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Determination of gross Alpha and Beta and to calculate $AEDE_{(\alpha \text{ and } \beta)}$, $AGDE_{(\alpha \text{ and } \beta)}$, $ELCR_{(\alpha \text{ and } \beta)}$ around Kaduna metropolis

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Abstract
A survey of the gross alpha and beta radionuclide activity of source of water from ground water kaduna state has been carried out. Ten water samples were collected from the residential in the community and were analyzed using the protean instrument corporation (PIC) MPC 2000DP, single channel proportional counters. The count results show that the mean alpha activities in the residential shows the value of gross alpha concentration (Bq/L) obtained from lowest to highest for CES is 0.0008±0.0001 to Zamfara R 0.09±0.01. While the value of gross beta concentration (Bq/L) for CRESCENT R from lowest to highest were obtained to be in the region of CRESCENT R 0.004±0.013 to BYE PASS 2.97±0.48 Three radiological parameters, which are annual effective dose equivalent (AEDE), the annual gonadal dose equivalent (AGDE) and the excess lifetime cancers risk (ELCR). were all determined. Where the excess lifetime cancer risk is the probability of developing cancer over a lifetime at a given exposure level. We are assuming 70years as the average duration of life for human, the summation of the results gotten are; $AEDE_{(\alpha \text{ and } \beta)}$ *0.0649/4.8729mSv/y,* $AGDE_{(\alpha \text{ and } \beta)}$ *0.1623/14.3961mSv/y and* $ELCR_{(\alpha \text{ and } \beta)}$*2.4465 /0.01202 respectively. The overall results show that the alpha and beta activities in the community are far below the practical screening levels of radioactivity in drinking water of 100 Bq* L^{-1} *for alpha and 100 Bq* L^{-1} *for beta recommended by ICRP and WHO and therefore may not pose any serious detrimental health side-effects to the public users of water in that environment.*

Keywords: gross α, and β, proportional counters, $AEDE_{(\alpha \text{ and } \beta)}$, $AGDE_{(\alpha \text{ and } \beta)}$, $ELCR_{(\alpha \text{ and } \beta)}$

Introduction
Gross alpha is more of a concern than gross beta for natural radioactivity in water as it refers to the radioactivity of Th, U, Ra as well as Rn and daughter isotopes, (WHO, 2011). For anthropogenic radioactivity, gross alpha may pertain to screening for transuranics in wastes, while gross beta to screening for fission products in accidental reactor releases (Semko and Parekh, 2000). ICRP and WHO in 2011 recommended a standard practical screening level of radioactivity in drinking water of 100 Bq L^{-1} for alpha and 1000 Bq L^{-1} for beta (Cothern and

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Lappensbush, 2014). The survey of the gross alpha and gross beta radioactivity in well water in Zaria and reported an average alpha activity of 6.35±0.45 and 75.34±1.53 Bq L^{-1} for beta activity (Onoja, 2004). Also the measurement of gross alpha and beta radioactivity in River Kaduna was reported to be in the range of 0.117±0.002 and 0.439±0.006 Bq L^{-1} for alpha and beta activity, respectively (Juliet, 2006). The overall results in the two separate research work show that both alpha and beta activities are below the WHO and ICRP practical screening level of radioactivity in drinking water.

Radionuclides are found in air, soil, water and plant. Every day, we ingest/inhale nuclides in the air we breathe, in the food we eat and the water we drink. Radioactivity is common in the rocks and soil that makes up our planet, in the water and oceans and even in our building materials and homes. It is just everywhere, there is no where on earth that one can get away from natural radioactivity soil acts as a source of transfers of radionuclides through the food chain depending on their chemical properties and the uptake process of the root to plants and animals; hence, it is the basic indicator of the radiological status of the environment. These radionuclides take part in several biogeochemical processes that determine their mobility and availability for biological updates. The major potential hazard from the natural radiation is from external exposure either by direct exposure to soil or as they enter in many building materials. Vegetables may be subjected to direct and indirect contamination of uranium series radionuclides. Use of fertilizers leads to elevation of uranium series, nuclides of thorium and uranium are the significant contributors of ingestion dose and are present in the biotic system of plants, animal, soil, water, air and thus food. Water contains a number of both alpha (such as ^{238}U, ^{226}Ra and ^{240}P) and beta emitters (such as ^{40}K, ^{228}Ra and ^{210}Pb). Natural radioisotopes as ^{40}K and the nuclides from the ^{228}U and ^{232}Th series are the greatest source of internal and external exposure in human beings. Many of these radionuclides exist only in trace amounts in nature, including all cosmogenic nuclides. Secondary radionuclides will occur in proportion to their half-lives, so short-lived ones will be very rare. For example, polonium can be found in uranium ores at about 0.1 mg per metric ton (1 part in 10^{10}). Further radionuclides may occur in nature in virtually undetectable amounts as a result of rare events such as spontaneous fission or uncommon cosmic ray interactions (WHO 2012).

Materials and Method

The following laboratory apparatus were used for this analysis of gross alpha, gross beta
APPARATUS: Laboratory beakers, petri-dishes, Hot plate, infra-radiator lamp, Experimental (Digital) weighing balance, planchets, cotton wool GPS map, 2litres of container keg (10pieces), fume cup board.
REAGENTS: Acetone, vinyl acetate and Nitric acid.

Sampling Method

Random sampling method was used for this study. Ten (10) water samples were collected from underground water sources (1) Zanfara Road Housing Estate Barnawa (2) Mallam Madori (3) Bye Pass Housing Estate Bungalow (4) Crescent road Housing Estate (5) Lemu Road (6) CASS Bye Pass (7) Panteka Housing Estate (8) Byepass Housing Estate Block of flats (9) CES Barnawa (10) Enugu Road.
All samples were collected in Kaduna metropolis area.

Methodology

The following procedures were carefully carried out during the collection and preparation of the samples:

Samples of water were collected directly into 2 liter plastic kegs (polyethylene containers) after washing the containers properly and rinsed with the water sample to be collected. About 10ml of concentrated hydrochloric acid (HNO_3) was added at the point of collection. The addition of concentrated HNO_3 help preserve the radionuclides present in the water samples and it also prevent the absorption of the water with the inner wall of the containers among others. The addition of HNO_3 assists in reducing the pH of the water samples below 2 (ICRP,2017). Surface water from borehole and pond within the area were collected and treated with the reagent. Care was taken to avoid fetching from the stagnant areas. Lake water samples (if there is any) should not be taken near the shoreline (W.H.O., 2012). Normally for bore-holes; electric pumps are used to pump water to the reservoir which is connected to different pipes and taps within the community. The tap boreholes were first turned on at full capacity for three (3) minutes to purge the plumbing system of any water which might have been there for some time. The flow rate was reduced to attain steady turbulence and radon loss while collecting the water into the kegs.

The water samples were transferred to CERT, ABU Zaria in clean condition where they were prepared and analyzed for gross alpha (α) and gross beta (β) activities. Ten (10) water samples were collected from underground water sources. These samples were kept in a plastic container and covered properly. The samples were analyzed at the Centre for Energy Research and Training (CERT), ABU Zaria, Kaduna state as stated above.
10ml of concentrated nitric acid were added to the water sample immediately after collection so as to: Reduce the pH, Minimize precipitation and Prevent the absorption on the wall of the container.

Procedure

The beakers, crucibles (petri-dishes), planchets and spatula were washed properly, rinsed with clean water and sterilized using acetone. Then the apparatus were kept and dried inside the oven. A little quantity of the water sample was used to rinse the beaker twice so as to ensure that there is no cross contamination before evaporation. About 500ml of the water sample was measured into the beaker and set on the hot plate with steady temperature below boiling point to allow gradual evaporation and to avoid excessive loss of the residue. This process continues until when the volume of the water sample reduced to a very little quantity (about 50ml), then it will be transferred into the petri-dish and evaporated to dryness under infra-radiator lamp. This process is known as surface drying. Having taking the initial weight (i.e empty dish), the weight of the residue together with petri-dish was measured using digital analytical weighing balance. The weight of the total residue obtained from the total volume evaporated was then calculated by using the relation below.

$$W_r = W_{(d+s)} - W_d \quad (2.1)$$

Where: $W_{(d+s)}$ is the weight of the dish with sample's residue,
W_d is the weight of empty dish
W_r is the weight of the total residue.
0.0770g of the residue is transferred in the sterilized planchet and the exact volume that produced this required weight (0.0770g) is calculated by the use of the expression that follows.

$$0.0770g \times V_{tr} = W_{tr} \times V. \quad (2.2)$$

Where: V_{tr} is the volume that generated total residue,
W_{tr} is the weight of the total residue obtained
V is the volume that yielded the required residue.
For samples with residue obtained greater than or equal to 0.0770g, the sample efficiency is said to be 100%. But for the samples with residue less than 0.0770g, its sample efficiency can be obtained using the expression below;

Sample eff. = $\frac{weight\ of\ residue}{0.0770g}$ X 100%. (2.3)

Sample Analysis

The international standards organization procedure (ISO 9696 and ISO 9697: 2014E) for the measurement of gross alpha (α) and gross beta (β) activities in water was employed in this analysis. This method provided a screening technique to measure the gross alpha (α) and gross beta (β) radioactivity in water samples. To analyze drinking-water for gross alpha (α) and gross beta (β) activities (excluding radon), the most common approach is to evaporate a known volume of the sample to dryness and measure the activity of the residue. As alpha (α) radiation is easily absorbed within a thin layer of solid material, the reliability and sensitivity of the method for alpha (α) determination may be reduced in samples with high total dissolved solids (TDS) content.

Samples analysis was done using a proportional counter system; a portable non filled gas MPC2000B-DP single channel gross alpha and gross beta radiation detector. The equipment was mainly designed purposely for gross alpha (α) and gross beta (β) counting. Each sample was placed on the detector and counted for 2700 seconds (45 minutes).

Result and Discussion

The Three Radiological Parameters

There are 3 radiological risk parameters. These include the annual effective dose equivalent (AEDE), the annual gonadal dose equivalent (AGDE) and the excess lifetime cancers risk (ELCR).

The Annual Effective Dose Equivalent Is Given By the Relative

AEDE = A (α, β) x Wc x F.D ---------- 1

Where A (α, β) = activity concentrations of gross alpha and gross beta in Bq/L

WC= water consumed by a person in a year. (For an adult it is approximately 2litre a day, which is approximately to 730L in a year)

F.D (α,β) = activity to dose conversion factor for gross alpha and gross beta radiations

It is assumed that the major contribution to AEDE due to ingestion of water from gross alpha radiation is radium – 226 and the major contribution to gross beta are pb – 210 and radium – 228. Activity dose conversion factor F.D for radium 226 is 2.8 x 10^{-4} $mSvy^{-1}$ for gross alpha radiation for radium 228 and pb – 210, dose conversion factor F.D = 6.7 x 10^{-4} $mSvy^{-1}$ for beta radiation.

The AEDE for gross alpha and gross beta radiation of sample ID fils with alpha activities 0.0041Bq/L and beta activities 0.3554 Bq/L is given usiing equation 1 and are calculated as follows

AEDEα for Underground water samples

AEDEα = A (α) x WC x F.D

0.0041Bq/L x 730 x 2.8 x 10^{-4} $mSvy^{-1}$ (assuming WC = 730L per year)

=8.3804 x 10^{-4}mSv/y^{-1}

AEDEβ (Beta) for Underground water

AEDEβ = A (β) x WC x F.D

0.03554 x 730 x 6.7 x 10^{-4}mSv/y

= 0.1738$mSvy^{-1}$

Table 1 shows the tabulated result of AEDE for gross alpha & gross beta radiation of all samples

S/N	Sample ID	Alpha Concentration (Bq/L)	AEDEα ($mSvy^{-1}$)	Beta Concentration (Bq/L)	AEDEβ ($mSvy^{-1}$)
1.	ZANFARA ROAD HOUSING ESTATE BARNAWA	0.09±0.01	1.84×10^{-2}	0.49±0.03	23966×10^{-1}
2.	MALLAM MADORI	0.03±0.01	6.132×10^{-3}	2.32±0.72	1.1347×10^{-1}
3.	BYE PASS HOUSING ESTATE BUNGALOW	0.05±0.02	$1..022 \times 10^{-2}$	0.98±0.55	4.7932×10^{-1}
4.	CRESCENT ROAD HOUSING ESTATE	0.003±0.0005	6.132×10^{-4}	0.004±0.013	1.9564×10^{-3}
5.	LEMU ROAD	0.03±0.01	6.132×10^{-3}	BDL	-
6.	CASS BYE PASS	0.0027±0.0009	5.5188×10^{-4}	1.64±0.56	8.0212×10^{-1}
7.	PANTEKA HOUSING ESTATE	0.015±0.0009	3.066×10^{-3}	0.35±0.46	1.7119×10^{-1}
8.	BYEPASS HOUSING ESTATE BLOCK OFFLATS	0.06±0.01	1.2264×10^{-2}	2.97±0.48	1.3206×10^{-2}
9.	CES BARNAWA	0.0008±0.0001	1.6352×10^{-4}	0.027±0.004	1.3206×10^{-2}
10.	ENUGU ROAD	0.036±0.001	7.3584×10^{-3}	1.182±0.450	5.7812×10^{-1}
			0.0649		4.8729

Table 1: Calculated AEDEα and AEDEβ ($mSvy^{-1}$) for both gross alpha and gross beta activity radiation

Annual Gonadal Dose Equivalent (AGDE)

Annual gonadal dose equivalent measures the dose of gross alpha and gross beta received by the gonadal surface cells as a result of exposure to radiation.

The computation of AGDE for gross α or gross β is given by the formula:

$$AGDE = \frac{AEDE}{R.W.F \; X \; T.W.F} \text{ ---------- 2}$$

Where R.W.F = Radiation weighing factor

T.W.F = Tissue weighing factor

R.W.F = 2 for α – activity

1 for β – activity

T.W.F = 0.20 (for both α and β activity)

The sum of AGDE for gross alpha and gross beta radiation is given as $AGDE_T$ (α, β)

$$= \sum_i(\alpha, \beta) \frac{AEDE}{R.W.F \; X \; T.W.F} \text{ ---------- 3}$$

Table 2 The AGDE for all samples

S/N	Sample ID	AEDEα ($mSvy^{-1}$)	AEDEβ ($mSvy^{-1}$)	AGDEα ($mSvy^{-1}$)	AGDEβ ($mSvy^{-1}$)
1.	ZANFARA ROAD HOUSING ESTATE BARNAWA	1.84×10^{-2}	2.3966×10^{-1}	0.046×10^{-1}	1.1933
2.	MALLAM MADORI	6.132×10^{-3}	1.1347×10^{-1}	0.01533×10^{-1}	5.6735
3.	BYE PASS HOUSING ESTATE BUNGALOW	$1..022 \times 10^{-2}$	4.7932×10^{-1}	2.555×10^{-2}	2.3966
4.	CRESCENT ROAD HOUSING ESTATE	6.132×10^{-4}	1.9564×10^{-3}	1.533×10^{-3}	9.782×10^{-3}
5.	LEMU ROAD	6.132×10^{-3}	-	1.533×10^{-2}	-
6.	CASS BYE PASS	5.5188×10^{-4}	8.0212×10^{-1}	1.3797×10^{-3}	4.0106
7.	PANTEKA HOUSING ESTATE	3.066×10^{-3}	1.7119×10^{-1}	7.665×10^{-3}	8.5995×10^{-1}
8.	BYEPASS HOUSING ESTATE BLOCK OF FLATS	1.2264×10^{-2}	1.3206×10^{-2}	3.066×10^{-2}	1.533×10^{-1}
9.	CES BARNAWA	1.6352×10^{-4}	1.3206×10^{-2}	4.088×10^{-4}	2.044×10^{-3}
10.	ENUGU ROAD	7.3584×10^{-3}	5.7812×10^{-1}	1.8396×10^{-2}	9.198×10^{-2}
			Total	**0.1623**	**14.3961mSvy^{-1}**

Table 2: The sum of AGDE for gross alpha for all samples is 01623$mSvy^{-1}$ and for gross beta is 14.3961$mSvy^{-1}$ respectively.

Excess Lifetime Cancer Risk (ELCR)

The excess lifetime cancer risk is the probability of developing cancer over a lifetime at a given exposure level. We are assuming 70years as the average duration of life for humans. The excess lifetime cancer risk is calculated for gross alpha or gross beta, using the formula;

$ELCR_{(\alpha, \beta)}$ = AEDE x DL x RF ---------- 7

$ELCR_T$ $(\alpha, \beta) = \Sigma_i^{(\alpha, \beta)}$ AEDE x DL x RF ---------- 8

Where; DL = Average duration of life (estimated at 70years)

RF = Risk factor (Sv^{-1}) which is fatal risk per sivert

For stochastic effect ICRP used RF = 0.5/sv equivalent to 5×10^{-5}/mSv for the public

The ELCRα for the first sample ID FISL is computed using (7) as follows

ELCRα for all Samples

ELCR(α) = AEDEα x DL x RF

Table 3: Showing result of Excess Lifetime Cancer Risk (ELCR)

S/N	Sample ID	AEDEα ($mSvy^{-1}$)	AEDEβ ($mSvy^{-1}$)	ELCRα	ELCRβ
1.	ZANFARA ROAD HOUSING ESTATE BARNAWA	1.84×10^{-2}	2.3966×10^{-1}	6.44×10^{-3}	8.3881×10^{-4}
2.	MALLAM MADORI	6.132×10^{-3}	1.1347×10^{-1}	2.1462×10^{-5}	3.97145×10^{-3}
3.	BYE PASS HOUSING ESTATE BUNGALOW	$1..022 \times 10^{-2}$	4.7932×10^{-1}	3.577×10^{-5}	1.67762×10^{-3}
4.	CRESCENT ROAD HOUSING ESTATE	6.132×10^{-4}	1.9564×10^{-3}	2.1462×10^{-6}	6.8474×10^{-6}
5.	LEMU ROAD	6.132×10^{-3}	-	2.1462×105^{3}	-
6.	CASS BYE PASS	5.5188×10^{-4}	8.0212×10^{-1}	1.943158×10^{-5}	2.80742×10^{-3}
7.	PANTEKA HOUSING ESTATE	3.066×10^{-3}	1.7119×10^{-1}	1.0731×10^{-5}	6.01965×10^{-4}
8.	BYEPASS HOUSING ESTATE BLOCK OFFLATS	1.2264×10^{-2}	14526×10^{-2}	4.2924×10^{-5}	4.6221×10^{-5}
9.	CES BARNAWA	1.6352×10^{-4}	1.3206×10^{-2}	5.7232×10^{-7}	2.6221×10^{-5}
10.	ENUGU ROAD	7.3584×10^{-3}	5.7812×10^{-1}	2.5754×10^{-6}	2.02342×10^{-3}
.					
			Total	**2.4465** $\times 10^{-4}$	**0.01202**

The total excess lifetime cancer risk for gross **α is 0.0132 and for gross β is 0.0167**

Discussion

The instrument used for this research work is a non gaseous ionization detector device use to measure particles of ionizing radiation. The key feature is it ability to measure the energy of incident radiation, by producing a detector output pulse that is proportional to the radiation energy absorbed by the detector due to an ionizing event, hence the detectors name. it is widely used where energy levels of incident radiation must be known, such as in the discrimination between alpha and beta particles or accurate measurement of X – ray radiation dose.

The MPC 2000 is protein instrument cooperating latest addition to an extensive hire of gross alpha/beta counting system. The MCP 2000 has modern control and interface options, a significantly reduced footprint and a non – gas flow detector option.

Annual Efficiency Dose Equivalent of alpha to be 0.0649, and beta to be 4.8729, an Annual Gonadal Dose Equivalent of alpha to be 0.1623mSv/y, and beta to be14.3961mSv/y and Excess Lifetime Cancer Risk of alpha to be 2.4465×10^{-4}, and beta to be 0.01202 respectively.

These are good values for this type of counter. A low background activity was also observant with a 0.33cpm for alpha and 0.22cpm for beta. This is quite representative of the environment. Similarly, the results obtained from all the counting modes are reproducible and are hence reliable. The gross alpha and beta activity concentrations in the water samples were found to be in the range 0.0008±0.0001Bq/L to 0.09±0.01 with a control of 0.06476±0.01159 for alpha concentration and 0.004±0.013 to 2.97±0.48 with a control of 0.28508±0.02058Bq/L for beta concentration respectively. This shows that the concentrated values of beta are much higher than their corresponding values of alpha and ICRP accepted values of 0.5Bq/L for alpha and 1Bq/L for beta shows elevated values.

Conclusion

The determination of gross alpha and gross beta radionuclide activities from water sample in Jayfi, Tungan Goro village of Pago in Minna Niger State has been studied. The gross alpha and beta activity concentration (Bq/L^{-1}), the Annual Effective Dose Equivalent (AEDE), Annual Gonadal Dose Equivalent (ADGE) and Excess Lifetime Cancer Risk (ELCR) in the water samples along the community differ in quantity from sample to sample. This is explained by the heterogeneity of radionuclide deposits, water transportation, precipitation by organic metabolism and effluent discharge. The overall low value gross alpha and gross beta of radionuclide activities observed may be due to the present mining activities in the community and the low level of soil formation that constitute the geology of the area.

The measured gross alpha and gross beta concentration (Bq/L^{-1}), AEDEs, AGDEs and ELCRs activities are higher than those reported in other parts of the country. The mean and average values of gross alpha and gross beta concentrations (Bq/L^{-1}) were also determined. The sum of AEDE, AGDE and ELCR of both gross alpha and gross beta of all samples were calculated. However, the values obtained are far below the WHO and ICRP recommended maximum permissible limit and may not pose any serious health side-effects to the public users as their source of drinking water.

Recommendation

The results of the values obtained are far below the 100 Bq L^{-1} for gross alpha and 100 Bq L^{-1} for gross beta WHO and ICRP recommended practical screening levels of radioactivity in drinking water.

Since, the results obtained are below the international standard recommended permissible limits for drinking waters, a regular programme of environmental audit and monitoring is hereby recommended to checkmate the mining activities and there is also the need to carry out other certain parameters such as sodium iodide thallium (NaITl), neutron activation analysis (NAA) and plants elemental analysis using the community soil samples.

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