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Determination of Annual Effective Dose Equivalent and The Excess Lifetime Cancers Risk in Water Samples From A Mining Site in Jayfi, Pago Tungan Goro of Minna, Niger State, Nigeria

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Abstract

Mining industry in Nigeria provides economic benefit of wealth creations and employment opportunities, however, the industry is associated with negative health impact to miners and the surrounding communities resulting from mining processes. Gross alpha and beta radionuclide activity of water sources from Jayfi, Pago of Tungan Goro, Minna, Niger state was carried out. Eleven water samples were collected from the farming, residential/commercial, and industrial zones in the community and were analyzed using the protean instrument corporation (PIC) MPC 2000DP, single channel proportional counters. Two radiological parameters, which are the Annual Effective Dose Equivalent (AEDE) and Excess Lifetime Cancer Risk (ELCR) were determined. We are assuming 70years as the average duration of life for humans, the results gotten are; AEDE $_{(a\ and\ \beta)}$ 0.013237/0.645534mSv/y and ELCR $_{(a\ and\ \beta)}$0.280742/1.77 X 10^3respectively. 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 show elevated values.

Keywords: Dose, Equivalent, Excess, Lifetime, Cancer, Risk.

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. 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 (WHO in 2011and ICRP) 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. Atoms are the smallest particles of mass with distinctive chemical properties. An atom consists of a nucleus surrounded by electrons. The

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nucleus consists of positively charged proton and uncharged neutrons. The diameter of an atom is of the order 10^{-10} meter (m) and the diameter of a nucleus is of the order 10^{-15}meter (m). In addition, protons and neutrons have a mass of 1.67×10^{-27}kg, while the mass of the negative charged electrons is 9.11×10^{-31}kg the elementary charge is 1.602×10^{-19} coulombs. The world is naturally radioactive and about 90% of human radiation exposures arise from natural sources such as cosmic radiations, exposure to radon gas, and terrestrial radiations. Significant naturally occurring radionuclides present in the soil are 238U, 232Th and 40^{K} . Since these radionuclides are not uniformly distributed, the knowledge of their distribution in soils and rocks play an important role in radiation protection and measurement (Umar et al., 2013). Beta Decay the most common source of fast electrons in radiation measurements is a radioisotope that decays by beta-minus emission. The process is written schematically where X and Y are the initial and final nuclear species, and C is the antineutrino. Because neutrinos and antineutrinos have an extremely small interaction probability with matter, they are undetectable for all practical purposes. The recoil nucleus Y appears with a very small recoil energy, which is ordinarily below the ionization threshold, and therefore it cannot be detected by conventional means. Thus, the only significant ionizing radiation produced by beta decay is the fast electron or beta particle itself (Glenn Knoll, 1999). Gross alpha and beta activity screening procedures have been developed to determine if radionuclide specific analysis is required to further characterize the water. Recommended gross alpha and beta activity screening methods generally employ gas proportional counting techniques (Ross et al., 2004). Water is polluted by the waste of civilization, and this is brought about by the discharge of water borne waste from human activities. While the health effect of ingesting polluted water could be illness, the consequence of prolonged exposure to radioactively polluted water include cancers, toxicity of the kidneys and bearing of children with birth defects. Greater radiation dose increases the chance of developing Leukemia, eye cataracts, Erithemia, hematological depression and incidence of chromosome aberrations (Avwiri and Ononugbo, 2011).In this study, we will employ Single channel proportional counters to determine the concentration of alpha and beta in the water samples and we calculate Annual Effective Dose Equivalent (AEDE) and Excess Lifetime Cancer Risk (ELCR).

MATERIALS AND METHOD

Sampling Method

A random sampling method was used for this study. Five (5) water samples were collected from underground water sources, another five (5) from the surface (pond), and one as control water sources. All samples were collected in Jayfi, Pago in the Tungan Goro area of Minna, Niger state.

Methodology

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

Samples of water were collected directly into 2-liters 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 helps preserve the radio-nuclides present in the water samples and it also prevents 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,2007). Surface water from boreholes and ponds within the area was collected and treated with the reagent. Care was taken to avoid fetching from the stagnant areas. 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 (Onoja, 2004).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.

The Radiological Parameters

There are several radiological risk parameters. These include the annual effective dose equivalent (AEDE), annual gonadal dose equivalent (AGDE) and the excess lifetime cancer risk (ELCR). However, in this study, we employed the annual effective dose equivalent (AEDE) and the excess lifetime cancer risk (ELCR).

Annual Effective Dose Equivalent (AEDE) = $A (\alpha, \beta) \times W^c \times F.D$ ------------------ 1

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

W^C= water consumed by a person in a year

(For an adult it is approximately 2litres a day, which is approximately 730L in a year)

F.D (α, β) = activity to the 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 the gross beta are Pb – 210 and radium – 228.

Activity dose conversion factor F.D for radium 226 is 2.8×10^{-4} $mSvy^{-1}$ for gross alpha radiation.

For radium 228 and Pb – 210, dose conversion factor F.D = 6.7×10^{-4} $mSvy^{-1}$ for beta radiation.

The AEDE for gross alpha and gross beta radiation of sample ID JFPond and BHL with alpha activities and beta activities is given by equation 1.

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 70 years as the average duration of life for humans. The excess lifetime cancer risk is calculated for gross alpha or gross beta, using the formula;

$$ELCR_{(\alpha, \beta)} = AEDE \times DL \times RF \text{ ------------------- } 2$$

$$ELCR_T (\alpha, \beta) = \Sigma_i^{(\alpha, \beta)} AEDE \times DL \times RF \text{ ------------------ } 3$$

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

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

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

Sample Analysis

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 alpha method (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).

RESULTS AND DISCUSSION

Results

Table 3.1 show gross alpha, gross beta concentration (BqL^{-1}) while Table 3.2 shows the tabulated result of AEDE for gross alpha & gross beta. The results of the average efficiencies of the detector in the alpha-only mode for JF pond is ±0.01159 while that of beta in beta-only mode is ±0.02058, thus the average efficiency of beta is greater than the average efficiency of alpha with the alpha-to-beta efficiency ratio.

Table 3.1: Gross Alpha, Gross Beta concentration (BqL^{-1})

S/N	Sample ID	Alpha Concentration (Bq/l)	Beta Concentration (Bq/l)
1.	JF 1 POND	0.02059±0.00779	0.06782±0.01183
2.	JF 2 POND	0.12392±0.02272	0.17276±0.02898
3.	JF 3 POND	0.03285±0.00851	0.07792±0.01217
4.	JF 4 POND	0.02274±0.00839	0.04240±0.01114
5.	JF 5 POND	0.00553±0.01037	0.08671±0.01642
6.	BHL 1	0.14628±0.02016	0.29893±0.02737
7.	BHL 2	0.00797±0.00552	0.00988±0.00693
8.	BHL 3	0.03922±0.01005	0.05905±0.01281
9.	BHL 4	0.00552±0.01036	0.16150±0.01877
10.	BHL 5	0.00968±0.01059	0.05781±0.01542
11.	CONTROL	0.06476±0.01159	0.28508±0.02058

Table 3.2 shows the tabulated result of AEDE for gross alpha & gross beta radiation of all samples

S/N	Sample ID	Alpha Concentration (Bq/L)	AEDE α($mSvy^{-1}$)	Beta Concentration (Bq/L)	AEDE β($mSvy^{-1}$)
1.	JF 1 POND	0.02059±0.00779	4.208596×10^{-3}	0.06782±0.01183	0.033171
2.	JF 2 POND	0.12392±0.02272	0.0253	0.17276±0.02898	0.0844969
3.	JF 3 POND	0.03285±0.00851	6.71454×10^{-3}	0.07792±0.01217	0.0381106
4.	JF 4 POND	0.02274±0.00839	4.64806×10^{-3}	0.04240±0.01114	0.02073784
5.	JF 5 POND	0.00553±0.01037	1.130332×10^{-3}	0.08671±0.01642	0.0424097
6.	BHL 1	0.14628±0.02016	0.02999	0.29893±0.02737	0.1462065
7.	BHL 2	0.00797±0.00552	1.629×10^{-3}	0.00988±0.00693	4.7934×10^{-3}
8.	BHL 3	0.03922±0.01005	8.01656	0.05905±0.01281	0.0289
9.	BHL 4	0.00552±0.01036	1.128×10^{-3}	0.16150±0.01877	0.07898
10.	BHL 5	0.00968±0.01059	1.979×10^{-3}	0.05781±0.01542	0.283
11.	CONTROL	0.06476±0.01159	0.013237	0.28508±0.02058	0.139433

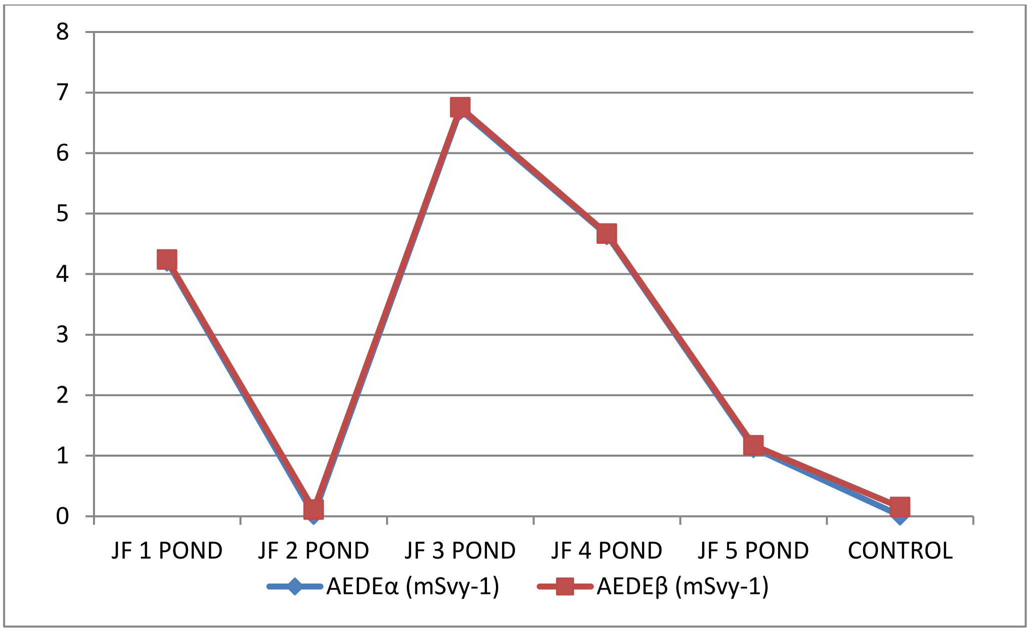

Fig 3.1: Graph of JF POND against AEDEα and AEDEβ ($mSvy^{-1}$) activity Concentrations

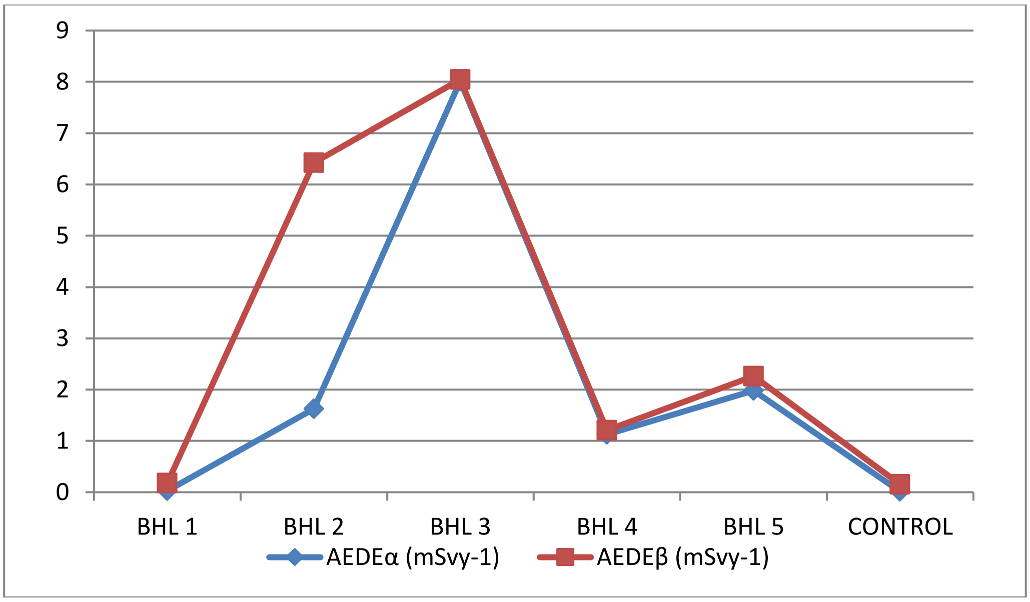

Fig 3.2: Graph of BHL against AEDEα and AEDEβ ($mSvy^{-1}$) activity Concentrations

The sum of AEDE for gross α and β radiation is given by

$AEDE_T (\alpha, \beta) (mSvy^{-1}) = \Sigma_i^{(\alpha, \beta)} A (\alpha,\beta) \times WC \times F.D (\alpha, \beta)$

For alpha: $AEDE_T \Sigma_i^{(\alpha, \beta)}$ for JF pond = $0.04200mSvy^{-1}$

$AEDE_T \Sigma_i^{(\alpha, \beta)}$ for BHL = $8.01656mSvy^{-1}$

For beta: $AEDE_T \Sigma_i^{(\alpha, \beta)}$ for JF pond = $0.218993mSvy^{-1}$

$AEDE_T \Sigma_i^{(\alpha, \beta)}$ for BHL = $0.2872mSvy^{-1}$

The sum of AEDEα for both pond and BHL are $0.4200mSvy^{-1}$ and $8.01656mSvy^{-1}$ and that of AEDEβ for both pond and BHL are $0.21893mSvy^{-1}$ and $0.2872mSvy^{-1}$ respectively.

Table 3.3: Excess Lifetime Cancer Risk (ELCR)

S/N	Sample ID	AEDEα ($mSvy^{-1}$)	AEDEβ ($mSvy^{-1}$)	ELCRα	ELCRβ
1.	JF 1 POND	4.20859×10^{-3}	0.033171	1.473×10^{-5}	1.16×10^{-4}
2.	JF 2 POND	0.0253	0.0844969	8.86×10^{-5}	2.96×10^{-4}
3.	JF 3 POND	6.71454×10^{-3}	0.381106	2.35×10^{-5}	1.33×10^{-4}
4.	JF 4 POND	4.64806×10^{-3}	0.02073784	1.63×10^{-5}	7.26×10^{-5}
5.	JF 5 POND	1.130332×10^{-3}	0.0424097	3.96×10^{-6}	1.48×10^{-4}
6.	BHL 1	0.02999	0.1462065	1.0497×10^{-4}	5.12×10^{-4}
7.	BHL 2	1.629×10^{-3}	4.7934×10^{-3}	5.70×10^{-6}	1.68×10^{-5}
8.	BHL 3	8.0165	0.0289	0.02806	1.01×10^{-4}
9.	BHL 4	1.128×10^{-3}	0.07898	3.95×10^{-6}	2.76×10^{-4}
10.	BHL 5	1.979×10^{3}	0.0283	6.93×10^{-6}	9.9×10^{-5}
11.	CONTROL	0.13237	0.139433	4.63×10^{-5}	4.88×10^{-4}

In Table 3.3: The total ELCR for gross alpha is 0.280742 and beta is 1.77×10^{-3}

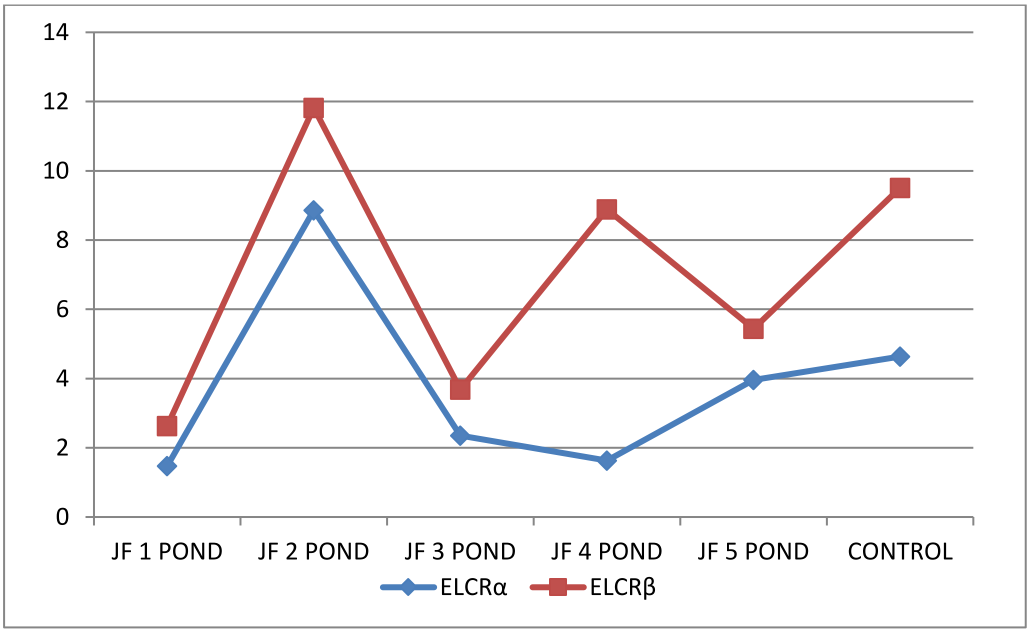

Fig 3.3: Graph of JF POND against **ELCRα** and **ELCRβ** activity Concentrations

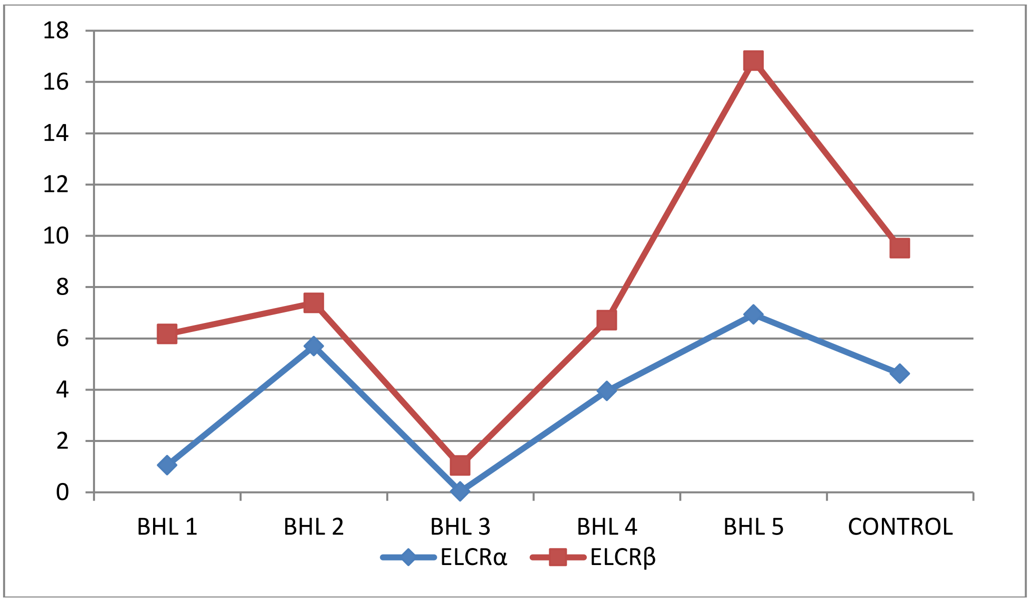

Fig 3.4: Graph of JF POND against **ELCRα** and **ELCRβ** activity Concentrations

DISCUSSION

The non-gas flow instrument used for this analysis gave the results of the two selected radiological parameters which include; Annual Efficiency Dose Equivalent of alpha to be 0.013237, beta be 0.64601064, and Excess Lifetime Cancer Risk of alpha to be 0.280742, and beta to be 1.77 x 10^{-3} respectively.

These are good values for this type of counter. Low background activity was also observed with 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 0.02059±0.00779Bq/L to 0.00968±0.01059 with a control of 0.06476±0.01159 for alpha concentration and 0.067882±0.01183 to 0.05781±0.01542 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 show elevated values.

CONCLUSION

The determination of gross alpha and gross beta radionuclide activities from water samples 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), 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 and precipitation by organic metabolism, and effluent discharge. The overall low-value gross alpha and a 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, and ELCRs activities are higher than those reported in other parts of the country. The mean values of gross alpha and gross beta concentrations (Bq/L^{-1}) were also determined. The sum of AEDE and ELCR of both gross alpha and gross beta of all samples was 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.

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