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ASSESSMENT OF NATURALLY OCCURRING RADIONUCLIDES IN IRRIGATION WATER FROM SELECTED VEGETABLE FARMS IN LAGOS, NIGERIA.

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ABSTRACT

This study aims at evaluating the radiological impact of industrial activities on untreated surface and well water used for irrigation on different farms in Lagos, Nigeria. The concentrations of naturally occurring radioactive materials (NORM) in water used for irrigation on different farms have been determined using Sodium Iodide activated with Thallium NaI (Tl) detector. The concentrations of ^{226}Ra, ^{232}Th and ^{40}K ranged from below detectable limit (BDL) to 5.71±0.41, BDL to 6.76±0.28 Bq/l and BDL to 14.93±1.06 Bq/l respectively. The mean overall activity concentrations for ^{226}Ra, ^{232}Th and ^{40}K are 4.14± 0.16 Bq/l, 2.68 ±0.05 Bq/l and 9.10±0.15 Bq/l respectively. Mean activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in surface water are 4.25±0.13 Bq/l, 2.96±0.02 Bq/l and 9.68±0.13 Bq/l respectively. For deep well water, activity concentrations are 3.69±0.29 Bq/l, 1.57±0.05 Bq/land 6.83±0.11 Bq/l respectively. Concentrations of ^{226}Ra, ^{232}Th and ^{40}K from deep well are 87%, 53% and 71% of the concentrations from the surface water respectively. The values obtained for ^{40}K are comparable to those in the literature but the values obtained for ^{226}Ra and ^{232}Th in surface and deep well water are above the recommended safe limits. The overall mean values obtained for ^{226}Ra and ^{232}Th are about 300% and 1680% times higher than the World Health Organization (WHO) reference values for each. The long-term use of these water sources for irrigation on vegetables farms in Lagos poses potential radiological health risks to consumers of the vegetables.

Key Words: Naturally Occurring Radioactive Materials (NORM); Activity Concentration; Irrigation Water; Gamma Spectrometer.

INTRODUCTION

Radiological assessment and regular monitoring of human radiation exposure to ionizing radiation play an essential role in public and environmental health. Whereas some other industrial activities have the potential to radiologically impact the environment and consequently man, the focus of radiological safety assessment is often on the nuclear industry. All minerals and raw materials contain radionuclides of natural origin. For most human activities involving minerals and raw materials, the levels of exposure to these radionuclides may not be significantly greater than normal background levels and are not of much concern for radiation protection (IAEA, 2008). However, certain human activities can give rise to significantly enhanced exposures that may need to be controlled by regulations. Materials giving rise to these enhanced exposures have become known as naturally occurring radioactive material (NORM).

Altering geological radioactive materials from their natural setting may result in relative increase in radiation exposure and health risks to the public (Agalga *et al*, 2013). Also, it has been reported that some industrial activities and materials may contain significant quantities of NORM that may lead to an increase in activity concentrations of radionuclides and background radiation in some cases much above recommended safe level (Sanni, 1973, Avwiri and Ebeniro, 1998 and Nwankwo and Akoshile, 2005).

Over 80% of industries in Nigeria discharge untreated solid, liquid and gaseous effluents into the environment. About 18% undertake rudimentary recycling prior to disposal (Jibiri and Adewuyi, 2008). Thus, radioactive materials from industrial wastes can reach surface continental

waters by different pathways. In the long term, radioactivity in water bodies in urban areas can attain significant levels as a result of contamination and become heavily polluted (Adewuyi *et al*, 2002 and Siyanbola *et al*, 2011, Agalga *et al*, 2013). The soil can also be contaminated by radionuclides deposition either from what is originally discharged into the atmosphere, or from direct discharge of wastes to land or waterways (Abdulaziz and El-Taher, 2013). Some radiological studies carried out around different industrial areas report that there was no significant radiological health burden on the environment due to these activities. However, they were quick to note that these activities may increase the radioactivity levels with longer period of operation due to long-term cumulative effects and that radiological indices were higher from industrial areas than nearby communities (Avwiri, 2005, Olubosede, 2012, Jibiri *et al*, 2014, Usikalu *et al,* 2014).

Studies in Lagos have shown that there is gross pollution of soil, leachate and underground water due to industrial activities and that there is need for treatment of industrial effluents before they are discharged into the environment (Adewuyi *et al*, 2002, Siyanbola *et al*, 2011 and Adedosu *et al*., 2013). Lagos State is a coastal area. It is the economic and industrial nerve center of the country. The high number of industries and the large population are responsible for the large amount of wastes and environmental contamination. Further, due to the industrial status of Lagos State and pressure on land for non-agricultural purposes, there is shortage of land for farming. Farmers have resorted to swamps and some available lands close to highways to cultivate vegetables. Thus, vegetable farming in the Lagos metropolis is majorly by irrigation. Most of these irrigation sites use untreated surface water or water from shallow hand dug wells. The continuous use of these waters, with the potential of being contaminated with NORM, will elevate the concentrations of NORM in soils.

Vegetables cultivated on these soils will absorb elevated NORM, thereby augmenting the NORM intake from the consumption of these vegetables hence, posing health challenges to consumers. The aim of this study therefore, is to assess the levels of ^{226}Ra, ^{234}Th and ^{40}K in the water used for irrigation in different parts of Lagos state so as to evaluate any potential health risks from these water sources in the irrigation of consumed vegetables

MATERIALS AND METHODS

Sampling Locations

Ten different irrigation-farming locations in Lagos State were chosen for this study. These farms cultivate vegetables through irrigation. They are major suppliers to markets and shops in Lagos State. The farms are located at Iba Road (IR), Okokomaiko (OK), Dantata (DA), Idi-Araba (IA), Lekki (LK), Epe (EP), Agbowa (AG), Ikorodu (IK), Ogudu (OG) and Alapere (AL), covering Ojo, Ikorodu, Epe, Eti-Osa, Lagos mainland, Mushin and Kosofe local Government areas of Lagos State. The selected farms were bounded by latitudes ranging from 6°27′0″N to 6°40′1.2″N and longitudes ranging from 3°16′1.2″E to 3°32′60″E, at elevations range of 6 to 7 m above sea level determined by using a high sensitivity hand Global Positioning System (GPS eTrex 10 outdoor, Garmin Ltd). All of the investigated farms grow vegetables through irrigation using surface water or shallow hand dug wells (SW) except two (Ikorodu and Agbowa) locations that use deep well (DW) water.

(a) Surface water

(b) Hand-dug well

(c) Vegetable farm and surface water for irrigation.

Figure 1. Vegetable farm and sources of water for irrigation

Sample Collection and Preparation

A total of 50 water samples were collected from different water sources used at the different vegetable farms. The number of samples collected at each farm was according to the size of the farm and numbers of sources of water. Forty-four of these samples were from surface water or very shallow wells while six were from deep wells. Prior to sample collection, 750 ml polyethylene sampling bottles were washed and rinsed with distilled water and dried. Each sample bottle was filled and labeled. These were acidified by adding 0.5 ml of concentrated HNO_3 per liter, to prevent adsorption or loss of radium (Ra) isotopes around the walls of the sampling container and to prevent growth of microorganisms. Each bottle was well shaken to attain a homogenous solution. The samples were then taken to the laboratory where they were emptied into a 500 ml standard Marinelli beaker. Each beaker was filled up to brim so as to completely remove air. All samples were hermetically sealed. The samples were then stored for at least 30 days to allow ^{238}U, ^{232}Th and their progenies to reach secular equilibrium before radiometric analysis (Usikalu *et al*, 2014 and Onoja *et al*, 2014).

Gamma Spectrometry.

The radioactivity measurements were carried out using Gamma Ray Spectrometer comprising of a Canberra 76 mm by 76 mm NaI (Tl) crystal detector model No. 802-series. The detector, shielded in a thick lead blocks, was coupled to a Canberra Multichannel Analyzer (MCA) (model 2007P) through a pre-amplifier base. Operating Voltage of the detector was 600 V with a 7.5% resolution (FWHM) at 662keV peak of ^{137}Cs. The energy and efficiency calibrations of the detector were done following the International Atomic Energy Agency (IAEA) document number 385 procedure. Each sample was placed in the detector and counted for 18000s (5h) to produce good counting statistical precision (Alausa *et al*, 2014). Counting was done to determine the background radiation level in the laboratory by placing a clean empty 500ml Marinelli beaker in the detector under the same conditions as when the samples were counted. The net sample count rate at each peak was obtained after the subtraction of the corresponding background rate. GENIE-2000

software was used to analyse the spectra. Concentration of ^{226}Ra(^{238}U) was determined from the concentrations of ^{214}Bi through the 1764.5 keV gamma peak in the samples. Concentration of ^{232}Th was determined from the concentrations of ^{208}Tl through the gamma peak of 2614.7keV, ^{40}K was determined directly from its gamma peak of energy 1460.8 keV.

CALCULATION

For all samples, the corresponding activity concentrations were determined using equations 1 (Alausa et al, 2014).

$$A(Bq/l) = \frac{C}{txvx\varepsilon xP\gamma} \quad 1$$

A is sample concentration, C net count for the sample in the peak energy range, ε detector energy dependent efficiency, t counting life time in s, *Pr* gamma-ray yield per disintegration of the radionuclides (branching ratio information), v volume of the sample in litter

RESULTS AND DISCUSSION

Gamma spectrometry was used in determining the activity concentrations of three naturally occurring radionuclides (^{226}Ra, ^{232}Th, and ^{40}K). Table 1 and figures 2, 3 and 4 present the distributions of the activity concentrations ^{226}Ra, ^{232}Th, and ^{40}K of in the different farms and locations. 98% of the samples had detectable ^{226}Ra, 76% had detectable ^{232}Th. And 74% of the samples had detectable ^{40}K.

Table I: Activity concentration of natural radionuclides in all of the water samples

		Activity concentration				Activity Concentration		
Location	Source	^{40}K(Bq/l)	^{226}Ra(Bq/l)	^{232}Th(Bq/l)	Location	^{40}K(Bq/l)	^{226} Ra(Bq/l)	^{232}Th(Bq/l)
AG1	DW	1.61±0.11	1.77±0.42	0.76±0.06	ID1	BLD	1.50±0.35	0.85±0.07
AG2	DW	BLD	4.06±0.86	3.08±0.24	ID2	10.46±0.69	2.56±0.54	BLD
AG3	DW	BLD	0.31±0.07	BLD	ID3	9.53±0.69	4.06±0.90	1.10±0.10
IK1	DW	12.53±0.92	10±2.35	0.82±0.07	ID4	10.35±0.72	1.63±0.37	0.42±0.03
IK2	DW	11.57±0.77	0.93±0.19	1.86±0.15	ID5	BLD	0.49±0.13	0.45±0.04
IK3	DW	BLD	5.87±1.20	0.96±0.08	ID6	10.18±0.74	1.46±0.36	0.87±0.07
IK4	DW	BLD	4.50±1.11	BLD	OG1	18.17±1.20	BLD	BLD
DA1	SW	1.96±0.14	12.05±2.93	5.81±0.46	OG2	BLD	6.62±1.42	BLD
DA2	SW	17.21±1.23	1.37±0.30	3.08±0.25	OG3	0.50±0.04	0.22±0.04	BLD
DA3	SW	0.43±0.03	0.93±0.20	3.64±0.30	OG4	12.89±0.99	1.55±0.31	2.48±0.20
DA4	SW	16.64±1.28	7.99±1.64	4.37±0.35	OG5	15.28±1.07	7.59±1.43	4.74±0.36
DA5	SW	11.50±0.84	2.52±0.58	5.02±0.39	OG6	1.75±0.13	6.36±1.28	BLD
DA6	SW	5.86±0.40	1.19±0.28	BLD	OG7	BLD	6.98±1.53	2.03±0.17
IR1	SW	BLD	2.12±0.44	1.52±0.12	OG8	8.39±0.60	5.21±1.06	2.51±0.2
IR2	SW	21.28±1.43	9.76±2.11	3.44±0.28	LK2	11.28±0.79	5.12±1.14	1.04±0.08
IR3	SW	0.32±0.02	5.52±1.19	BLD	LK3	7.75±0.57	0.31±0.06	BLD
IR4	SW	7.21±0.51	6.53±1.42	3.70±0.29	LK4	BLD	1.19±0.25	1.98±0.16
IR5	SW	4.57±0.33	4.59±1.03	4.85±0.39	LK5	1.54±0.11	1.37±0.33	1.35±0.12
IR6	SW	5.68±0.42	7.20±1.54	2.71±0.22	LK6	20.64±1.32	0.40±0.09	1.38±0.12
IR7	SW	12.71±0.98	3.93±0.88	BLD	LK8	BLD	3.4±0.67	1.44±0.12
OK1	SW	BLD	5.74±1.16	7.59±0.60	AL1	6.11±0.46	6.89±1.53	0.48±0.04
OK2	SW	BLD	1.90±0.37	BLD	AL2	9.64±0.70	5.56±1.24	5.90±0.47
OK3	SW	14.93±1.06	9.49±0.203	5.93±0.46	AL3	8.46±0.60	0.75±0.17	0.76±0.07
EP1	SW	7.71±0.55	6.93±1.44	1.55±0.12	AL4	5.36±0.42	3.27±0.61	2.20±0.18
EP2	SW	4.39±0.32	1.10±0.25	2.68±0.21	AL5	15.25±1.10	10.69±2.20	1.13±0.09

BLD- Below Detectable Limit

SW- Surface Water

Dw- Deep well

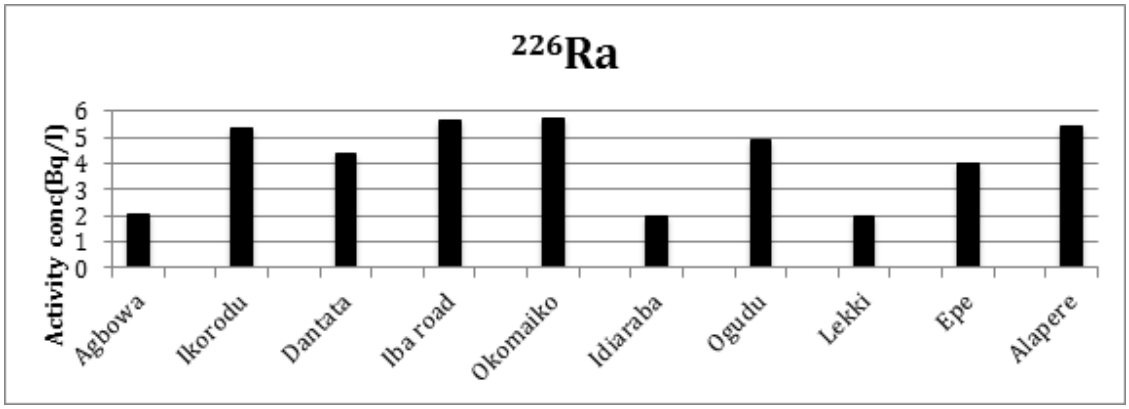

Figure 2. Distribution of ^{226}Ra in irrigation water from the studied locations

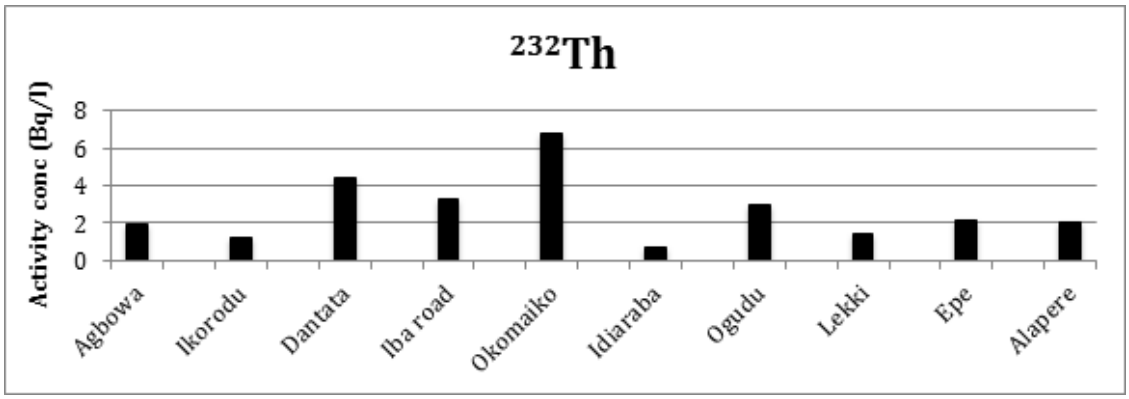

Figure 3. Distribution of ^{232}Th in irrigation water from the studied locations

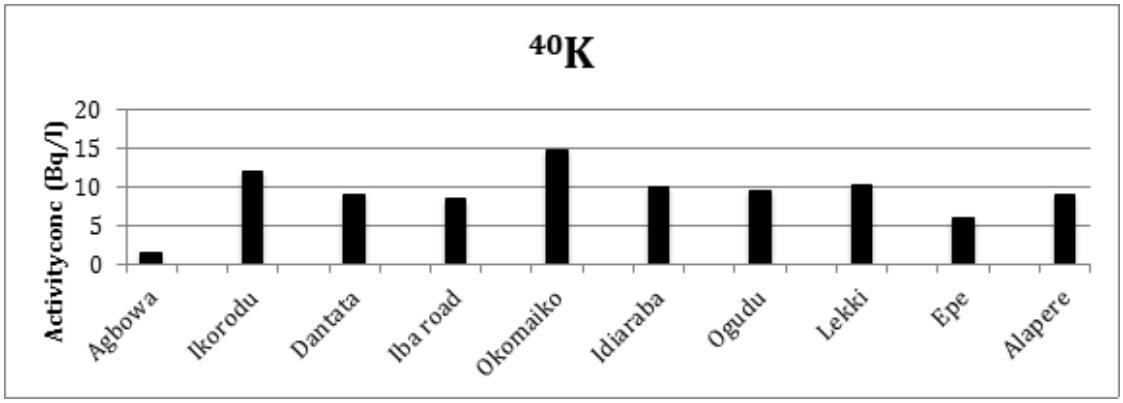

Figure 4 Distribution of ^{40}K in irrigation water from the studied locations

Table I presents the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the water samples collected in the different farms of the 10 locations of this study. The table shows concentrations from both surface water and deep well water sources.

Figures 2, 3 and 4 present the distributions of ^{226}Ra, ^{232}Th and ^{40}K in the different water sources of the different locations. The concentrations of the natural radionuclides vary from one location to the other. The highest concentrations of ^{226}Ra, ^{232}Th and ^{40}K were recorded from Okokomaiko. The lowest concentrations of ^{226}Ra and ^{232}Th were obtained from Idi Araba while Agbowa had the lowest concentration of ^{40}K. The high concentrations of the natural radionuclides could be attributed to the presence of a metal scrap dump located close to the some of the farms in Okokomaiko.

Table II: Mean activity concentrations of radionuclides from the different locations and different water sources

LOCATION	ELEVATION (m)	LATITUDE (^{0}N)	LONGITUDE (^{0}E)	^{226}Ra(Bq/l)	^{232}Th(Bq/l)	^{40}K(Bq/l)
Agbowa	28	6.667	3.717	2.05±0.32	1.92±0.12	1.61±0.11
Ikorodu	37	6.652	3.520	5.33±0.72	1.21±0.06	12.05±0.60
Dantata	10	6.457	3.267	4.34±0.39	4.38±0.16	8.93±0.39
Iba road	13	6.467	3.207	5.66±0.50	3.24±0.12	8.63±0.31
Okokomaiko	9	6.483	3.183	5.71±0.41	6.76±0.28	14.93±1.06
Idi Araba	12	6.517	3.353	1.95±0.73	0.74±0.12	10.13±0.32
Ogudu	6	6.583	3.400	4.93±0.20	2.94±0.03	9.50±0.36
Lekki	7	6.450	3.550	1.97±0.43	1.44±0.10	10.30±0.33
Epe	9	6.667	3.551	4.02±0.29	2.12±0.05	6.05±0.41
Alapere	6	6.589	3.399	5.43±0.60	2.09±0.10	8.96±0.31
Deep Well				3.69±0.29	1.57±0.05	6.83±0.11
Surface Water				4.25±0.13	2.96±0.02	9.68±0.13
Range				BLD -5.71±0.41	BLD – 6.76±0.28	BLD -14.93±1.06
Overall Mean				4.14±0.16	2.68±0.05	9.10±0.15
Reference Value				1.00	1.00	-

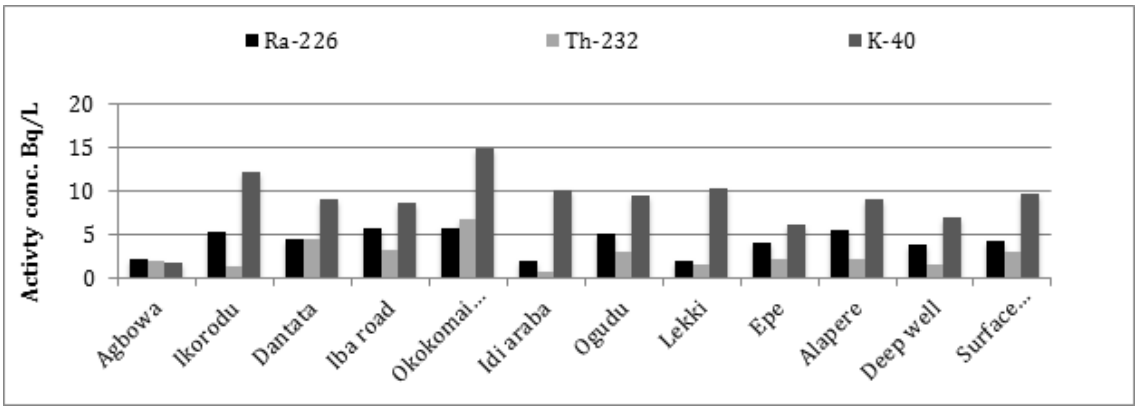

Figure 5. Distributions of natural radionuclides in the studied locations

Table II presents the elevations, latitudes, and longitudes of the farms locations for traceability. Together with figure 5 the mean activity concentrations of the studied NORM in the 10 farm locations of this study are presented.

The mean values of concentrations of natural radionuclides (^{226}Ra, ^{232}Th and ^{40}K) for deep well water were 3.69±0.29, 1.57±0.05 and 6.83±0.11 Bq/l while the concentrations in surface water were 4.25±0.13, 2.96±0.02 and 9.68±0.13 Bq/l respectively. The concentrations of natural radionuclides in deep well water are lower than the results obtained for the surface water. This suggests that surface water sources are prone to more contaminations from industrial wastes, which, could result from the contamination from wastewater run off. The discrepancy however, in the concentrations obtained from the two locations using deep well (Ikorodu and Agbowa) suggests that concentrations of radionuclides in water do not only depend on the source but on other factors such as the industrial or human activities. Ikorodu is a location with many industrial activities such as: paints-making, building and construction materials, steel and metal milling, metal recycling compared with Agowa which is farther from industrial activities.

The activity concentrations for ^{226}Ra, ^{232}Th and ^{40}K ranged from BDL to 5.71±0.41 Bq/l, BDL to 6.76±0.28 Bq/l and BDL to 14.93±1.06 Bq/l respectively. The overall mean concentrations were 4.14±0.16 Bq/l, 2.68±0.05 Bq/l and 9.10±0.15Bq/l for ^{226}Ra, ^{232}Th and ^{40}K respectively. The values obtained from surface water and deep

wells were higher than the reference values for WHO ^{226}Ra and ^{232}Th, which is 1 Bq/l for each. The overall mean values for ^{226}Ra and ^{232}Th are about 300% and 168% higher than the reference values of the WHO respectively.

Table III. Comparison of the levels of natural radionuclides in water obtained in this study with those from literature

Region	Source	^{226}R (Bq/l)	^{232}Th(Bq/l)	^{40}K(Bq/l)	Reference
Ondo-Nigeria	Sachet water	7.75	ND	19.09	Ajayi and Adesida, 2009
Ghana	Well water	-	0.394	2.589	Nguelem et al, 2013
Finland	Dug well	0.02	-	-	Vesterbacka, 2007
	Drilled well	0.05			
Bangladesh	Industrial	1.49± 0.93	0.94±0.48	ND	Jahan et al, 2016
Selanngor	River – Estuary	0.17-0.67	0.69±1.14	1.22-5.57	Hamzah et al, 2014
Egypt	Red sea coast	1.67±0.92	0.078±0.22	13.69±0.77	Arafat et al, 2017
Yemen	Irrigation	1.4400	1.2000	18.3400	Harb et al, 2014
Saudi Arabia	Irrigation	1.12±0.07	-	-	Alkhomashi et al, 2016
Lagos	Irrigation	4.14±0.16	2.68±0.05	9.10±0.15	Present study
Reference Value		1.00	1.00		WHO, 2011

Table III presents a comparison of the obtained concentrations obtained from this study with the literature. Mean activity concentrations of ^{40}K obtained from this study was higher that the values reported by Nguelem *et al*, 2013 and Hamzah *et al*, 2014 but lower than the values reported by Ajayi & Adesida, 2009, Harb *et al*, 2014 and Arafat *et al*, 2017. The results obtained for ^{232}Th and ^{226}Ra in this study were higher than those of other studies except the result of ^{226}Ra from the study of Ajayi and Adesida, 2009. Although the study was not based on the direct absorbed dose from the consumption of water through drinking, contaminated water has indirect effects on the food chain and food security and consequently on human health. The health risks related to long-term exposure to radionuclides through ingestion of contaminated food range from muscular weakness, paralysis, kidney disease, cardiovascular disorder, chromosomal aberrations, leukaemia, cancers and death.

CONCLUSION.

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in 50 water samples from 10 different vegetable farms in Lagos have been determined. The overall mean activity concentration of ^{40}K has been found comparable to the literature. The concentrations of ^{226}Ra and ^{232}Th in the sampled water sources were however, higher than the WHO reference values. The obtained value for ^{226}Ra is also higher than the results obtained from the literature. The results from this study reveals that both surface water and deep well water used for irrigation in Lagos have elevated concentrations of ^{226}Ra and ^{232}Th that are above the recommended safe limits. The use of these water sources therefore, has potential radiological health risks for the consumers of vegetables cultivated through irrigation in Lagos. It is therefore, recommended that clean uncontaminated water should be used for agricultural activities because the continuous use of contaminated water will increase radioactivity level in soil which will in turn increase the concentrations of NORM in vegetables. Routine surveillance should also be carried out to detect major changes in the environmental radioactivity level due to continuous industrial activities as radionuclides accumulate over time.

CONFLICTS OF INTEREST

There are no conflicts of interest.

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