RADIOACTIVITY IN LAUTECH WATER SUPPLIES, NIGERIAA

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Abstract

In this work, the radionuclide contents of the water supplies in the Ladoke Akintola University of Technology, Ogbomoso, Nigeria, (LAUTECH) environment have been measured by means of gamma spectrometry. The sampling indicated that groundwater (both through boreholes and dug wells) is the main source of the water supplies in this environment. The data obtained from the samples of the water supplies measured show that the radionuclides identified in the samples belong to the natural radionuclide series headed by ^{226}Ra and ^{228}Ra and the singly occurring radionuclide ^{40}K. The activity concentrations vary from 0.33 $Bqkg^{-1}$ for ^{226}Ra to 802 $Bqkg^{-1}$ for ^{40}K. These values fall within natural background radioactivity levels. The dose due to the activity concentrations in the water supplies was also estimated The data obtained show that the total dose rates vary from 0.100 $mSvy^{-1}$ to 14.372$mSvy^{-1}$. *The data obtained in the work would serve as baseline data of radioactivity levels for water in the LAUTECH environment.*

Key words: *Water supplies, radioactivity, LAUTECH and dose.*

1. Introduction

The importance of water to human well-being cannot be over-emphasized, since water is essential to the normal functioning of the human body. Water in the body serves as solvent that promotes chemical activity, transportation medium for nutrients, hormones, enzymes, minerals, nitrogenous wastes and respiratory gases as well as several other important functions. The provision of clean (safe) drinking water is therefore essential. Radiation from natural sources gives more than 80% of the total exposure received by the average member of a population and a portion of this comes from dietary intake. Water an essential part of this intake is considered a potentially highly variable and significant source of radionuclide ingestion (Harley, 1988). A number of the dietary estimates reported (Harley, 1988) give water intakes generally not more than 10% of the diet. This has been attributed to the low concentrations in the surface water supplies used by most large population groups. However concentrations are always higher in groundwater supplies and the most highly contaminated supplies are used by smaller groups. Groundwater, like water in a sponge, is held in the ground.

They are held generally, in open spaces called pores within, the soil and rocks. The use of groundwater through borehole and dug wells has become increasingly popular in the study site because of the inadequate supply of treated surface water from dams. However, in most cases, groundwater is not treated before human use, and since there are naturally-occurring and artificially released radionuclides in soils and rocks, the tendency is for groundwater to contain a certain concentration of radionuclides depending on their solubility in water. In any case, treatment of groundwater before use reduces immensely the concentrations of these radioactive elements, thereby enhancing its "useability". There are two main year-long sources of water available for human consumption in Nigeria and in the study area. They are pipe-borne water supply, derived from treated surface water and groundwater supply which is the main focus of this study. The most significant naturally-occurring radionuclides in water include, Radium-226 (^{226}Ra), Radon-222 (^{222}Rn), Polonium218 (^{218}Po) and Potassium40 (^{40}K). Of all these, it is well established that radium, whose chemical properties are similar to those of calcium which make it easily absorbed into human body, is of major concern as a source of dietary contamination and consequently of internal radiation to man (UN, 1962).The concentrations of radionuclides in water could also become very significant, if the efficient uptake of ^{226}Ra from water as postulated by Lucas (1960) is correct and if it extends to other radionuclides of interest. Ionizing radiation from natural sources has always been part of the human environment and that from artificial sources since the beginning of the 20th century. Although, both the benefits of controlled exposure for medical purposes and the catastrophic effects of large doses of radiation (for example those received by the inhabitants of Hiroshima and Nagasaki, in 1945) are well understood, what is less clear is the effect of small doses on the general public. In order to determine their effects knowledge of the actual source strength, pathways and cycling of radioactivity through the environment and their flux rate and the possible rates of exposure for man is required. According to UNSCEAR (2000) an average radiation dose of 0.29 mSv.y^{-1} is received worldwide via ingestion of the natural radionuclides of ^{238}U and ^{232}Th during habitual consumption of food and water. Water quality is determined by the concentration of biological, chemical and physical contaminants. Biological contaminants result from human and animal wastes plus some industrial processes. Chemicals enter the water supply from industrial processes and agricultural use of fertilizers and pesticides. Physical contaminants result from erosion and disposal of solid wastes. All these sources contribute to degradation of water quality. In view of the above, it is essential to investigate the different sources of water available for human use in order to identify the radionuclides present and determine their concentrations so as to be able to estimate the contribution of water consumption to the radionuclide intake of man.

Thus, in this study, the radionuclide contents of the water supplies available for the use of the Ladoke Akintola University of Technology, Ogbomoso (LAUTECH) community were determined,in addition an estimate of the corresponding doses to people consuming the water is presented. The data obtained in this work would serve as baseline data of radioactivity levels for the water supplies in the LAUTECH campus environment. They would also provide a basis for assessment of the radioactivity levels in the event of an elevated background radiation or contamination of the water supplies which may result from accidental releases of radioactive materials into the environment.

2. Sampling

The study was conducted over the LAUTECH campus environment, both within and around the immediate physical environment of the university. The study site is located in Ogbomoso town in the South-Western part of Nigeria and details of its location, climate, relief, as well as geology of the area had previously been discussed (Akinloye et al., 2002). A total of five (5) sampling locations comprising three (3) boreholes and two (2) shallow wells were selected based on population distribution and degree of usage. The above sources of water supplies serve staff and students as well as their dependants and other members of the public who reside around the LAUTECH environment as well as some residents of the town, Ogbomoso, who obtain their water supply from the boreholes located in LAUTECH environment. The population which these water supplies serve would therefore amount to close to half of the population of the town which is about 300,000.

3. Sample Collection and Preparation

The water samples obtained from the dug wells using clean containers were collected directly from the wells employing the usual manual procedure for collection by the local users. This involved dipping the container which had been firmly tied to a rope long enough to reach the water level in the well. The rope is spinned such that the open end of the container goes down first, so that water rushes into it and it is pulled up when it is full. Before collecting water from the borehole, the faucet was first turned on at full speed for several minutes to purge the plumbing system of any water which might have been there for some time.

The faucet was thereafter turned down to a low flow rate to reduce turbulence and, thus, reduce radon loss during the collection directly from the faucet (Kent and Watson, 1978). The samples of water collected in each case described above were transferred into 2.5L kegs and they were immediately acidified at the rate of 10ml of 11M HCl per litre of water. This is required in order to prevent adsorption of radionuclides onto the walls of the containers (IAEA, 1989). Four samples of 250ml capacity were prepared from the water collected from each source. Thus a total of twenty (20) samples were prepared. The samples were transferred into containers which had been thoroughly washed with dilute H_2SO_4, rinsed with distilled water and dried. Each container was firmly sealed and left for a period of 28d in order to allow for the buildup of radon and radon daughters in the ^{226}Ra and ^{228}Ra decay series and thereby establish a state of secular radioactive equilibrium before their gamma spectrometry measurements commenced.

4. Measurements, Estimation of Concentration of Radionuclide and Analysis

The method applied for the measurement of the radionuclide concentrations was the passive gamma spectrometry using a well-shielded and well-calibrated $2^1/_2$ x $2^1/_2$ NaI(Tl) detector model 3M3/3, serial number Ff669 coupled to a photomultiplier model PA14, serial number AG472; both products of Bicron Corporation United, States of America. The detector was connected to a Canberra Multichannel Analyser (MCA) which was housed in an IBM personal computer. The gamma spectrometry system is located in the environmental laboratory of the Department of Physics, Obafemi Awolowo University, Ile-Ife, Nigeria. The sealed samples after attaining a state of secular radioactive equilibrium were each placed on the NaI (Tl) detector and counted for a period of 36000s. An empty container of identical geometry as the samples was also counted for the same period to obtain the background gamma-ray spectrum distribution The most prominent gamma energies observed in the spectra belonged to the naturally-occurring radionuclides ^{226}Ra, ^{228}Ra and their progenies as well as that of ^{40}K. Other nuclides if present occurred at levels below the minimum detectable limit or appeared at low levels. The γ-energies used for estimation of the radionuclide concentrations were 609.31 keV of ^{214}Bi for ^{226}Ra and 583.19 keV of ^{208}Tl for ^{228}Ra. The 1460.75 keV of ^{40}K was used to estimate the activity concentration of ^{40}K. The characteristics of these monitor lines are as listed in Akinloye (1998) and presented in Table 1. The specific activity for each nuclide determined at 2-standard deviation analytical error was calculated on the basis of a mean value of the four samples of water obtained from each Source.

In order to calculate the concentrations of the radionuclides, the detector was calibrated using an International Atomic Energy Agency (IAEA) multienergetic γ-standard source with an identical geometry as the water samples. Each radionuclide concentration, C in each water sample was calculated based on the detector efficiency and energy calibration measurements in the energy range from 100 to 1500 keV using the expression:

$$C = \frac{N(E_\gamma)}{\varepsilon(E_\gamma) I_\lambda V t_c} \text{ Bq l}^{-1} \quad (1)$$

where $N(E_\gamma)$ = net peak area of the radionuclide of interest

$\varepsilon(E_\gamma)$ = efficiency of the detector for a γ-energy of interest

I_γ = intensity per decay for the γ-energy of interest

V = volume of the water sample

t_c = total counting time in seconds (36,000 s)

Table 1: Characteristics of the monitor radionuclides

	Energy (keV)	Iγ
Bi-214 (^{226}Ra)	609.31	0.433
Tl-208 (^{228}Ra)	583.19	0.8577
K-40	1460.75	0.107

Table 2: Radionuclide concentrations in the water samples

Radionuclide	Concentration (Bq /l)				
	Borehole			Dug well	
	Yoaco Hostel	Lesbora Hostel	Health Centre	Underg Hostel	Canaan Hostel
Ra-226	4.20±0.29	2.39±0.18	0.33±0.02	16.24±0.58	-
Ra-228	3.80±0.13	4.32±0.15	3.05±0.10	15.24±0.49	6.44±0.20
K-40	712.52±66.98	802.82±75.23	528.08±48.86	788.44±66.00	730.47±62.00

5. Estimation of Dose

Estimates of the radiation doses corresponding to the radionuclide concentrations in the water samples analyzed were carried out using the relation (Fatima *et al.*, 2006).

$$D_W = wC_W C_{RW} D_{CW} \quad (2)$$

where

D_W = annual effective dose in Svy^{-1} due to ingestion of radionuclide

C_W = activity concentration of radionuclide in the water in Bql^{-1}

C_{RW} = annual intake of drinking water ly^{-1}

D_{CW} = ingested dose conversion factor for radionuclide in $mSvBq^{-1}$

w = age dependent weighting factor

The C_{RW} and D_{CW} values used for the calculations were taken from the Institute of Water Studies guidelines for domestic water use (IWS, 2002) for ^{226}Ra and ^{228}Ra while those used for ^{40}K were taken from Fredj *et al.* (2005). The values used of the weighting factors (w) were taken from the Institute of Water Studies guidelines for domestic water use (IWS, 2002). The age dependent values of C_{RW}, D_{CW} and w are presented in Table 3 while the estimated D_W values are presented inTable 4

Table 3: C_{RW}, D_{CW} and w values

Radionuclide		D_{CW} (SvBq^{-1})		
	Age range	< 1 y	2 – 7 y	> 17y
^{226}Ra		4.7×10^{-6}	6.2×10^{7}	2.8×10^{-7}
^{228}Ra		3.0×10^{-5}	3.4×10^{6}	6.9×10^{-7}
^{40}K		6.2×10^{8}	2.1×10^{8}	6.2×10^{-9}
	C_{RW} (ly^{-1})	200	300	730
	Age dependent weighting factor, w	1.4×10^{-2}	7.1×10^{-2}	7.6×10^{-1}

6. Results and Discussion

The average activity concentrations of the naturally-occurring radionuclides obtained for the water samples analysed in this work are shown in Table 2. The results show that ^{40}K made the largest contribution to the specific activities in all the water samples with concentrations ranging from 528.07 to 802.80 Bq l^{-1} with an average of 712.47±143.21 Bq l^{-1}. The average activity concentrations obtained for the series radionuclides headed by ^{226}Ra range from 0.33 to 16.24 Bq l^{-1} with an average of 5.79±1.40 Bq l^{-1}. While the concentrations obtained for the series radionuclides headed by ^{228}Ra range from 3.05 to 15.24 Bq l^{-1} with an average of 6.57±0.87 Bq l^{-1}. However, the ^{226}Ra concentrations in the water samples obtained from the well located at Canaan hostel were below detectable limit.

These results when compared with reported values (Cothern et al., 1986; Marc et al., 1991 and Tchokossa, 1998) are found to be within the same range, and indicate radioactivity levels for normal radiation background area. The results of a previous survey of the radioactivity levels in soils in the LAUTECH environment also show that the radionuclides which occurred with regularity in the soil samples belong to the natural radionuclide decay series headed by ^{238}U and ^{232}Th as well as the singly occurring radionuclide ^{40}K (Adeniran, 1997). No man-made radionuclide was detected in the soil samples, also no manmade radionuclide was detected in the water samples analysed.The quality of water has been described in terms of five water quality classes which represent ranges of annual dose for daily use of specific water source, associated health effects and typical exposure scenarios (IWS, 2002). Table 5 presents this description. The data obtained show that the total dose rates vary from 0.100 mSvy^{-1} to 14.372mSvy^{-1}. The data when analysed according to the classification shown in Table 5 shows that the water samples fall within classes 1 and 2 of good quality water and marginal quality water respectively. This means that periodical monitoring of the water sources is required.

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Table 4: Estimated dose rates ($mSvy^{-1}$)

Radionuclide	Age range	Dose rate ($mSvy^{-1}$) Borehole: Yoaco Hostel	Borehole: Lesbora Hostel	Borehole: Health Centre	Dug well: Underg Hostel	Dug well: Canaan Hostel
^{226}Ra	< 1	0.055±0.004	0.032±0.002	0.043±0.002	0.214±0.008	-
	2 – 7	0.055±0.003	0.032±0.002	0.004±0.001	0.214±0.008	-
	> 17	0.654±0.045	0.342±0.030	0.053±0.004	2.523±0.091	-
Total dose		0.764±0.052	0.406±0.034	0.100±0.007	2.951±0.107	-
^{228}Ra	< 1	0.319±0.011	0.363±0.013	0.256±0.008	1.280±0.041	0.541±0.017
	2 – 7	0.275±0.009	0.313±0.011	0.221±0.007	1.104±0.035	0.466±0.014
	> 17	1.452±0.053	1.657±0.053	1.170±0.038	5.834±0.190	2.462±0.076
Total dose		2.046±0.073	2.333±0.077	1.647±0.053	8.218±0.266	3.469±0.107
^{40}K	< 1	0.124±0.012	0.139±0.013	0.092±0.008	0.137±0.011	0.127±0.011
	2 – 7	0.319±0.030	0.359±0.033	0.236±0.026	0.353±0.030	0.327±0.028
	> 17	2.455±0.228	2.759±0.258	1.816±0.167	2.713±0.228	2.516±0.213
Total dose		5.708±0.395	5.996±0.369	3.891±0.261	14.372±0.702	6.439±0.359

Table 5: Different ranges of water quality (IWS, 2002)

Class	Dose range mSv/a	Health effects and typical exposure scenarios	Intervention decision and time frames
0 Ideal water quality	0.01 – 0.1	• There are no observable health effects • This is the range of exposure from ideal quality water sources • Most treated water falls in this water quality range • Additional doses that result from human activities that fall within this range are difficult or impossible to determine and/or to distinguish from variations in background doses with sufficient confidence.	Intervention not applicable for this class of water
1 Good water quality	> 0.1 – 1	• There are no observable health effects. • It is the range of exposure from some natural and untreated water sources (e.g. groundwater/wells) as well as water sources that could be influenced by mining and mineral processing activities. • A dose between 0.2 to 0.8 mSv/a is the typical worldwide range of ingestion radiation dose resulting from water as well as food. • A dose equal to 1 mSv/a corresponds to the regulatory public dose limit for human activities involving radioactive material.	No intervention is required although ALARA principles apply.
2 Marginal water quality	> 1 – 10	• A small increase in fatal cancer risk associated with this range. • Probably only a small number of natural water sources of this quality exist resulting from exceptional geological conditions.	Intervention considerations within 2 years
3 Poor water quality	> 10 – 100	• Health effects are statistically detectable in very in very large population groups. • This range represents excessive exposure. • It is highly unlikely to find water of this poor quality in the natural environment.	Intervention is required in less than 1 year
4 Unacceptable water quality	> 100	• Health effects may be clinically detectable and a significant increase in the fatal cancer risk (greater than one in a thousand). • A dose greater than 100 mSv can usually only occur during a major accident at a nuclear facility. These facilities have to demonstrate that such an accident cannot happen with a frequency of more than once in a million years	Immediate intervention is required

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