kehinde, 2005; WHO, 2011). Hence this work aimed at evaluating the radiation emanating from these dumpsites/open landfills in order to provide accurate data and scientific information on the radiological health implications of such exposure.

MATERIALS AND METHODS

Study Area

The study area lies within latitude $04^0$53'14" N and $04^0$55'20"N and longitude $06^0$55'08"E and $06^0$55'58"E situated at the western Niger Delta region of Nigeria as shown in Figure 1. It comprises the Aluu and Rumuolumeni towns of Obio-Akpor local Government Area of Rivers State. These landfills have received more than 50% of the total refuse in Rivers area since 1989. The state has a population of 5 million and an annual growth rate of 3.6% (NPC, 2006; Avwiri *et al*., 2011).

Sample Preparation

Twenty-one soil and seventeen ground water samples of different wasteland were collected randomly to spatially cover the selected landfills. Soil were air-dried in the laboratory to a constant weight, crushed and made to pass through a 0.5 mm mesh sieve. Tap water was acidified with 11 M HCl at the rate of 10 ml per litre immediately after collection to avoid adsorption of radionuclide on the walls of the container (IAEA, 1999). The sample container were previously washed with dilute tetraoxosulphate (VI) acid and dried to avoid contamination. All the samples were sealed, labeled and stored in cylindrical named Marinelli beaker for at least 28 days before counting in order to attain a state of secular radioactive equilibrium among the radionuclide present and their progeny (Veiga *et al*., 2006) before the γ-ray counting.

Gamma Counting

The counting used a Sodium Iodide (NaI(Tl) gamma ray spectrometer system coupled to an electronic set. It has an energy resolution of 2.0 KeV and relative efficiency of 33% at 1.33 MeV and is encapsulated in a 15 cm thick cylindrical lead shield with a 10 cm thick cover at the top. The counting time was 10,000 seconds. The calibrations were carried out using a standard radioactive mixed sources supplied by the International Atomic Energy Agency (IAEA). The photo peaks corresponding to

Table 1. Location of the sampling point's and the Activity concentration of ^{238}U, ^{232}Th and ^{40}K in Soil Samples (Bqkg^{-1}).

S/N	Sample Code	Activity Concentration (Bqkg^{-1})		
		^{40}K (Bqkg^{-1})	^{238}U (Bqkg^{-1})	^{232}Th (Bqkg^{-1})
1.	SALU1	470.06±89.51	38.08 ± 13.32	21.75± 7.86
2.	SALU2	390.86± 78.75	41.36± 14.56	40.94± 12.08
3.	SALU3	497.41± 91.83	33.19± 9.31	44.65± 11.87
4.	SALU4	457.35± 102.08	44.68± 16.20	38.96± 10.69
5.	SALU5	379.86± 72.28	43.20± 11.31	39.84± 10.02
6.	SALU6	420.9± 68.37	47.74± 12.37	40.81± 13.03
7.	SALU7	298.69± 53.74	51.32± 18.06	45.72± 20.11
8.	SALU8	347.57± 97.37	39.78± 10.41	37.24± 9.20
9.	SALU9	603.77± 129.35	37.53± 8.95	41.95±16.89
10.	SALU10	342.52± 81.13	51.21± 16.40	45.67± 20.03
11.	SALU11	467.48± 117.46	47.73± 12.32	39.89± 17.18
12.	SALU12	316.69± 99.84	43.62± 15.18	38.77± 14.97
13.	SREP1	197.88± 87.51	33.23± 12.36	25.54± 8.79
14.	SREP2	156.49± 49.26	29.31±9.12	16.21±5.81
15.	SREP3	174.46± 53.32	22.55± 7.38	9.56± 3.10
16.	SREP4	162.72± 42.85	19.87± 8.29	7.98± 2.34
17.	SREP5	110.85± 36.84	23.53± 6.88	8.95± 3.01
18.	SREP6	168.76± 45.37	21.98±9.02	7.62±2.71
19.	SREP7	130.44±29.74	17.09± 6.34	15.14± 4.17
20.	SREP8	159.86± 46.89	19.14 ±8.49	13.84± 3.19
21.	SREP9	260.55± 72.47	20.19± 7.03	11.59± 4.01
Mean		**310.25±68.30**	**34.59**± 11.12	**27.27± 7.89**
Standard		**400**	**35**	**30**

gamma lines at 1460.30, 1764.5 (^{214}Bi) and 2614.5 (^{208}Tl) KeV were used to identify ^{40}K, ^{238}U and ^{232}Th respectively (IAEA, 1999; Yussuf *et al*., 2012; Ramasamy *et al*., 2009).

The activity concentration (C) of the radionuclide was calculated after subtracting decay correction using the following expression;

$$C_S = \frac{C_a}{P_\gamma (M_s / V_s)\varepsilon_\gamma t_c} \text{ (Bq kg}^{-1} \text{ or Bq l}^{-1}\text{)} \quad (1)$$

Where C_S = Sample concentration, C_a = net peak area of a peak at energy, ε_γ = Efficiency of the detector for a γ-energy of interest, M_S/V_s= sample mass/volume for soil/water, t_c = total counting time, P_γ is the abundance of the γ-line in a radionuclide.

Radiological Risk Parameters

In order to quantify the radiation hazard posed on the populace that are exposed to these radionuclides due to their use of the soil for building and consumption of water from resources near the landfills, some radiological parameters were estimated:

Radium Equivalent Activity (Ra_{eq})

The radium equivalent (Ra_{eq}) activity represents a weighted sum of activities of ^{238}U, ^{232}Th and ^{40}K. It is based on the estimation that 1 Bq kg^{-1} of ^{238}U, 0.7 Bq kg^{-1} of ^{232}Th and 13 Bq kg^{-1} of ^{40}K produce the same radiation dose rates. The radium equivalent activity index was estimated using the relation (Avwiri et al., 2013).

$$Ra_{eq} = C_{U+} 1.43C_{Th} + 0.077C_K \quad (2)$$

Where C_u, C_{Th} and C_K are the activity concentration in Bqkg^{-1} or Bql^{-1} of ^{238}U, ^{232}Th and ^{40}K.

Absorbed Dose rate (D)

The absorbed dose rate (D) was computed using the following expression[23].

$$D = 0.462C_{Ra+}0.604C_{Th} + 0.0417C_K \quad (3)$$

Where, D is the absorbed dose rate in nGy hr^{-1}, C_U, C_{Th}, and C_K are the concentrations of uranium, thorium and potassium respectively.

Annual Gonadal Equivalent Dose (AGED)

An increase in AGED has been known to affect the bone marrow, causing destruction of the red blood cells that are then replaced by white blood cells. This situation results in a blood cancer called leukemia which is fatal. The

AGED for the resident using such material for building were evaluated using the equation (UNSCEAR, 2000).

$$AGED\ (Sv/yr) = 3.09C_{Ra} + 4.18C_{Th} + 0.314C_K \quad (4)$$

Where C_{Ra}, C_{Th} and C_K are the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil samples or water samples.

the absorbed dose emitted from radionuclide in the environment such as ^{226}Ra, ^{232}Th and ^{40}K.

The annual effective dose resulting from the ingestion of water was estimated based on the assumption that a daily intake of water per person is 2 l d^{-1} from the following expression (WHO, 2011; Avwiri *et al*., 2013).

Table 2. Location of the sampling point's and the Activity concentration of ^{238}U, ^{232}Th and ^{40}K in Water Samples.

S/N	Sample Code	Activity Concentration (Bql^{-1})		
		$^{40}K(Bql^{-1})$	$^{238}U(Bql^{-1})$	$^{232}Th(Bql^{-1})$
1.	WALU1	125.30**±** **2**9.35	14.25 ± 5.66	17.27± 5.34
2.	WALU2	246.38± 68.75	16.79± 7.15	12.65± 3.09
3.	WALU3	245.73± 57.32	10.58±4.12	9.07± 2.87
4.	WALU4	179.18± 7.85	7.85± 3.53	10.99± 3.65
5.	WALU5	120.82±33.62	9.07± 2.87	8.52± 2.87
6.	WALU6	141.98±45.30	8.10± 4.11	7.53± 2.19
7.	WALU7	211.95± 68.48	9.96± 3.21	8.46± 3.16
8.	WALU8	118.91± 42.52	8.02± 3.11	7.92±3.10
9.	WREP1	118.74± 31.93	13.50± 3.19	18.72± 6.82
10.	WREP2	246.01± 91.12	12.03±4.21	15.70±5.93
11.	WREP3	244.77± 69.46	14.23± 5.13	21.62± 7.32
12.	WREP4	222.98±46.39	11.48± 3.17	14.24± 6.07
13.	WREP5	226.60± 50.01	8.61± 2.34	22.30± 8.11
14.	WREP6	137.41± 37.62	7.86±3.09	14.02±4.21
15.	WREP7	226.60±74.92	9.25± 2.18	17.28± 6.09
16.	WREP8	217.16± 46.58	8.99±3.29	13.02± 4.21
17.	WREP9	392.66± 97.23	13.15± 4.11	9.46± 3.21
Mean		**170.19±55.28**	**10.81± 3.67**	**13.49± 4.60**
WHO, 2011 standard		**10**	**10.0**	**1.0**

Representative Gamma Index (I_γ)

This is used to estimate the gamma radiation hazard associated with the natural radionuclides in the investigated samples. The representative gamma index was estimated as follows[11].

$$I_\gamma = C_{Ra}/150 + CTh/100 + CK/1500 \leq 1 \quad (5)$$

Annual Effective Dose Equivalent (AEDE)

The annual effective dose equivalent received by a member of the public is calculated from the absorbed dose rate by applying dose conversion factor of 0.7Sv/Gy and occupancy factor for outdoor and indoor was 0.2 and 0.8 respectively[21]. AEDE is determined using the following equations (Veiga *et al*., 2006).

$$AEDE_{(outdoor)}\ (\mu Sv/y) = \text{Absorbed dose D (nGy/h) x } 8760h \text{ x } 0.7Sv/Gy \text{ x } 0.2 \text{ x} 10^{-3} \quad (6)$$

$$AEDE_{(indoor)}(\mu Sv/y) = \text{Absorbed dose D (nGy/h) x } 8760h \text{ x } 0.7Sv/Gy \text{ x } 0.8 \text{ x} 10^{-3} \quad (7)$$

The AEDE indoor occurs within a house whereby the radiation risks due to building materials are taken into consideration. AEDE outdoor involves a consideration of

$$AEDE = I \text{ x } A \text{ x } C \times 365 \quad (8)$$

Where AEDE is the annual effective dose, I is the water intake per day, A is the daily intake of radionuclide and C is the ingestion coefficient of the specific radionuclide.

Excess Lifetime Cancer Risk (ELCR)

The Excess Lifetime cancer risk (ELCR) was calculated using the following equation (Jankowski *et al*., 2011).

$$ELCR = AEDE \times DL \times RF \quad (9)$$

Where AEDE is the Annual Equivalent Dose Equivalent, DL is the average duration of life (estimated to be 70 years), and RF is the Risk Factor (Sv^{-1}), i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for public.

Hazard Indices (H_{ex} and H_{in})

The external hazard (H_{ex}) and internal hazard (H_{in}) indices were evaluated using the relations (Ramasamy *et al*., 2009).

$$H_{ex} = C_{Ra}/370 + C_{Th}/259 + C_K/4810 \leq 1 \quad (11a)$$

$$H_{in} = C_{Ra}/185 + C_{Th}/259 + C_K/4810 < 1 \quad (11b)$$

Table 3. Hazard Indices and Excess lifetime Cancer Risk for soil Samples.

Sample code	D(nGy/h)	Ra_{eq} ($Bqkg^{-1}$)	AGED $mSvy^{-1}$	$AEDE_{outdoor}$ μSvy^{-1}	$AEDE_{indoor}$ μSvy^{-1}	H_{in}	H_{ex}	Iγ	ELCR X 10^{-3}
SALU1	50.33	178.21	356.18	63.62	246.90	0.29	0.39	0.79	0.86
SALU2	60.13	130.00	421.66	73.74	294.34	0.35	0.46	0.95	1.03
SALU3	63.04	135.34	345.81	77.30	309.25	0.37	0.46	1.00	1.08
SALU4	63.25	135.61	444.52	77.60	310.28	0.37	0.49	0.99	1.09
SALU5	59.86	129.42	419.30	73.41	293.65	0.35	0.47	0.94	1.03
SALU6	64.26	138.51	450.27	78.81	315.23	0.37	0.50	1.01	1.10
SALU7	63.78	139.70	443.48	78.22	312.88	0.32	0.52	1.00	1.10
SALU8	55.36	120.02	387.72	67.89	271.57	0.32	0.43	0.87	0.95
SALU9	67.86	144.01	480.90	83.22	332.89	0.39	0.49	1.07	1.17
SALU10	65.52	142.89	456.69	80.37	321.46	0.39	0.52	1.03	1.13
SALU11	65.64	140.77	461.01	30.50	322.00	0.38	0.51	1.03	1.13
SALU12	56.76	123.45	396.29	69.61	278.44	0.33	0.45	0.89	0.97
SREP1	39.03	59.52	271.57	47.87	191.47	0.23	0.32	0.41	0.67
SREP2	29.86	64.54	207.46	36.62	146.40	0.17	0.25	0.46	0.51
SREP3	23.47	29.65	164.42	28.78	115.13	0.10	0.20	0.36	0.40
SREP4	20.79	43.81	145.84	25.50	101.99	0.12	0.17	0.32	0.36
SREP5	20.90	44.86	144.93	25.63	102.53	0.12	0.19	0.25	0.36
SREP6	21.79	45.87	157.48	26.72	106.89	0.12	0.18	0.34	0.37
SREP7	22.48	48.78	157.05	27.57	110.28	0.13	0.18	0.35	0.39
SREP8	23.87	37.40	167.99	29.27	117.10	0.14	0.19	0.37	0.41
SREP9	27.19	36.83	147.37	33.35	133.38	0.15	0.21	0.33	0.47
Mean	45.96	93.77	315.61	47.06	213.49	0.26	0.36	0.70	0.79

Where, C_{Ra}, C_{Th} and $C_K$are the radioactivity concentration in Bq/kg (or Bq/l) of ^{226}Ra, ^{232}Th, and ^{40}K respectively

Correlation between ^{238}U and ^{232}Th, ^{238}U and ^{40}K and ^{232}Th and ^{40}K

The elemental concentrations of Uranium-238 (in ppm), Thorium-232 (in ppm) and Potassium (in %) were calculated from the measured activity concentrations of ^{238}U, ^{232}Th and ^{40}K in $Bqkg^{-1}$ using the conversion factors recommended by the IAEA Technical Report No 1363.The correlation of the radionuclide was performed to ascertain their relationship.

RESULTS AND DISCUSSION

The results of the gamma ray spectrometry of various samples are presented in Table 1 and Table 2. The radionuclide observed with reliable regularity belonged to the decay series chain headed by ^{238}U and ^{232}Th as well as the non- series ^{40}K.

The activity concentration of all the radionuclides (^{238}U, ^{232}Th and ^{40}K) in soil samples collected around the Aluu landfill is considerably higher than that from the Rumu-olumeni landfill as shown in Table 1. This is an indication that the wastes in the Aluu landfill are rich in radionuclide as a result of the medical wastes from the teaching hospital and Health centre within the vicinity of the landfill. In all the sampling sites, mean activity concentration is of the order ^{232}Th $<^{238}$U $<^{40}$K in particular SALU7 and SALU10, the activity concentration of ^{238}U is high, which may be due to solubility and mobility of $U(VI)O_2$ (Ibe and Njoku, 1999).

However, increasing concentration of ^{232}Th and ^{40}K may be due to the high content of monazite (Ramasamy *et al*., 2009) while that of ^{40}K is due to presence of loamy and clay sediments and the composition of the landfill. The concentration of ^{238}U, ^{232}Th and ^{40}K in all the measured soil samples from the Aluu landfill except one spot exceeded the world average values which are 35.0Bq kg^{-1}, 30.0 Bq kg^{-1} and 400.0Bq kg^{-1} for ^{238}U, ^{232}Th and ^{40}K is respectively. While the activity concentrations of ^{238}U, ^{232}Th and ^{40}K in soil from Rumu-olumeni landfill is within the world average values. The values of ^{238}U, ^{232}Th and ^{40}K obtained from Aluu landfill were higher than the values reported in other works in a similar environment (Faweya and Babalola, 2010). This may be due the volume and variation in the compositions of the un-segregated wastes in the landfill.

The activity concentration of ^{238}U, ^{232}Th and ^{40}K in all the water samples follow the same trend as in soil and exceeds the World Health Organization [18] standard for drinking water of 10.0, 1.0 and 10.0 Bq l^{-1} for ^{238}U, ^{232}Th and ^{40}K respectively as shown in Table 2. This is due to the infiltration of radionuclide from medical sources along with other hazardous wastes from landfill in the Aluu and industries in Rumu-olumeni. This compared well with the work done by Ibe and Njoku (1999) which presented variability of ^{226}Ra to ^{228}Ra concentration ratio content.

Table 4. Estimated daily intake and Annual Effective Dose from ingestion of water.

Sample Code	Daily intake per person (Bq d^{-1})		Annual Effective Dose (AEDE)(mSv y^{-1}) Ingestion dose Coefficient (Sv Bq^{-1}) (WHO, 2011)				
	6.2×10^{-9} for ^{40}K			4.5×10^{-8} for ^{238}U	$2.3\times$ 10-7 for ^{232}Th		
	^{40}K	^{238}U	^{232}Th	^{40}K	^{238}U	^{232}Th	Total	AEDE
WALU1	125.30± 29.35	14.25 ± 5.66	17.27± 5.34	0.57	0.47	2.90	3.94	
WALU2	246.38± 68.75	16.79± 7.15	12.65± 3.09	1.12	0.55	2.06	3.73	
WALU3	245.73± 57.32	10.58±4.12	9.07± 2.87	1.11	0.35	1.52	2.98	
WALU4	179.18± 7.85	7.85± 3.53	10.99± 3.65	0.81	0.26	1.85	2.92	
WALU5	120.82±33.62	9.07± 2.87	8.52± 2.87	0.55	0.30	1.43	2.28	
WALU6	141.98±45.30	8.10± 4.11	7.53± 2.19	0.64	0.27	1.26	2.17	
WALU7	211.95± 68.48	9.96± 3.21	8.46± 3.16	0.96	0.33	1.42	2.71	
WALU8	118.91± 42.52	8.02± 3.11	7.92±3.10	0.54	0.26	1.33	2.13	
WREP1	118.74± 31.93	13.50± 3.19	18.72± 6.82	0.54	0.44	3.14	4.12	
WREP2	246.01± 91.12	12.03±4.21	15.70±5.93	1.11	0.40	2.64	4.15	
WREP3	244.77± 69.46	14.23± 5.13	21.62± 7.32	1.11	0.47	3.63	5.21	
WREP4	222.98±46.39	11.48± 3.17	14.24± 6.07	1.01	0.38	2.39	3.78	
WREP5	226.60± 50.01	8.61± 2.34	22.30± 8.11	1.03	0.28	3.74	5.05	
WREP6	137.41± 37.62	7.86±3.09	14.02±4.21	0.62	0.26	2.35	3.23	
WREP7	226.60±74.92	9.25± 2.18	17.28± 6.09	1.03	0.30	2.90	4.23	
WREP8	217.16± 46.58	8.99±3.29	13.02± 4.21	0.98	0.30	2.19	3.47	
WREP9	392.66± 97.23	13.15± 4.11	9.46± 3.21	1.78	0.43	1.59	3.80	
Total	**170.19±55.28**	**10.81± 3.67**	**13.49± 4.60**	**1.20**	**0.36**	**2.26**	**3.52**	

All the radiological hazard indices calculated in soil samples from Aluu and Rumu-olumeni landfill are presented in Table 3.The radium equivalent doses calculated for soil from the Aluu and Rumu-olumeni landfill are within the world average value of 370.0 Bq kg^{-1}. The results show that the mean absorbed dose in soil from Aluu landfill is higher than the world average value of 55 nGy h^{-1} and also other reported works (Baykara *et al*., 2005; Tchokossa *et al*., 2012). The annual effective dose (outdoor) for soil from Aluu landfill is higher than the world average value of 70.0 μSvy^{-1}. The mean annual effective dose (indoor) in soil from the two landfill namely Aluu and Rumu-olumeniwere lower than the world permissible value of 450 μSv y^{-1}(Ramasamy *et al*., 2009) but still within the range obtained by other workers (Innocent *et al*., 2013).

The average annual gonadal dose equivalent of soil from Aluu landfillis higher than the permissible value of 300 mSv y^{-1}as shown in Figure 3. This may pose a threat to the bone marrow and the bone surface cells of persons exposed by the use of soil from the Aluu landfill since the landfill is situated in farmland. Also, the external hazard index, internal hazard index and representative gamma index are less than the world permissible value of unity (Avwiri *et al*., 2013) though the gamma index exceeded at four sampling points. This indicates that the immediate radiation hazard could not be noticeable but might have long term impact. The average excess lifetime cancer risk (ELCR) for soil samples from Aluu and Rumu-olumeni landfill are 0.79×10^{-3} and 0.44×10^{-3} respectively and is shown in Figure 2. For the ground water samples ELCR for Aluu and Rumu-olumeni landfill are 0.33×10^{-3} and 0.38×10^{-3}respectively. These values are slightly higher than the world average of 0.29×10^{-3}as shown in Figure 4. This implies that the chances of having cancer by populace that use the water and soil from the area of study are significant.

The estimated daily intake of radionuclide and annual effective dose from ingestion of water as presented in Table 4 are higher than the values reported by other researchers (Baykara *et al*., 2005; Adewole, 2009) due to variation in the composition of the landfills. The absorbed dose rate due to ingestion of water from Aluu and Rumu-olumeni landfill as presented in Table 5 are within the safe limits. There is no significant difference in radionuclide concentration shown by the water samples from the two landfills. This is due to frequent migration of radionuclides in the direction of flow of water. These radionuclides deposited over a period of time are infiltrated from the landfill via the soil and contaminate groundwater which then migrates following the direction of flow. The mean value of the annual effective dose of water samples from Aluu landfill and Rumuolumeni are above the recommended value of 1.0 $mSvyr^{-1}$due to borehole water only and 0.1 mSv yr^{-1} for drinking water (WHO, 2011). Also, external hazard index, internal hazard index and representative gamma index are less than the world permissible value of unity as shown in Table 5. The excess life time cancer risk in all the water

Table 5. Hazard Indices and Excess lifetime Cancer Risk for Water Samples.

Sample	**D**	**Ra_{eq} (nGy h^{-1})**	**AGED (Bq l^{-1})**	**$H_{ex}H_{in}$ (mSv y^{-1})**	**I_γ × 10^{-3}**	**ELCR**	code
WALU1	22.24	48.84	137.85	0.13	0.17	0.51	0.47
WALU2	25.67	36.90	136.14	0.15	0.15	0.29	0.44
WALU3	20.61	42.47	105.01	0.12	0.14	0.33	0.35
WALU4	17.74	37.36	126.46	0.10	0.12	0.28	0.31
WALU5	14.37	30.56	101.57	0.08	0.11	0.23	0.25
WALU6	14.21	29.80	101.09	0.08	0.10	0.22	0.24
WALU7	18.55	32.99	137.69	0.10	0.13	0.17	0.32
WALU8	13.47	28.47	95.23	0.08	0.10	0.21	0.23
WREP1	22.50	41.71	157.25	0.13	0.17	0.08	0.39
WREP2	20.22	39.12	180.05	0.14	0.18	0.40	0.35
WREP3	29.84	63.99	217.56	0.17	0.21	0.47	0.51
WREP4	14.03	49.01	165.01	0.13	0.16	0.37	0.24
WREP5	26.90	42.55	190.97	0.16	0.18	0.23	0.46
WREP6	17.83	38.46	126.04	0.10	0.13	0.28	0.31
WREP7	16.13	51.41	171.97	0.14	0.16	0.39	0.28
WREP8	21.07	44.33	150.39	0.12	0.14	0.34	0.36
WREP9	28.16	56.91	203.47	0.15	0.19	0.44	0.48
Mean	**20.21**	**59.70**	**147.28**	**0.12**	**0.15**	**0.43**	**0.35**

samples exceeded the world accepted safe limit (Udom and Esu, 2004).

The ranges of the calculated elemental activity concentrations in all soil samples are found to be between 1.38 ± 0.03 and 4.16 ± 0.04 ppm for uranium, 1.88 ± 0.01 and 11.26 ± 0.05 ppm for thorium and 0.15 ± 0.001 to 1.6 ± 0.02 % for potassium with an arithmetic mean of 2.90±0.03ppm, 6.86±0.05ppm and 0.94±0.002% respectively. It can be seen that there is a good correlation between Uranium and thorium with a correlation coefficient of 0.797. The relationship between U and Th can be considered in terms of the Th/U ratio. In the current study, the obtained result of elemental ratios for Th/U varies from 1.06 to 4.09, with an arithmetic mean of 2.34 which is lower than the theoretical value of 3.0. A relatively high or low value of the ratio as measured in some studied locations may be an indicative of an enrichment of Thorium or depletion of Uranium of which may be due to alteration or natural processes in that area (Ononugbo *et al*., 2013; USEPA, 2012).

The activity concentrations of natural radionuclides and their associated radiological health risk parameters determined in the two landfills are high when compared with other works done in similar environment. This is an indication that the environment has been contaminated by the un-segregated wastes which may contain some radioelements. Therefore, residents, Scavengers and workers of the landfills areas may be exposed daily to different doses of radiation which may result to health problems such as radiation poisoning, cancer and cell mutation for a long exposure.

CONCLUSION

The activity concentration of ^{238}U, ^{232}Th and ^{40}K in soil and ground water from the two landfills has been studied with the aid of a well calibrated Gamma ray spectrometry and was found to be high compared to results of other works done in a similar environment and their stipulated world safe limit. The annual gonad equivalent dose and excess lifetime cancer risk calculated from the activity concentration of these radionuclides exceeded the permissible values of 300 $mSvy^{-1}$ and 0.29 × 10^{-3} respectively in soil samples. The mean absorbed dose of radiation calculated from soil samples from Aluu landfill is higher than the world value of 55 $nGyh^{-1}$ and also other values reported from a similar environment. The estimated daily intake of radionuclides and the AEDE from ingestion of those radionuclides are higher than the values reported in other works and also the world accepted safe limits.

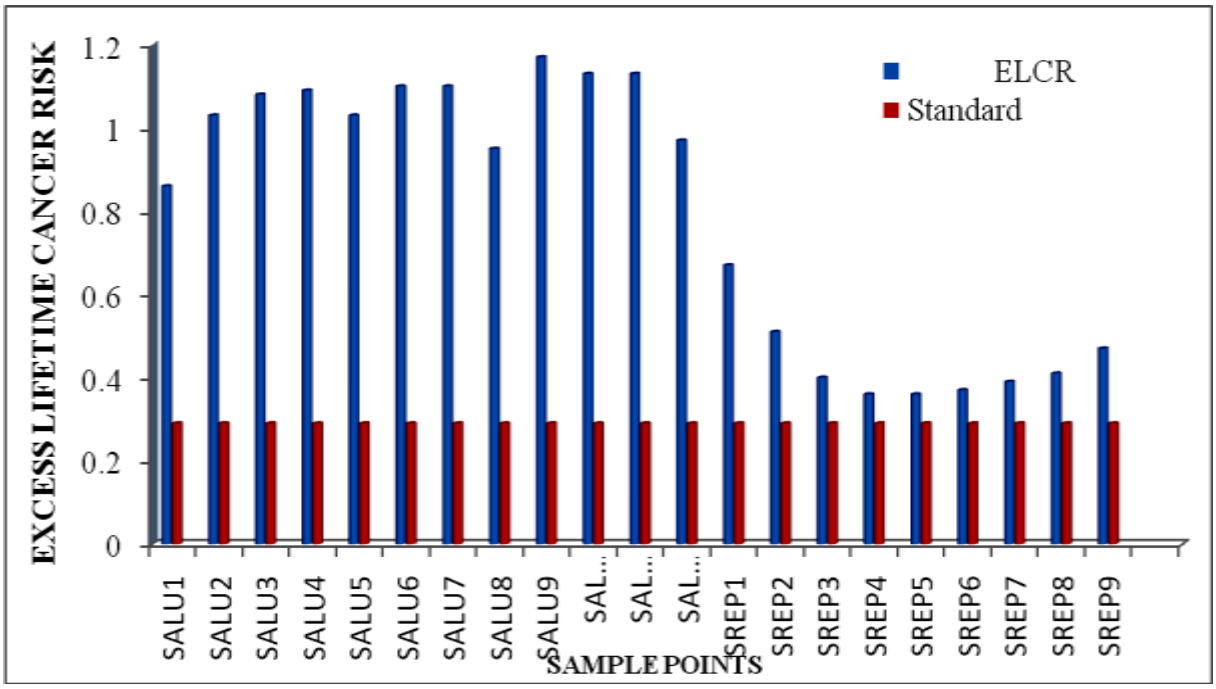

Fig. 2. Comparison of ELCR in soil with UNSCEAR, 2000 Threshold.

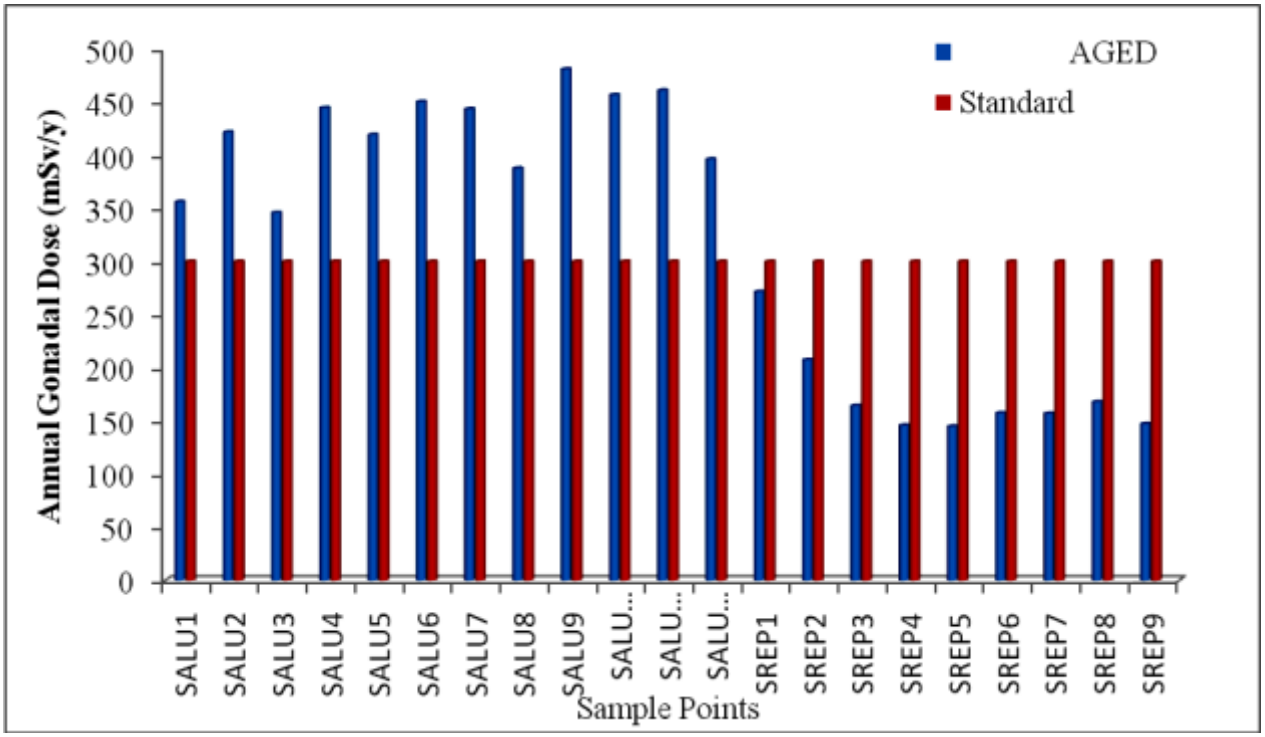

Fig. 3. Comparison of Annual Gonad dose in soil with UNSCEAR, 2000 Standard.

The study therefore conclude that the area have been radiologically polluted by the waste dumps in both landfills , therefore residents, scavengers and workers of the landfill are exposed to varying doses of radiation which could lead to radiation related health hazard for long term exposure. We therefore recommend that the wastes be sorted out from domestic wastes and appropriate disposal option be adopted to help safeguard

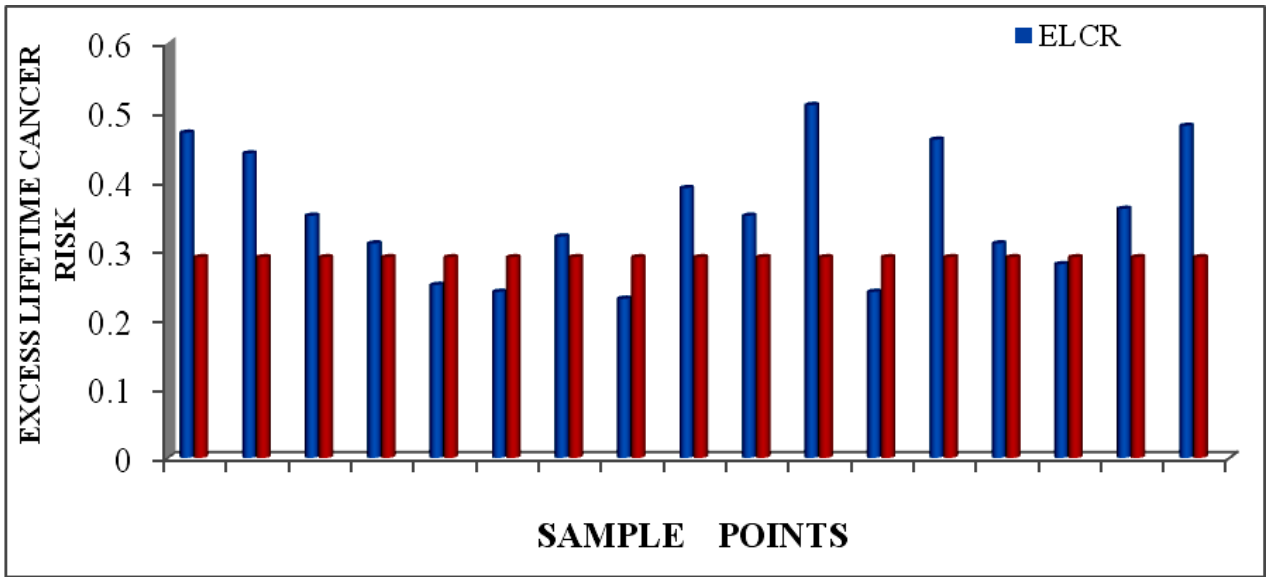

Fig. 4. Comparison of ELCR in water with UNSCEAR, 2000 Threshold.

the lives of the people residing close to the landfills and their environment. Also, boreholes in the area should incorporate ion exchange of reverse osmosis technology in order to eliminate the radionuclides from the water before consumption.

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REFERENCES

Adewole, AT. 2009. Waste management towards sustainable development in Nigeria: A case study of Lagos state. Int. NGO J. (3):45-57.

Ajayi, TR., Torto, N., Tchokossa, P. and Akinlua, A. 2009. Natural Radioactivity and Trace Metals in Crude Oils: Implication for Health. Environ Geochem Health. 31:61-69.

Alatise, OO., Babalola, IA. and Olawofela, JA. 2008. Distribution of some Natural Gamma Emitting Radionuclides in the Soils of the Coastal areas of Nigeria. Journal of Environmental Radioactivity. 99(11):1746-1749.

Avwiri, GO., Nte, FU. and Olanrewaju, AI. 2011. Determination of Radionuclide Concentration of Landfill at Eliozu, Port Harcourt, Rivers State. Scientia Africana. 10(1):46-57.

Avwiri, GO., Egieya, JM. and Ononugbo, CP. 2013. Radiometric Survey of Aluu landfill in Rivers State, Nigeria. J. Advanced in Physics Theories and Application. 22:24-29.

Baykara, O., Hasar, H., Obek, E. and Dogru, E. 2005. Determination of Radioactive Pollution from an Open Landfill. Journal of Radioanalytical and Nuclear Chemistry. 265(1):95-99.

Eja, MK., Alobi, NO., Ikpeme, EM., Ogiri, OR. and Iyang, AO. 2010. Environmental and public Health related assessment of solid waste Management in Uyo, Akwa-Ibom State, Nigeria. World Journal of Applied Science and Technology. 2(1):110-123.

Faweya, EB. and Babalola, S. 2010. Radiological Safety Assessment and Occurrence of Heavy Metals in Soils from Designated waste dumpsites used for building and composting in South Western Nigeria. The Arabic Journal for Science and Engineering. 35(2):219-225.

Ibe, KM. and Njoku, JC. 1999. Migration of Contaminants in ground water at a landfill site. Nigerian Journal of Environmental Hydrology. 7(8):1-9.

Innocent, AJ., Onimisi, MY. and Jonah, SA. 2013. Evaluation of naturally occurring Radionuclide Materials in Soil samples collected from some mining sites in Zamfara State, Nigeria. British Journal of Applied Science and Technology. 3(4):684-692.

International Atomic Energy Agency (IAEA). 1999. Safety Report on Radiation Protection and the Management of a Radioactive Waste in mine, oil and gas industries. New York, USA.

Jankowski, J., Chuscielewski, W., Kamimski, Z. and Zak, A. 2011. Natural Radioactivity of underground water supplies in the Region laulz in Poland. In Proceedings of the IRPA 10 on Scientific Topics-1Natural.

Jibril, NN., Farai, IP. and Alausa, SK. 2007. Activity Concentration of ^{226}Ra,^{232}Th and ^{40}K in different food crops form a high background radiation area in Bisichi, Jos Plateau state, Nigeria. Radiat Environ. Biophysics. 46:53-59.

Longe, EO. and Kehinde, MO. 2005. Investigation of potential ground water impact at an unlined waste disposal site in Agege, Lagos Nigeria. Proc 3rd Faculty of Engineering International Conference, University of Lagos, Nigeria.

NPC. 2006. National Population Commission of Nigeria: Provisional Census Result of Federal Republic of Nigeria.

Olubosede, O., Akinnagbe, OB. and Adekoya, E. 2012. Assessment of Radiation Emission from waste Dumpsite in Lagos State of Nigeria. International Journal of Computational Engineering Research. 2(3):806-811.

Odunaike, R.K., Laoye, JA. ,Alausa, SK., Ijeoma, GC. and Aelaja, AD. 2008. Radiation Emission Characterization of waste Dumpsites in the city of Ibadan in Oyo State of Nigeria. Research Journal of Environmental Toxicology. (2):100-103.

Oladapo, OO., Oni, EA., Olawoyin, AA., Akereke, OO. and Tijani, SA. 2012. Assessment of Natural Radionuclides levels in Wasteland Soils around Olusosun Dumpsite Lagos. Nigerian Journal of Applied Physics. 2(3):38-43.

Ojoawo, S., Agbeole, O. and Sangodoyin, S. 2011. A. Physical Composition of solid wastes in selected Dumpsites of Ogbomoso land, South-Western Nigeria. Journal of water Resources and protection. (3):661-661.

Ononugbo, CP., Avwiri, GO. and Egieya, JM. 2013. Evaluation of Natural Radionuclide Content in Surface and Ground Water and Excess Lifetime Cancer Risk Due To Gamma Radioactivity. Academic Research International. 4(6):636-647.

Ramasamy, V., Suresh, G., Meenakshisundaram, V. and Gajendran, V. 2009. Evaluation of Natural Radionuclide content in River sediments and excess lifetime cancer Risk due to Gamma Radioactivity. Research J. of Environmental and Earth Sciences. 1(1):6-10.

Tchokossa, P., Olomo, JB., Balogun, FA. and Adesanmi, CA. 2012. Radiological Study of Soils in Oils and Gas Producing Areas in Delta State, Nigeria. Radiation Protection Dosimetry. 1-6. doi:10.1093/rpd/nsc101

Taskin, H., Karavus, M., Ay, P., Topuzoglu, S., Hindiroglu, N. and Karahan, G. 2009. Radionuclide Concentrations in soil and Lifetime cancer risk due to the gamma radioactivity in Kirklareli, Turkey. J. of Environmental Radioactivity. 100:49-53.

Udom, GJ. and Esu, EO. 2004. A preliminary assessment of the impact of solid wastes on soil and ground water system in parts of Port Harcourt city and its Environs, Nigeria. 4(1):23-32.

Uosif, MA., Mahmond, T., Shams, AM. and Reds, E. 2012. Naturally Occurring Radionuclides in Sludge samples from some Egyptian Drinking water Purification Stations. International Journal of Advanced Science and Technology. 42:69-81.

United Nations Scientific Committee on Effect of Atomic Radiation. (UNSCEAR). 2000. Report to the general assembly Annex B: exposure from natural radiation source.

United States Environmental Protection Agency (UNSEPA). 2012. Edition of the Drinking water Standards and Health Advisories. Spring.

Veiga, RG., Sanches, N. and Anjos, RM. 2006. Measurement of natural radioactivity in Brazilizn beach sands. Radiation Measurements. 41:189-196.

World Health Organization (WHO). 2011. Guidelines for Drinking Water Quality. (4th edi.). Incorporating the 1st and 2nd Agenda vol.1 Recommendations, Geneva.

Yussuf, NM., Hossain, I. and Wagiran, H. 2012. Natural Radioactivity in Drinking and Mineral water in Johor Bahru (Malaysia). Scientific Research and Essays. 7(9):1070-1075.

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