http://www.knowledgebasepublishers.org/ENV%20SCI.html
Comprehensive Journal of Environment and Earth Sciences Vol. 3(1), pp. 38-50 Dec. 2014
ISSN-2315-7488

RADIATION HAZARD INDICES AND EXCESS LIFETIME CANCER RISK IN SOIL, SEDIMENT AND WATER AROUND MINI-OKORO/OGINIGBA CREEK, PORT HARCOURT, RIVERS STATE, NIGERIA.

Avwiri G.O, Ononugbo C.P, Nwokeoji I.E.
University of Port Harcourt, Port Harcourt
Corresponding Author Email: ijeomanwokeoji@gmail.com

Accepted 30 October

The growth of human population and rapid industrialization has led to increased use of urban waters as sewers, compromising their other uses. The discharge of industrial effluents has led to inevitably alterations in the quality of the environment. The objective of this work therefore, was to estimate the radiation health hazard indices and excess lifetime cancer risk associated with exposure to river water, soil and sediments from Mini-Okoro/Oginigba Creek. The determined activity concentrations of ^{238}U, ^{232}Th and ^{40}K in all the samples were within the world acceptable values but was higher than results of other works done in similar environment. There were poor correlations between ^{238}U and ^{232}Th, ^{238}U and ^{40}K and ^{232}Th and ^{40}K. The ratio of Th/U for water, sediment and soil samples ranged from 0 to 7.63, 0.54 to 4.72 and 0.17 to 3.64 respectively. Whereas, the ratio K/U and K/Th ranged from 0 to 0.33, 0 to 1.66 and 0.01 to 0.87 and 0.04 to 0.16, 0 to 0.35 and 0.01 to 0.77 for water, sediment and soil respectively. To assess the radiological hazard of river sediments, water and soil ,the radiological hazard indices such as absorbed dose rate, annual effective dose equivalent (AEDE), hazard indices (H_{in} and H_{ex}),activity utilization index (I), annual gonads dose and excess lifetime cancer risk (ELCR) were calculated and found to be below the internationally recommended values. The contribution of ^{238}U, ^{232}Th and ^{40}K to the effective dose were 56.9%, 27.2% and 15.9% respectively in water, 33.6%, 21.2% and 45.2% respectively in sediment and 71.8%, 14.2% and 14.0% respectively in soil. The results indicate that the radiation hazard from primordial radionuclide in all river water, river sediments and river bank surface soil samples from the area studied is not significant. Therefore there is no immediate radiation health hazard associated with the use of any of the samples studied.

KEY WORDS: Radionuclide, Mini-Okoro/Oginigba, Spectroscopy, lifetime cancer risk, Gonad

INTRODUCTION

Humans are always exposed to background radiation that comes from both natural and human-made sources. The knowledge of radionuclide distribution levels in the environment is important in assessing

the effects of radiation exposure due natural and human-made sources. Natural radioactivity concentrations depend mainly on geological and geographical conditions and appear at different levels in soils of different geological regions (UNSCEAR, 2000).Soil radionuclide activity concentration is one of the main determinants of the natural background radiation. When rocks are disintegrated through natural process, radionuclides are carried to soil by rain and flows (Taskin, et al., 2009). In addition to the natural sources, soil radioactivity is also affected by human-made activities.

Radioactivity of various building materials was measured by many authors, including river sediment, soil, water, ceramics and so on in different parts of the world(Avwiri and Ononugbo,(2012), Ramassamy, et al.,(2006) and (2009), Vesterbacka,(2007) Ononugbo et al., (2013), Agbalagba et al.,(2013).

Natural waters contain small and variable quantities of alpha and beta emitters from decay of uranium, thorium and their daughters together with ^{40}K (UNSCEAR, 1993). River sediments are also known to contain natural radionuclide, the concentration of which if beyond certain limits can cause adverse health effects (Okeyode, 2012).The concentration of naturally occurring radionuclide in river sediments is measured in an effort to better understand the spatial distribution of the radionuclide and their associated health hazards. The growth of human population and rapid industrialization has led to increased use of urban waters as sewers, compromising their uses. The discharge of industrial effluents has led inevitably to alterations in the quality and ecology of receiving waters (Wahid, et al., 1999).

In the coastal areas of Nigeria, the dominant industry is oil and gas exploration and production. Apart from medical exposure, the petroleum industry is the largest importer and consumer of radioactive materials (Oni et al., 2011). Despite conscious efforts and measures to ensure safety, there is a possibility, based on accident, mishandling of equipment, improper discharge that radioactive materials of natural and artificial sources may pollute the terrestrial and aquatic areas which are mainly network of rivers and creeks. Researches on effects of radiation on humans, has shown that exposure to radiation could lead to lung, pancreas, hepatic, bone, skin and kidney cancers, cataracts, sterility, atrophy of the kidney and leukaemia (Taskin, et al., 2009). Knowledge of natural radioactivity present in river sediment, water and surface soil enables one to assess any possible radiological hazard to humans by the use of such materials. Hence the objective of this study was to estimate the radiation health hazard indices and excess life time cancer risk associated with exposure to water, soil and sediments from mini-okoro/Oginigba creek.

MATERIALS AND METHODS

Study Area

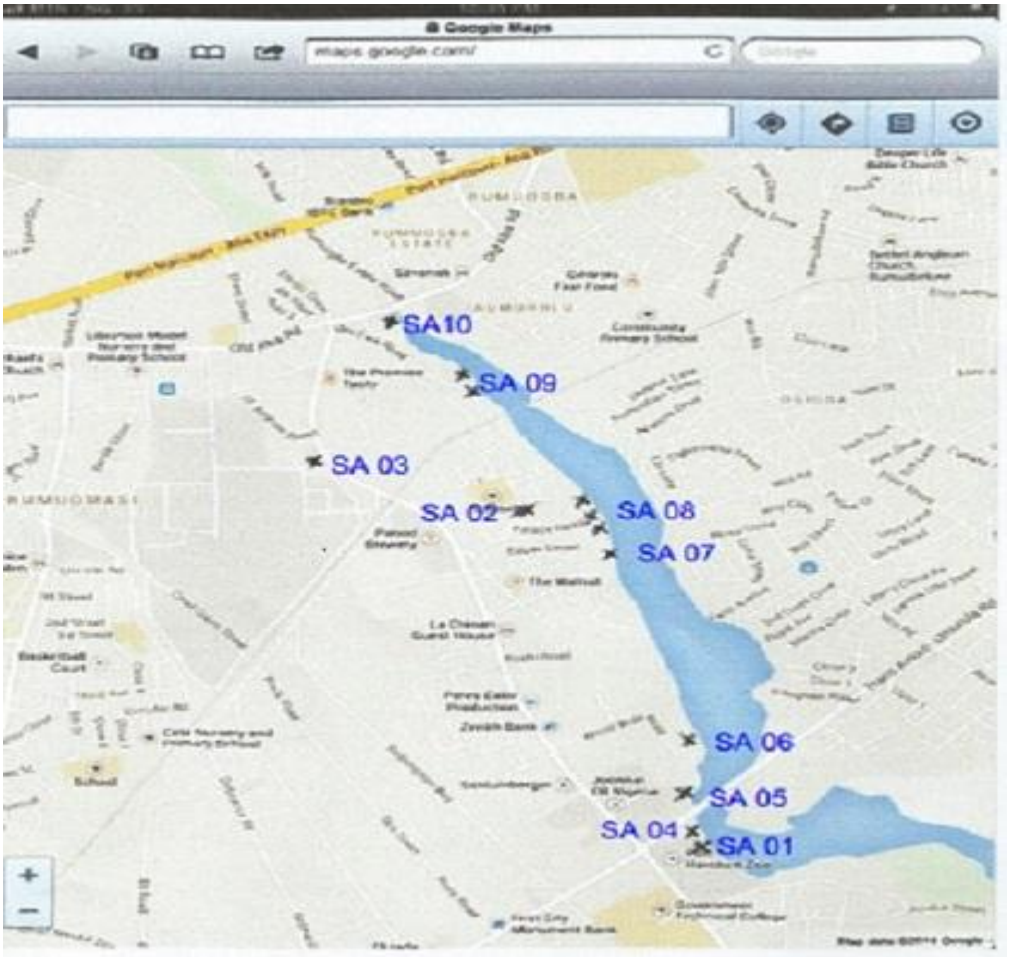
The study area is located in Port Harcourt the Capital of Rivers state, it lies along the Bonny River and is located in the Niger Delta. Port Harcourt lies about 468m above sea level and between latitudes 4^0 46′ 38" N and 7^0 00′ 48" E (Avwiri and Ononugbo 2012).Rivers State lies on the recent coastal plain of the eastern Niger Delta. Its surface geology consists of fluvial sediments. This includes the recent sediment transported by Niger River distributaries and other rivers such as Andoni, Bonny and new Calabar rivers.

The mini-okoro/oginigba creek in the Trans-Amadi area of Port Harcourt in Rivers state, originates before the mini-okoro bridge. It flows from Rumubiakani through Oginigba community and empties into the Bonny estuary. The sediment and water from the stream/creek are used to mould blocks for building constructions. Fishing and farming activities are also taking place in the area. Industries and households in the area discharge and dump wastes into the water body, thereby polluting it.

Sample collection and preparation

A total of 30 samples were collected from the study area, 10 samples each of soil, water and sediment. Table1: shows the sampling points and the number of samples collected. The water samples were collected using 2 litre plastic bottles. They were acidified with 0.1MHCl, at a rate of 10ml per litre to minimize the precipitation of the radionuclide present in the water samples (ISO, 1998). Soil and sediment samples were collected in black nylon bags about 2kg each. They were sprayed in trays and air dried the samples were crushed and made to pass through 2mm mesh sieve. They were weighed, sealed and stored in the laboratory for four weeks before being analyzed to allow for radon and its short-lived

progenies to reach secular equilibrium prior to gamma spectroscopy (Zarie and Al mugren, 2011; Agbalagba, et al., 2012).



. **Figure 1:** Map of the study Stream/Creek showing sampling points

Table1: Sample Collection Plan

Area code	Sampling Area	soil	Water	Sediments
SA01	Zoo area	1	-	-
SA02	State school, Oginigba	1	-	-
SA03	Shell Gutter, Rumubiakani	1	-	-
SA04	Bridge Area by Zoo	1	1	1
SA05	Bridge by slaughter	1	1	1
SA06	Tekon area	1	1	1
SA07	Eze's Palace Oginigba	1	1	1
SA08	Pabod waste area	1	3	3
SA09	Rumubiakani dump site	1	2	2
SA10	Mini-okoro bridge area	1	1	1
Total		10	10	10

Measurement

Gamma Counting

The experiments for radioactivity measurement of the river water, sediment and soil samples were carried out at the National Institute of Radiation Protection and Research (NIRPR) university of Ibadan using a thallium activated Canberra vertical high purity 3″×3″ Sodium iodide [NaI(TI)] detector connected to ORTEC 456 amplifier. The detector was connected to a computer program MAESTRO window that matched gamma energies to a library of possible isotopes. The detector was shielded by 15cm thick lead on all four sides and 10cm thick on top. The energy resolution of 2.0kev and relative efficiency of 33% at 1.33Mev was achieved in the system with the counting time of 10000 seconds. The standard International Atomic Energy Agency (IAEA) sources were used for calibration (IAEA, 2003). From the counting spectra, the activity concen-trations of ^{238}U, ^{232}Th and ^{40}K was determined using computer program. The peak corresponds to 1460 kev (^{40}K) for ^{40}K, 1764.5 Kev (Bi-214) for ^{238}U and 2614.5 kev (Ti-208) for ^{232}Th were considered in arriving at the activity levels (Bqkg-1).
The activity concentration (C) of the radionuclide was calculated after subtracting decay correction using the following expression (Arogunjo, et al., 2005);

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

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.

Radiation Hazards

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 as (Avwiri et al., 2013)) and shown in Tables 1-3:
:

$$Ra_{eq}(Bqkg^{-1}) = C_U + 1.43C_{Th} + 0.077C_K \quad (2)$$

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)

Absorbed dose is a measure of the energy deposited in a medium by ionizing radiation per unit mass. It may be measured as joules per kilogram and represented by the equivalent S.I.unit, gray (G_y) or rad. The absorbed dose rate (D) was calculated using the following expression (UNSCEAR, 2000) and shown in Table 7.

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

Where, D is the absorbed dose rate in nGyh^{-1}, C_U, C_{Th}, and C_K are the concentrations of Uranium, Thorium and Potassium, respectively.

Annual Gonadal Equivalent Dose (AGED)

The gonads, the bone marrow and the bone surface cells are considered as organs of interest by UNSCEAR (2000) because of their sensitivity to radiation. 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 by evaluated by the following equation (Avwiri, et al., 2012)

$$AGED\ (\mu Svy^{-1})\ C = 3.09C_u + 4.18C_{Th} + 0.314C_K \qquad (4)$$

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

Representative Gamma Index (I_γ)

This is used to estimate the gamma radiation hazard associated with the natural radionuclide in specific investigated samples. The representative gamma index was estimated as follow (Avwiri,et al.,2013)

$$I_\gamma = C_{Ra}/150 + C_{Th}/100 + C_K/1500) \qquad \leq 1 \qquad (5)$$

Annual Effective Dose Equivalent (AEDE)

The annual effective dose equivalent received outdoor 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 (Veiga, et al., 2006). AEDE is determined using the following equations (Veiga, et al., 2006):

$$AEDE(Outdoor)(\mu Sv/y) = \text{Absorbed dose } D(nGy/h) \times 8760h \times 0.7\ Sv/Gy \times 0.2 \times 10^{-3} \qquad (6)$$

$$AEDE(Indoor)(\mu Sv/y) = \text{Absorbed dose } D(nGy/h) \times 8760h \times 0.7\ Sv/Gy \times 0.8 \times 10^{-3} \qquad (7)$$

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 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} (WHO, 2011) from the following expression (Avwiri, et al., 2013):

$$AEDE\ (mSvy^{-1}) = I \times A \times C \times 365 \qquad (8)$$

Where AEDE is the annual effective dose, I, is the water intake per day (ld^{-1}), A is the daily intake of radionuclide (Bql^{-1}) and C is the ingestion coefficient of the specific radionuclide (Bql^{-1}).

Excess Lifetime Cancer Risk (ELCR)

The Excess Lifetime cancer risk (ELCR) was calculated using the following equation (Taskin, et al., 2009):

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

Where, AEDE is the Annual Equivalent Dose Equivalent, DL is the average duration of life (estimated to 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 (Taskin,et al., 2009)

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

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

$$H_{ex} = C_U / 370 + C_{Th} / 259 + C_K / 4810 \leq 1 \quad (10)$$

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

Where, C_U, C_{Th} and C_K are the radioactivity concentration in Bqkg-1 (or Bql-1) of 226Ra, 232Th, and 40K respectively. H_{in} should be less than unity for the radiation hazard to be negligible. Internal exposure to radon is very hazardous which can lead to respiratory diseases like asthma (Tufail, et al., 2007). Natural radionuclide in soil, sediment and rocks produce an external radiation field to which all humans are exposed. H_{ex} must be less than unity for this external radiation hazard to be negligible (Beretka and Mathew, 1985). H_{ex} equal to unity corresponds to the upper limit of radium equivalent dose (370 $Bqkg^{-1}$) (Beretka and Mathew, 1985).

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 %) can be calculated from 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 as follows:-

$$1\%\ K = 313\ Bq\ kg^{-1}\ of\ ^{40}K \quad (12)$$

$$1\ ppm\ U = 12.35\ Bq\ kg^{-1}\ of\ ^{238}U \quad (13)$$

$$1\ ppm\ Th = 4.06\ Bq\ kg^{-1}\ of\ ^{232}Th \quad (14)$$

RESULTS AND DISCUSSIONS

The result of the gamma ray spectrometry of various samples is presented in Table 1 and Table 3. 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.

Table 2: Specific activity of ^{40}K, ^{232}Th and ^{238}U in water samples and their radium equivalent values.

S/N	Sample Code	^{40}K (Bql^{-1})	^{232}Th (Bql^{-1})	^{238}U (Bql^{-1})	Ra_{eq} (Bql^{-1})
1	WAT 01	7.30 ± 0.09	0.78 ± 0.02	BDL	1.7161
2	WAT 02	4.43 ± 0.05	0.84 ± 0.02	0.91 ± 0.16	1.4423
3	WAT 03	5.11 ± 0.06	1.10 ± 0.01	2.37 ± 0.09	4.3365
4	WAT 04	7.89 ± 0.10	1.18 ± 0.01	0.69 ± 0.11	2.9827
5	WAT 05	8.17 ± 0.10	0.64 ± 0.01	2.18 ± 0.10	4.3239
6	WAT 06	5.74 ± 0.07	1.93 ± 0.01	2.06 ± 0.10	1.2619
7	WAT 07	5.04 ± 0.06	1.49 ± 0.01	0.59 ± 0.11	1.6788
8	WAT 08	2.43 ± 0.03	1.52 ± 0.01	1.13 ± 0.11	2.6460
9	WAT 09	2.27 ± 0.03	0.73 ± 0.1	1.46 ± 0.09	2.6787
10	WAT 10	1.03 ± 0.01	0.86 ± 0.1	1.56 ± 0.10	1.9321
	Mean	4.94±0.06	1.11±0.03	1.30±0.10	2.4999

The ranges of activity concentrations of ^{238}U, ^{232}Th and ^{40}K were 0.91± 0.16 to 2.37 ±0.09(Bql^{-1}), 0.64±0.01 to 1.93±0.01 (Bql^{-1}) and 1.03±0.01 to 8.17±0.10 (Bql^{-1}) respectively, 2.87± 0.15 to 7.14 ±0.14 ($BqKg^{-1}$), 1.29±0.02 to 5.53±0.02 ($BqKg^{-1}$)and 2.73±0.03 to 66.52±0.81 ($BqKg^{-1}$) respectively and 0.71±

Table 3: Specific activity of ^{40}K, ^{232}Th and ^{238}U in sediment samples and their Radium equivalent values.

S/N	Sample Code	^{40}K (BqKg^{-1})	^{232}Th (BqKg^{-1})	^{238}U (BqKg^{-1})	Ra_{eq} (BqKg^{-1})
1	SED 01	45.00 ± .055	1.67 ± 0.02	1.08 ± 0.15	5.1881
2	SED 02	23.96 ± 0.29	1.22 ± 0.02	3.25 ± 0.14	6.8109
3	SED 03	7.41 ± 0.09	0.83 ± 0.02	2.72 ± 0.16	4.4775
4	SED 04	0.22 ± 0.003	0.97 ± 0.02	2.10 ± 0.15	3.5040
5	SED 05	11.96 ± 0.15	3.12 ± 0.02	4.45 ± 0.13	9.0625
6	SED 06	BDL	1.80 ± 0.02	0.71 ± 0.15	1.0540
7	SED 07	10.26 ± 0.13	3.85 ± 0.02	4.58 ± 0.13	7.0255
8	SED 08	28.08 ± 0.35	4.70 ± 0.02	7.64 ± 0.14	9.9002
9	SED 09	3.91 ± 0.05	1.03 ± 0.02	5.78 ± 0.14	6.5232
10	SED 10	12.23 ± 0.15	2.97 ± 0.02	5.49 ± 0.14	6.8487
	Mean	14.30±0.13	2.22±0.02	3.78±0.14	6.039

Table 4: Specific activity of ^{40}K, ^{232}Th and ^{238}U in Soil samples and their Radium equivalent

S/N	Sample code	^{40}K (Bqkg^{-1})	^{232}Th (Bqkg^{-1})	^{238}U (Bqkg^{-1})	Ra_{eq} (BqKg^{-1})
1.	SND01	9.32±0.11	3.63±0.02	4.27±0.12	10.18
2.	SND 02	5.67±0.07	4.86±0.02	7.14±0.14	14.78
3.	SND 03	2.73±0.03	3.43±0.02	2.87±0.15	5.98
4.	SND 04	17.80±0.02	1.62±0.03	6.37±0.14	23.61
5.	SND 05	32.27±0.39	0.54±0.02	3.06±0.15	5.78
6.	SND 06	10.29±0.13	1.29±0.02	3.25±0.15	4.89
7.	SND 07	7.55±0.09	3.58±0.02	5.43±0.14	7.55
8.	SND 08	7.71±0.09	1.92±0.02	3.87±0.14	6.83
9.	SND 09	66.52±0.81	5.53±0.02	4.75±0.14	16.64
10.	SND 10	2.76±0.03	3.81±0.02	6.62±0.14	12.13
	MEAN	**16.25±0.19**	**3.92±0.02**	**4.76±0.14**	**10.84**

0.15 to 7.64 ±0.14 (BqKg^{-1}), 0.83±0.02 to 4.70±0.02 (BqKg^{-1}) and BDL to 45.00±0.055 (BqKg^{-1}) respectively for water, soil and sediment samples respectively. The activity concentrations of ^{238}U, ^{232}Th and ^{40}K in all the samples were within the world safe limit of 10.0, 1.0 and 10.0 Bql^{-1} respectively for water as shown in Figures 2 to 4, 35.0, 30.0 and 400.0 Bqkg^{-1} respectively for soil and 50.0, 50.0 and 500.0 Bqkg^{-1} respectively for sediment samples by UNSCEAR, 2000 and WHO, 2008 standards. The elemental concentration of the radionuclide in the samples was calculated from the activity concentrations in Bqkg^{-1} using the conversion factor in equations (12) to (14). The ranges of the calculated elemental concentrations in all water samples are found to be 0.0 to 0.29 ppm for uranium, 0.16 to 0.48ppm for thorium and 0.30 to 2.60 % for potassium with an arithmetic mean of 0.11 ± 0.01 ppm, 0.007 ± 0.01 ppm and 0.040 ± 0.01 %, respectively as shown in Table 5,while the elemental concentrations in all sediment samples are found to be 0.057 to 0.62 ppm for uranium, 0.20 to 1.16ppm for thorium and0.10 to 14.4 % for potassium with an arithmetic mean of 0.31 ± 0.01 ppm, 0.55 ± 0.01 ppm and 0.46 ± 0.01 %, respectively as shown in Table 6.The ranges of the calculated elemental concentrations in all the soil samples are found to be 0.23 to 2.41 ppm for uranium, 0.13 to 1.36ppm for thorium and 0.009 to 0.30 %

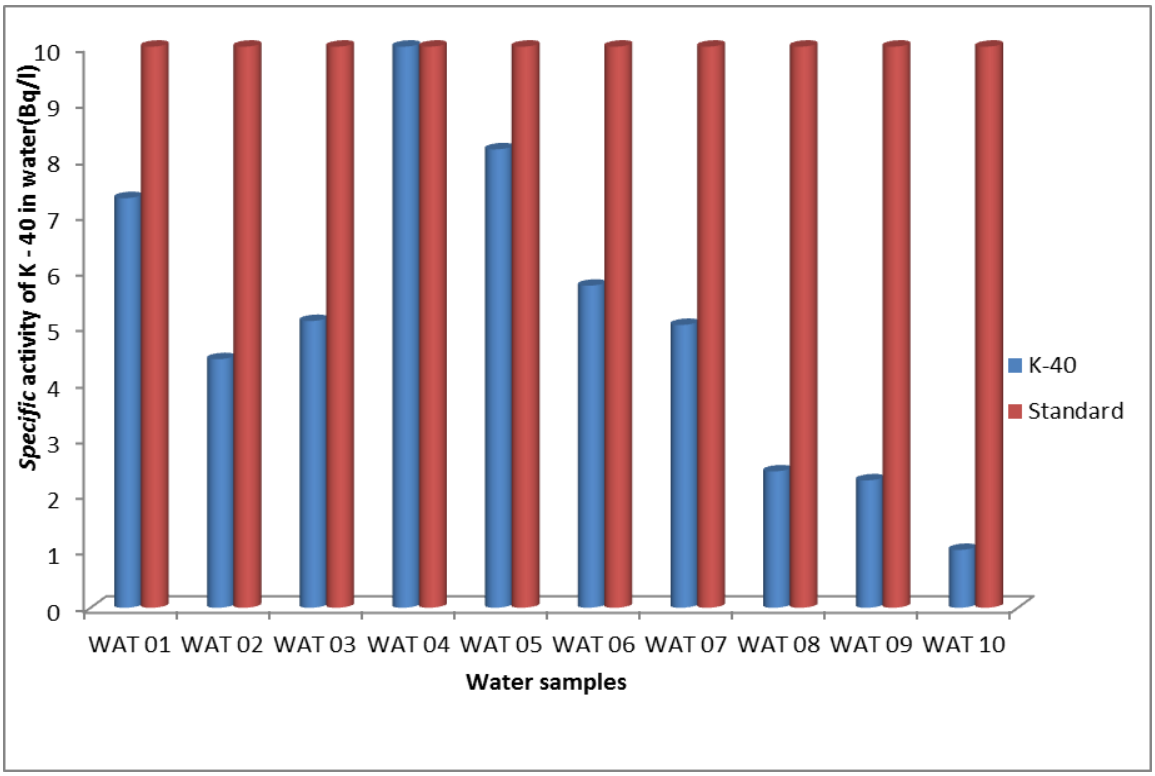


Figure 2: Comparison of Specific Activity of K-40 in Water Samples with WHO (2008) Standard

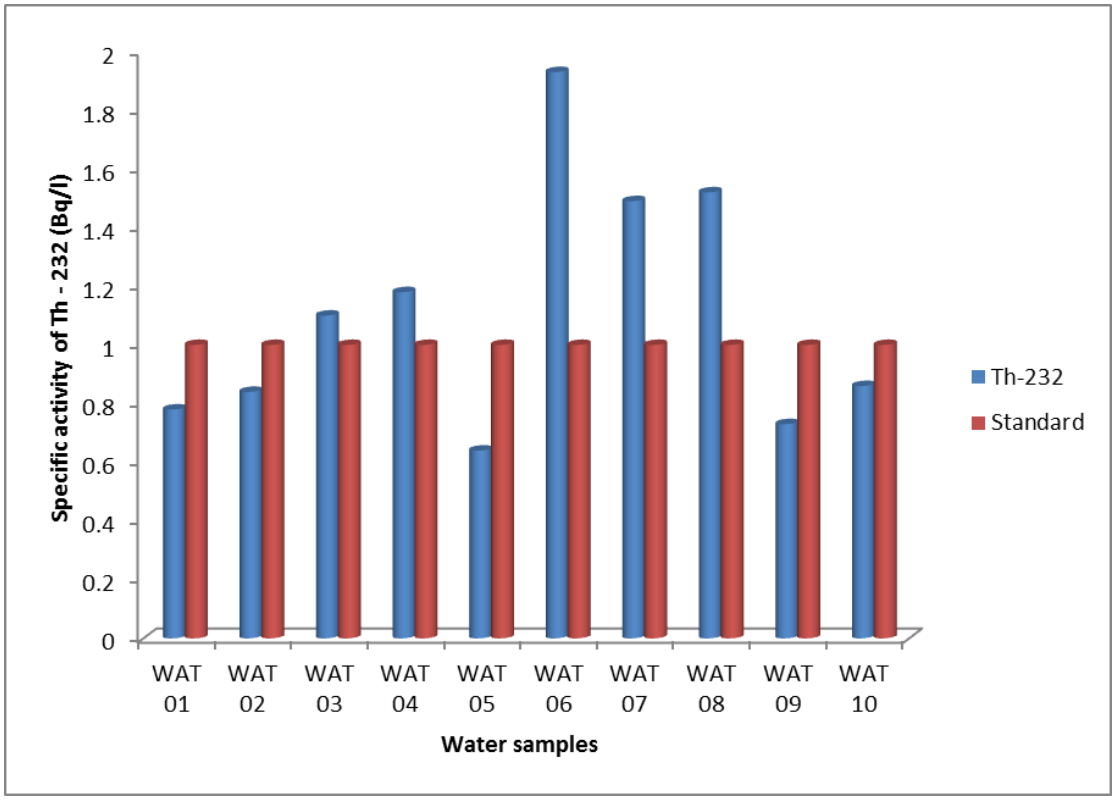


Figure 3: Comparison of Specific Activity of Th-232 in Water Samples with WHO (2008) Standard

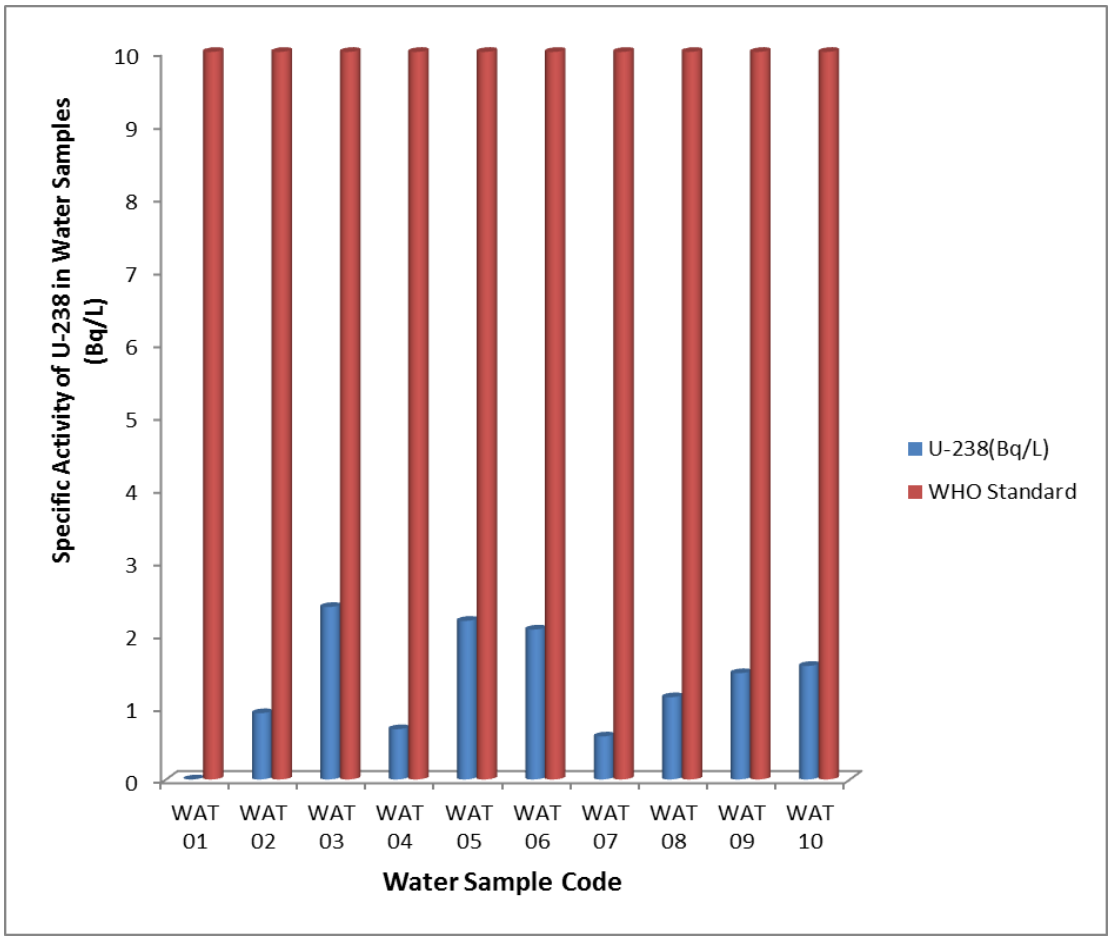


Figure 4: Comparison of Specific Activity of U-238 in Water Samples with WHO (2008) Standard.

Table5: Elemental Concentration of ^{238}U, ^{232}Th and ^{40}K (ppm) in water samples with their ratios

S/N	Sample	^{238}U	^{232}Th	^{40}K	Th/U	K/U	K/Th
1.	WAT 01	0	0.192	0.023	0	0	0.12
2.	WAT 02	0.074	0.270	0.014	3.65	0.19	0.05
3.	WAT 03	0.192	0.443	0.016	2.31	0.04	0.04
4.	WAT 04	0.294	0.158	0.025	1.97	0.16	0.16
5.	WAT 05	0.177	0.478	0.026	2.86	0.05	0.05
6.	WAT 06	0.167	0.475	0.018	2.84	0.04	0.04
7.	WAT 07	0.048	0.366	0.016	7.63	0.33	0.04
8.	WAT 08	0.091	0.374	0.007	4.11	0.02	0.02
9.	WAT 09	0.118	0.179	0.007	1.52	0.04	0.04
10.	WAT 10	0.126	0.212	0.003	1.68	0.01	0.01
	Mean	**0.105**	**0.007**	**0.400**	**3.17**	**0.09**	**0.06**

for potassium with an arithmetic mean of 0.39 ± 0.01 ppm, 0.97 ± 0.01 ppm and 0.052 ± 0.01 %, respectively as shown in Table 7.

The correlations between the activity concentrations of (i) ^{238}U and ^{232}Th; (ii) ^{238}U and ^{40}K; and (iii) ^{232}Th and ^{40}K, respectively showed that there is a good correlation between ^{238}U and ^{232}Th with a correlation coefficient of 0.84. The relationship between uranium and thorium can be considered in terms of the Th/U ratio. According to Tzortzis and Tsertos (2004) and Al-Hamarneh and Awadallah (2009), the theoretical values of the elemental ratios of Th/U are expected to be approximately 3.0 for normal continental crust.

Table 6: Elemental Concentration of ^{238}U, ^{232}Th and ^{40}K (ppm) in Sediment samples with their ratios

S/N	Sample	^{238}U(ppm)	^{232}Th(ppm)	^{40}K(ppm)	Th/U	K/U	K/Th
1.	SED 01	0.087	0.411	0.144	4.724	1.66	0.35
2.	SED 02	0.263	0.300	0.076	1.141	0.29	0.25
3.	SED 03	0.220	0.204	0.024	0.927	0.09	0.12
4.	SED 04	0.170	0.238	0.001	1.400	0.01	0.04
5.	SED 05	0.360	0.253	0.038	0.703	0.11	0.15
6.	SED 06	0.057	0.443	0.000	7.772	0.00	0.00
7.	SED 07	0.371	0.948	0.033	2.555	0.09	0.03
8.	SED 08	0.619	1.158	0.090	1.871	0.15	0.08
9.	SED 09	0.468	0.254	0.012	0.543	0.03	0.05
10.	SED 10	0.445	0.732	0.039	1.645	0.09	0.05
	Mean	**0.306**	**0.547**	**0.046**	**2.330**	**0.25**	**0.05**

Table7: Elemental Concentration of ^{238}U, ^{232}Th and ^{40}K in soil samples with their ratios

S/N	Sample	^{238}U	^{232}Th	^{40}K	Th/U	K/U	K/Th
1.	SND 01	0.346	0.894	0.301	2.58	0.87	0.34
2.	SND 02	0.578	1.197	0.018	2.07	0.03	0.02
3.	SND 03	0.232	0.845	0.009	3.64	0.04	0.01
4.	SND 04	0.516	0.399	0.057	0.77	0.11	0.14
5.	SND 05	0.248	0.133	0.103	0.54	0.42	0.77
6.	SND 06	2.407	0.399	0.033	0.17	0.01	0.08
7.	SND 07	0.440	0.882	0.024	2.00	0.05	0.03
8.	SND 08	0.313	0.473	0.025	1.52	0.08	0.05
9.	SND 09	0.385	1.362	0.213	3.54	0.55	0.16
10.	SND 10	0.536	0.938	0.009	1.75	0.02	0.01
	Mean	**0.385**	**0.966**	**0.052**	**1.85**	**0.22**	**0.16**

Table 8a: Radiation Hazard parameters for water samples

S/N	Sample Code		D(nGyh^{-1})	AEDE(μSvy^{-1})	AGED(Svy^{-1})	ELCR×10^{-3}	H_{in}	H_{ex}	I_γ
1.	WAT01	0.83	1.02	5.55		0.004	0.004	0.004	0.013
2.	WAT02	1.14	1.66	7.71		0.006	0.009	0.006	0.017
3.	WAT03	1.98	2.43	13.53		0.009	0.018	0.012	0.029
4.	WAT04	1.42	1.74	9.54		0.006	0.009	0.008	0.028
5.	WAT05	1.71	2.09	11.98		0.007	0.016	0.010	0.114
6.	WAT06	1.16	1.43	16.24		0.002	0.020	0.020	0.074
7.	WAT07	1.42	1.74	9.63		0.006	0.026	0.005	0.022
8.	WAT08	0.98	1.20	10.61		0.004	0.012	0.009	0.047
9.	WAT09	1.20	1.48	8.28		0.005	0.011	0.007	0.022
10.	WAT10	1.28	1.57	8.74		0.006	0.014	0.008	0.020
	Mean	**1.31**	**1.64**	**10.18**		**0.005**	**0.017**	**0.071**	**0.039**

In the current study, the obtained result of the elemental ratios for Th/U for water, sediment and soil samples varies from 0 to 7.63, 0.54 to 4.72 and 0.17 to 3.64 respectively, with an arithmetic mean and standard deviation of 3.17 ± 0.50, 2.33±0.02 and1.85±0.001 respectively for the full data, which is consistent with the theoretical value in the case of water. A high or low value of the Th/U ratio as measured in some studied locations may be indicative of a depletion of uranium or an enrichment of thorium due to alteration of natural processes in that areas [Tzortzis and Tsertos(2004) , Al-Hamarneh and Awadallah, (2009)].

The ratios of K/U and K/Th ranged from 0 to 0.33 and 0 to 1.66, 0.01 to 0.87 and 0.04 to 0.16, 0 to 0.35and 0.01 to 0.77 for water, sediment and soil respectively. The correlation plots showed that a rather

Table 8b: Radiation Hazard parameters for Sediment samples

S/N	Sample Code	D(nGyh^{-1})	AEDE(μSvy^{-1})	AGED(Svy^{-1})	ELCR×10^{-3}	H_{in}	H_{ex}	I_γ
1.	SED01	3.51	4.31	25.32	0.015	0.028	0.018	0.054
2.	SED02	3.23	3.96	22.67	0.014	0.027	0.018	0.050
3.	SED03	2.03	3.80	14.20	0.013	0.030	0.012	0.034
4.	SED04	1.55	1.90	10.61	0.007	0.015	0.009	0.024
5.	SED05	4.69	5.73	30.55	0.020	0.039	0.027	0.162
6.	SED06	1.50	1.83	10.29	0.006	0.049	0.009	0.023
7.	SED07	4.98	6.07	33.47	0.021	0.042	0.029	0.141
8.	SED08	7.63	9.36	52.07	0.033	0.065	0.045	0.157
9.	SED09	3.57	4.38	23.39	0.015	0.036	0.020	0.051
10.	SED10	4.84	5.95	33.25	0.021	0.044	0.029	0.074
	Mean	**3.75**	**4.73**	**25.58**	**0.017**	**0.038**	**0.031**	**0.067**

Table 8c: Radiation Hazard parameters for Soil samples

S/N	Sample Code	D(nGyh^{-1})	AEDE(μSvy^{-1})	AGED(Svy^{-1})	ELCR×10^{-3}	H_{in}	H_{ex}	I_γ
1.	SND01	4.63	5.68	31.29	0.020	0.039	0.026	0.071
2.	SND02	6.51	7.92	44.16	0.028	0.059	0.039	0.097
3.	SND03	3.61	4.43	26.39	0.016	0.043	0.022	0.126
4.	SND04	10.81	13.26	37.20	0.048	0.079	0.062	0.231
5.	SND05	1.81	2.21	21.85	0.008	0.026	0.017	0.024
6.	SND06	3.62	4.44	18.67	0.015	0.025	0.016	0.053
7.	SND07	5.25	6.44	34.11	0.023	0.045	0.030	0.149
8.	SND08	3.26	3.99	22.41	0.014	0.030	0.010	0.150
9.	SND09	6.78	8.32	58.68	0.029	0.049	0.036	0.102
10.	SND10	5.75	7.05	34.62	0.025	0.051	0.033	0.090
	Mean	**5.20**	**6.37**	**32.94**	**0.023**	**0.045**	**0.030**	**0.099**

weak relationship between ^{238}U or ^{232}Th versus ^{40}K is observed across all the water samples, with correlation coefficients of 0.083 and 0.35, respectively.

The contribution of ^{238}U, ^{232}Th and ^{40}K to the absorbed dose were 56.9%, 27.2% and 15.9% respectively in water, 33.6%, 21.2% and 45.2% respectively in sediment and 71.8%, 14.2% and 14.0% respectively in soil. This showed that uranium had the highest contribution to the total absorbed dose in water and soil samples whereas potassium contributed most in sediment samples.

The radiological hazard to humans due to the radioactivity arising from radionuclide contained in all water, sediment and soils collected from the areas studied was assessed. The estimated absorbed dose rates based on water, sediment and soil radioactivity range from 0.83 to 1.98nGyh^{-1}, 1.55 to 7.63 nGyh^{-1} and 1.81 to 10.81 nGy.h^{-1} respectively. ^{238}U is the main contributor (56.9% and 71.8%of the total absorbed dose rate) to the absorbed dose rate in most of the water and soil samples measured in the current work. The effective dose for the different locations in water, sediment and soil samples in this study varied from 1.02 to 2.43, 1.90 to 9.36 and 2.21 to 13.26 μSv.y^{-1} respectively with the arithmetic mean values of 1.64, 4.73 and 6.37 μSvy^{-1}, which is far below the worldwide effective dose of 70 μSvy^{-1} (Orgun et al., 2007).

Total activity concentrations in term of the radium equivalent activity (Ra_{eq}) range from 1.26 to 4.33, 1.05 to 9.90 and 4.89 to 23.61 Bqkg^{-1} for water, sediment and soil samples with an overall arithmetic mean of 2.50Bql^{-1}, 6.04 Bq.kg^{-1} and 10.84Bqkg^{-1} respectively which are lower than the accepted safety limit value of 370 Bq.kg^{-1} as recommended by the Organization for Economic Cooperation and Development (OECD). The calculated values of the external hazard index, internal hazard index, excess lifetime cancer risk, and gamma index for water, sediment and soil samples studied were below the safe limit. The results show that the H_{ex}, H_{in}, I_γ values for water, sediment and soil samples are below the limit of unity, meaning that the radiation dose is below the permissible limit of 1mSvy^{-1} recommended by IAEA (2007). The values of the radiation hazard parameters from this current study are not extremely high compared to the

world averages and the recommended values and therefore unlikely to cause additional radiological health risks to the people living in the areas studied.

CONCLUSIONS

The level of natural radioactivity in riverbank surface soil, sediments and river water collected along the Mini-Okoro/Oginigba basin has been evaluated using high resolution gamma-ray spectrometry and the following conclusion drawn:

1. The mean activity concentration of ^{238}U, ^{232}Th and ^{40}K in water, sediment and surface soil samples were within the world permissible value of 10.0, 1.0 and10.0 Bql^{-1}, 50.0 and 500.0 $Bqkg^{-1}$ and 35.0, 30.0 and 400.0 $Bqkg^{-1}$ respectively.
2. Comparison with the previous work done on the creek shows an enhancement of all the radionuclide identified.
3. ^{238}U contributed 56.9% and 71.8% to the total dose rate in water and soil samples whereas ^{40}K has the highest (45.2%) contribution to the total dose rate in sediment samples.
4. The mean effective dose calculated in water, sediment and soil samples were 1.64, 4.73 and 6.37 μSvy^{-1} respectively and are lower than the world safe limit of 70 μSvy^{-1}.
5. The mean elemental ratios for Th / U for water, sediment and soil are 3.17±0.54, 2.33±0.02 and 1.85±0.001 respectively. For normal continental crust, the ratio of Th/U must be equal to 3 but the results showed a lower value for sediment and soil which is an indication of a depletion or enrichment of thorium due to alteration of natural processes in that area.
6. Excess lifetime cancer risk, annual gonad dose and other radiological hazard indices were within the safe limits of each and therefore the use of soil and sediment from the studied creek may not pose any immediate health hazard to the populace but for long term radiation health risk, the following recommendation were made.
    - Further studies to be carried out in the study Creek in order to determine any possible source of Uranium or thorium enrichment.
    - Further studies need to be carried out in order to allow comparison with regions in which there are no industrial effluent discharges.

REFERENCES

Ajayi JO, Adedokun O, Balogun BB (2012). Levels of Radionuclide Contents in Stream waters of some selected Rivers in Ogbomoso land, South West Nigeria. Res. J. of Environmental and Earth Sci. 4(9): 835-837.

Avwiri GO, Ononugbo CP (2012). Natural Radioactivity levels in surface soil of Ogba/Egbema/Ndoni Oil and Gas fields. Energy Science and Technology. 4(2): 92-101.

Avwiri GO, Osimobi JC, Agbalagba EO (2012). Evaluation of Radiation Hazard Indices and Excess Lifetime Cancer Risk Due to Natural Radioactivity in soil profile of Udi and Ezeagu Local Government Areas of Enugu State, Nigeria. Comprehensive J. of Environmental and Earth Sci. 1(1): 1 – 10.

Al-Hamameh IF, Awadallah MI (2009). Soil Radioactivity levels and Radiation Hazard Assessment in the Highlands of Northern Jordan. Radiation Measurements. 44: 102-110.

IAEA (2003). International Atomic Energy Agency. Radiation protection and the management of radioactive waste in the oil and gas industry: IAEA – Safety report series No 34, Vienna

IAEA (2007). International Atomic Energy Agency. Safety Glossary, Terminology used in Nuclear Safety and Radiation Protection- 2007 Edition.

Oni OM, Farai IP, Awodugba AO (2011). Natural Radionuclide concentration and Radiological Impact Assessment of Rivers Sediments of the coastal Area of Nigeria. J. of Environmental Protection. 2: 418-423.

Ononugbo CP, Avwiri GO, 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.

Orgun Y, Altisoy N, Sahin SY, Gungor Y, Gultekin AH, Karaham G, Karaak Z (2007). Natural and Anthropogenic Radionuclide in Rocks and Beach Sands from Ezine Region, Western Anatolia, Turkey.Applied Radiation and Isotopes. 65: 739-747.

OECD (1979). Organisation for Economic Cooperation and Development.Exposure to Radiation from the natural radioactivity in building materials.Nuclear Energy Agency; Paris France.

Taskin H, Karavus M, Topuzoglu A, Hindiroglu S, Karahan G (2009). Radionuclide concentrations in soil and Lifetime cancer risk due to the gamma radioactivity in Kirklareli, Turkey. J. Environmental Radioactivity. 100: 49-53.

Tzotzis M, Tsertos H (2004). A Comprehensive Study of Natural Gamma Radioactivity levels and Associated Dose Rates from Surface Soil in Cyprus. Radiation Protection Dosimetry, 109(3): 217-224.

Ramasamy V, Suresh G, Meenakshisundaram V, Gajendran V (2009). Evaluation of Natural Radionuclide content in River sediments and Excess LifetimeCcancer Risk due to Gamma Radioactivity . Res. J. of Environmental and Earth Sci. 1(1): 6-10.

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

UNSCEAR (2008).United Nations Scientific Committee on Effect of Atomic Radiation. Sources and Effect of IonisingRadiation . Report vol.1 to the General Assembly with scientific Annexes: United Nations Sales Publications,United Nations, New York.

Veiga RG, Sanches N, Anjos RM, Macario K, Bastos J, Iguatemy M, Aguitar JG, Santos MA, Mosquera B, Carvaiho C, Baptista M, Umisedo NK (2006). Measurement of natural radioactivity in Brazilizn beach sands. Radiation Measurements. 41: 189-196.

Wahid, A.S.S, Ahmad, M.G.A, Nasir, A. (1999). Water pollution and its impact on fauna and flora of a polluted stream of Lahore. ActaScientia. 9(2): 65 – 74.

WHO, World Health Organisation (2011). Guidelines for Drinking Water Quality. Fourth edition incorporating the 1st and 2nd Agenda vol.1 Recommendations; WHO Geneva.

WHO, World Health Organisation (2008). Guidelines for Drinking Water Quality in Cooperating first Addendum vol.1, Recommendations, third Edition. Radiological Aspect Geneva: World Health Organiztion.WHO Geneva.