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Determination of Radionuclide Concentrations and Hazard Indices of Water and Fish in Eko-Ende Dam, Ifelodun Local Government Area, Osun State, Nigeria

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Abstract: The radionuclide concentrations in water and fishes (*Oreochromis niloticus* and *Chrysichthys auratus)* of Eko-Ende Dam situated in Ifelodun Local Government Area, Osun State were analyzed using the Sodium Iodide (NaI) gamma-ray spectrophotometer and from the activity concentrations, their radiological health hazard indices were evaluated. The results of the samples taken between November 2013 and October 2014 were analyzed. The mean activity concentrations due to ^{40}K in the water and fish (*Oreochromis niloticus* and *Chrysichthys auratus*) was 390.63 ± 11.78 and 162.45 ± 11.36 and 136.87 ± 10.64 Bq/kg respectively. ^{238}U had a mean value of 36.73 ± 4.93 in the water samples, and 34.04 ± 5.26 and 28.77 ± 4.80 Bq/kg in *Oreochromis niloticus* and *Chrysichthys auratus (fish)* respectively while ^{232}Th presented a mean value of 36.73 ± 4.93 in water and 26.55 ± 4.77 and 21.52 ± 3.37 Bq/kg in fish samples. The mean activity concentrations obtained in the water samples were higher than the permissible values while in fish samples the values were below the permissible values. The health hazard indices, radium equivalent activity (Ra_{eq}), annual effective dose equivalent and the excess lifetime cancer risk (ELCR) were found to lower than the permissible limit in the water and fish samples.

Keywords: Radionuclide, Hazard Indices, Eko-Ende.

1 Introduction

Human beings have always been exposed to natural radiations beneath the surface and above the earth. The exposure of natural radiations is due to naturally occurring radionuclides such as ^{238}U, ^{232}Th and ^{40}K and their concentrations in soil, sediments, water, food and rocks depend upon the geology of each region in the world [1]. Radioactive elements are generally classified into two categories, naturally occurring and artificially produced. Radioactivity due to natural radionuclides in rocks, soil and water generates a significant component of background radiation exposure to the population in the area. The terrestrial component of the natural background radiation is dependent on the composition of the rocks, food, soil and water in which the natural radionuclides are contained [2]. Among the radioactive elements in the environment, the most abundant are ^{40}K, and the radioisotopes of the natural decay series of ^{238}U and ^{232}Th, which are present in the earth's crust. Therefore, materials from the earth's crust such as soil, water and building materials become a major source of external radiation exposure to humans in the environment. Human beings become exposed to radionuclides through pollution of the food chain which results from the direct deposit of radionuclides on sediment or water, leaves of plants, and from drinking of contaminated water and eating of contaminated fish [3]. The long-term exposure to uranium and radium through inhalation has several health effects such as chronic lung diseases, acute leucopoenia, anemia and necrosis of the mouth [4]. Estimating the concentrations of radionuclides in the environment is key in examining the health exposure of the populace and provides a locus for recording variations in environmental radioactivity as a result of anthropogenic works [5]. Knowledge of naturally occurring radioactive materials present in water and fish enables one to assess any possible radiological hazard to mankind [6]. Therefore, the study aimed at determining the radionuclide concentrations and hazard indices of water and fish samples obtained from Eko-Ende Dam in Osun State, Nigeria.

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2 Experimental Section

2.1 Materials and Methods

The study area lies between Latitude 7°54'30"N and 7°57'0"N and Longitude 4° 33'30"E and 4° 35'30"E. The Eko-Ende Dam on the Otin River was impounded in 1973 to form a Dam with storage capacity of 5.5 MCM. The head works were designed to improve existing water supply to the communities of Eko-Ende, Eko-Ajala, Ikirun, Iragbiji, Okuku and Oba [7]. The Dam serve as source of drinking water and fishing activities for the resident of Osogbo, Eko-Ende, Eko-Ajala, Ikirun, Iragbiji, Okuku and Oba. Eko-Ende Dam is located within a comparatively semi-urban to rural area. The regional relief of the study area is rugged with elevations ranging from 35 m to over 400 metres above sea level [8]. Radioactivity analysis of the water and fish samples were carried out using Gamma Spectrometry.

2.2 Fish Sample Preparation

Twelve (12) samples of *Oreochromis niloticus and Chrysichthus auratus* each, the most commonly consumed types of fish in Eko-Ende Dam, were caught with fishing net on a monthly basis. The fresh fish samples collected were carefully kept in plastic containers with ice to keep the temperature at less than 5 ^{0}C and labeled before taken to the laboratory for identification. The fishes were oven dried at a temperature of 80 ^{0}C [9]. The dried fish samples were pulverized to fine quality using mortar and pestle and 250g was weighed and packed in plastic containers. The weighed samples were hermetically sealed with the aid of PVC tape to prevent the escape of airborne ^{222}Rn and ^{220}Rn from the samples for twenty-eight (28) days in order to maintain secular radioactive equilibrium before it was analyzed via gamma-ray spectrophotometer.

2.3 Water Sample Preparation

About 2 L of water sample was obtained from three (3) points along Eko-Ende Dam. The water samples were collected in plastic containers previously cleaned. During sampling, sample bottles were rinsed with sampled water three times and then filled to the brim. These water samples were pre-treated with 2 ml of concentrated HNO_3 in 1 litre of water sample using clean prewashed container with screw caps. The sample was homogenously mixed and 200 ml was measured and stored for 28 days in order to establish secular radioactive equilibrium.

2.4 Determination of Radiological Hazard Index

2.4.1 Radium Equivalent Activity Concentration Index (Ra_{eq})

Radium equivalent (Ra_{eq}) index in Bq/kg is a widely used radiological hazard index. It is a convinient index to compare the specific activities of samples containning different concentrations of ^{238}U,^{232}Th and ^{40}K. This radium equivalent concept allows a single index or number to describe the gamma output from different mixtures of uranium, thorium and potassium in the water and fish samples obtained from Eko-Ende Dam. [10,11].

It was calculated using the formula;

$$Ra_{eq}=A_U+ 1.43A_{Th}+ 0.077A_K \quad (3.4)$$

where A_U, A_{Th} and A_K are the specific activity concentrations of ^{238}U, ^{232}Th and ^{40}K in Bq/kg respectively.

2.4.2 The Absorbed Gamma Dose Rate

The input of natural radionuclides to the absorbed dose rate in air (D_R) at average height of one meter above the surface of ground depends on the natural specific activity concentration of ^{238}U, ^{232}Th and ^{40}K. If a radionuclide activity is known then, its exposure dose rate in air at 1 m above the ground can be estimated using the formular given by Kurnaz *et al.*[12] and Ravinsankar *et al*. [11]:

$$D_R\ (nGyh^{-1}) = 0.43A_U + 0.666A_{Th} + 0.042A_K \quad (3.5)$$

2.4.3 The Annual Effective Dose Equivalent

The annual effective dose equivalent (AEDE) to the population, the UNSCEAR, United Nations Scientific Committee on the Effects of Atomic Radiation [13] reports a value of 0.7 $SvGy^{-1}$ for the conversion coefficient from absorbed dose in air to effective dose received by adults, the indoor to outdoor ratio (1:4), the outdoor occupancy factor 0.2 and the indoor occupancy factor 0.8 [14]. Therefore, the annual effective doses outdoors and indoors equivalent are calculated by using the relations:

$$D_{outdoor}\ (mSv/yr) = [D_r\ (mGy/hr) \times 24\ hr \times 365.25\ d \times 0.2 \times 0.7\ Sv/Gy] \times 10^{-6} \quad (3.6)$$

$$D_{indoor}\ (mSv/yr) = [D_r\ (mGy/hr) \times 24\ hr \times 365.25\ d \times 1.4 \times 0.8 \times 0.7\ Sv/Gy] \times 10^{-6} \quad (3.7)$$

The corresponding worldwide values of D_{out}, D_{ind} and D_{tot} are 0.08, 0.42 and 0.50 $mSvy^{-1}$ respectively.

2.4.4 The Excess Lifetime Cancer Risk

The Excess Lifetime cancer risk (ELCR) was calculated using the following equation:

$$ELCR=AEDE\times DL\times RF \quad (3.8)$$

where, AEDE is the Annual Equivalent Dose Equivalent, DL is the average duration of life (estimated to 54 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 [15].

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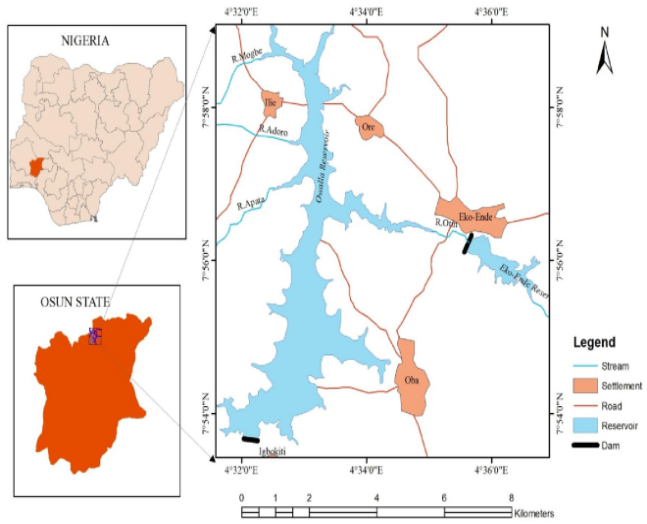

Fig. 1: The Map of Nigeria showing Osun State; insetting Eko-Ende Dam Source: [16]

3 Results and Discussion

3.1 Activity Concentrations and Hazard Indices

The mean activity concentration of ^{40}K, ^{238}U and ^{232}Th in the water and fish samples of Eko-Ende on a monthly basis are presented in Figures 2-4. The mean activity concentrations of the radionuclides are presented in Table 1; all values are given in Bq/kg. The range for the mean activity concentrations due to ^{40}K was 521.59 ± 11.05 Bq/kg, mean value of ^{232}Th was 52.05 ± 5.88Bq/kg while mean value of ^{238}U was 36.73 ± 1.44 Bq/kg in the water samples. *Oreochromis niloticus* and *Chrisycthus auratus* presented mean values of ^{40}K was 365.31 ± 11.36 and 326.18 ± 10.64 Bq/kg respectively, the mean values of ^{238}U in *Oreochromis niloticus* samples was 34.04 ± 5.26Bq/kg while in *Chrisycthus auratus,* the value was 28.77 ± 4.80Bq/kg. The mean values of ^{232}Th were 26.55 ± 4.77 and 21.52 ± 3.37 Bq/kg respectively. The mean activity concentration of the radionuclides in the water samples from the Dam was found to be higher than world average values, (World average concentrations are 35Bqkg^{-1}, 30Bqkg^{-1} and 500Bqkg^{-1} for ^{228}U, ^{232}Th and ^{40}K respectively [13] while in the fish samples, the mean activity concentration was lower than the world average concentrations.

The high concentration of ^{40}K observed in the water sample could be as a result of mans' activities such as fertilizer and manure application on farm land which leached into the water body and variation in geological structure. The mean radium equivalent activity (Ra_{eq}) in Eko-Ende water and fish samples (Table 2) are 183.66 Bqkg^{-1}, and 163.81 Bqkg^{-1} and 156.57 Bqkg^{-1} respectively. These values are less than the safe limit (370 Bqkg^{-1}) recommended by UNSCEAR [17]. The mean absorbed dose rate for the water and fish samples is 69.16 nGyh^{-1} and 39.14 nGyh^{-1} and 32.45 nGyh^{-1} respectively. The values are comparable to the world average 58 nGy/h. These values are lower when compared with obtained values of Almayahl *et al.* [18]. The absorbed dose rate itself does not give an indication of possible biological effects until it is converted to the effective dose equivalent, which is measured in Sieverts (Sv) [19]. The annual effective dose equivalent of Eko-Ende water and fish samples were calculated and presented in Table 2. The mean annual effective dose equivalent for the water and fish (*Oreochromis niloticus* and *Chrysicthus auratus*) samples are 0.08 µSv, 0.05 µSv and 0.04 µSv respectively. The calculated values was found to be lower than the recommended value of 1 µSv implying that the radiation hazard is insignificant for the population in Eko-Ende community [19]. The potential carcinogenic effects are characterized by estimating the probability of cancer incidence in a population of individuals for a specific lifetime from projected intakes (and exposures). The mean calculated values of the excess lifetime cancer risk (ELCR) for males and females in the water samples presented a value of 0.23 and 0.23 x 10^{-3}respectively. In the fish samples (Table 2), mean effective life cancer risk in *Oreochromis niloticus* was 0.13 x 10^{-3} and in *Chrysicthus auratus* was 0.11 x 10^{-3}. When the values were compared with United Nations Scientific Committee on the Effect of Atomic Radiation [13] who recommended a safe limit of 0.29 x 10^{-3}, the values obtained in the water and fish samples were found to be lower. This indicated that the water from this Dam was safe for drinking and fish fit for consumption as at the time the samples were taken and will not lead to respiratory diseases such as asthma, cancer and external diseases such as erythema, skin cancer and cataracts [20]. However, there is need for constant monitoring on the accumulation of these radionuclides in the ecosystem.

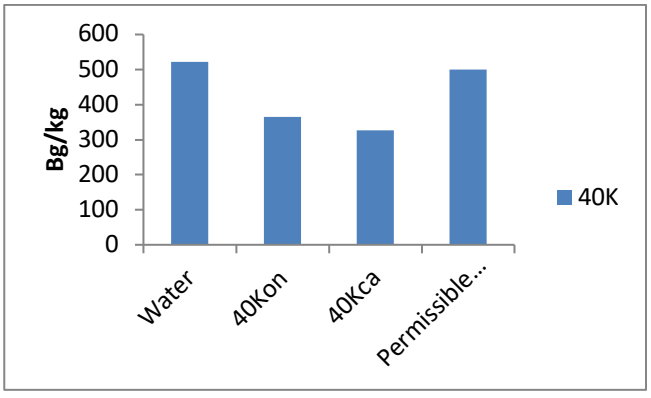

Fig.2:^{40}K comparison in the Water and fish (*Oreochromis niloticus* and *Chrysicthus auratus)* samples of Eko-Ende Dam.

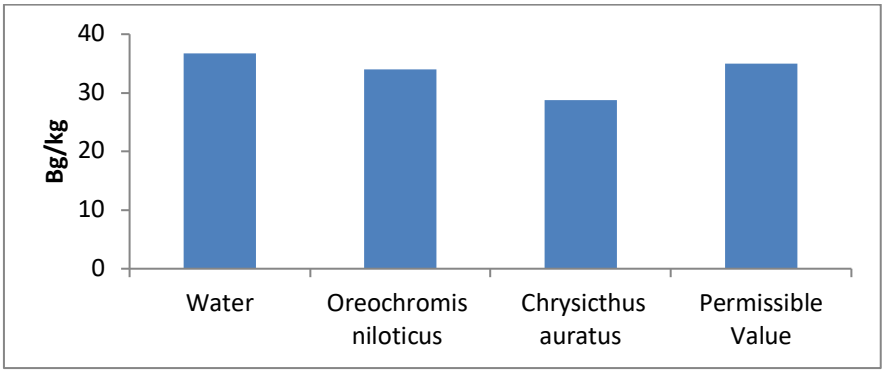

Fig.3: ^{238}U comparison in the Water and *Oreochromis niloticus* and *Chrysicthus auratus*

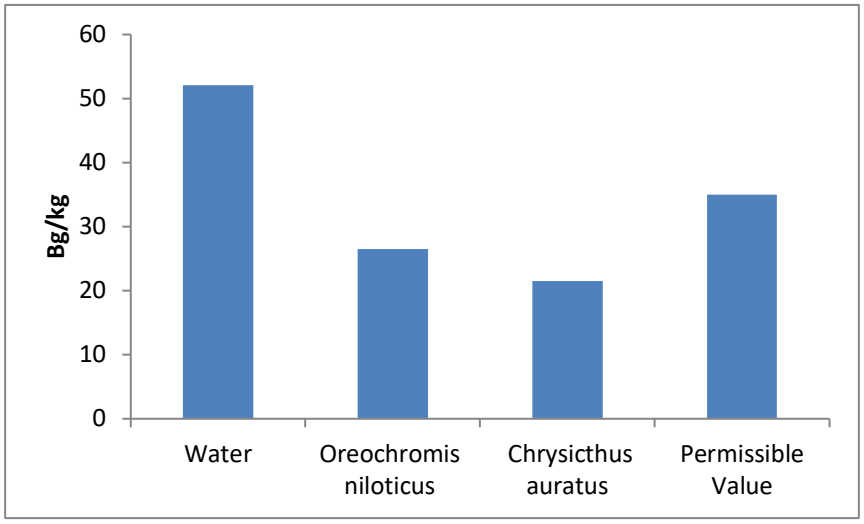

Fig.4: ^{232}Th Comparison in the Water and Fish samples (*Oreochromis niloticus* and *Chrysicthus auratus)*

Table 1: Mean Activity concentration of radionuclide's at Eko-Ende Dam in Bg/kg.

Sample	^{40}K (Bq/kg)	^{238}U (Bq/kg)	^{232}Th (Bq/kg)
Water	521.59 ±11.05	36.73 ± 1.44	52.05 ± 5.88
$^{40}K_{on}$	365.31 ± 11.36	34.04 ± 5.26	26.55 ± 4.77
$^{40}K_{ca}$	326.18 ± 10.64	28.77 ± 4.80	21.53 ± 3.37
Permissible Limit	500	35	35

Table 2: Calculated Hazard Indices at Eko-Ende Dam.

Sample	$Ra_{(eq)}$ (Bq/kg)	D_R (Abs. gamma dose rate) nGy/h	AEDE (μSv)	ELCR Male $^{x}10^{-3}$	ELCR Female $^{x}10^{-3}$
Water	189.27	69.24	0.08	0.23	0.23
$^{40}K_{on}$	163.81	39.14	0.05	0.13	0.13
$^{40}K_{ca}$	156.57	32.45	0.04	0.11	0.11
Permissible Limit	370	58	1	0.29	0.29

4 Conclusions

The average activity concentration of the radionuclides in the water samples from the Dam was found to be higher than the world average values while the fish samples presented values within the world average values (World average concentrations are 35 Bq kg^{-1}, 30 Bq kg^{-1} and 500 Bq kg^{-1} for ^{228}U, ^{232}Th and ^{40}K respectively UNSCEAR, 2000). The high concentration observed could be as a result of man's agricultural activities such as fertilizer and manure application on farm land which encroached into water bodies and variation in geological structure. The health hazard indices from Eko-Ende study areas i.e. radium equivalent activity (Ra_{eq}), estimated absorbed dose rates, annual effective dose equivalent and the excess lifetime cancer risk (ELCR) were within permissible limit. This study can serve as baseline information for further research to help in the monitoring of the safety and quality of the Dam and river for domestic water use as it is the first survey of its kind since they serve as source of fish, production of water for all-year-round irrigational farming and also as a source of drinking water for the local inhabitants in the study areas and beyond.

References

[1] N. Harikrishnan, A. Chandrasekaran, G. Elango, P. Eswaran and R. Ravisankar. An Evaluation of Natural Radioactivity and Its Associated Health Hazards Indices of Coastal Sediments from Rameshwaram Island, Tamilnadu, India. International **Journal** of Radiation **Applications** and Instrumentation., **2(1)**, 23-27, 2014.

[2] G. Karahan, and A. Bayulken. Assessment of gamma dose rates around Istanbul (Turkey). Journal of Environmental Radioactivity., **47**, 221-231, 2000.

[3] B. Fosu, D.D Wemegah, K.P Thomas, B. Boadi, A.M, Isaac, Amankwah Oppong et al. Interpretation of Geological Structures Hosting Potential Gold Deposits in the Konongo Gold Mine Using Airborne Magnetic, Electromagnetic and Radiometric Datasets. Journal of Geoscience and Environment Protection., **7(6)**, 203-225, 2019.

[4] F. Caridi, S. Marguccio, A. Belvedere, and G. Belmusto. Measurements of Gamma Radioactivity in River Sediment Samples of the Mediterranean Central Basin. American Journal of Condensed Matter Physics., **5(3)**, 61-68, 2015

[5] R. I. Obed, I. P. Farai & N. N. Jibiri. Population dose distribution due to soil radioactivity concentration levels in 18 cities across Nigeria. *Journal of Radiological Protection*., ***25*(3)**, 305–312, 2015.

[6] V. Ramasamy, G. Suresh, V. Meenakshisundaram and V. Gajendran. Evaluation of Natural Radionuclide Content in River Sediments and Excess Lifetime Cancer Risk Due to Gamma Radioactivity. Journal of Environmental and Earth Sciences., **1(1)**, 6-10, 2009

[7] A.O. Hassan, A. O. J. Amoo, O.P. Akinwale, A.M. Deji-Agboola, M.A. Adeleke, P.V. Gyang and A. Oluwadun. Human water contact activities and urinary schistosomiasis around Erinle and Eko-Ende Reservoirs. Global Advanced Research Journal of Medicine and Medical Sciences., **1(4)**, 077-084, 2012

[8] A. Adediji and L.T. Ajibade. The change detection of major Reservoirs in Osun State, Nigeria using remote sensing (RS) and GIS techniques. Journal of Geography and Regional Planning., **1(6)**, 110-115, 2008.

[9] O. Sowole. Radioactivity concentrations and dose rates of natural radionuclides in fishes from major rivers in Ijebu waterside southwest, Nigeria Sciences World Journal., **9**, 25-29, 2014.

[10] J. Beretka and P. Mathew. "Natural Radioactivity of Australian Building Materials, Industrial Wastes and by Products," *Health Physics.*, **48(1)**, 87-95, 1995.

[11] R. Ravisankar, A. Sivakumar, J. Chandrasekaran, P.P. Jebakumar, I. Vijayalakshmi, P. Vijayagopal, and B. Venkatraman. Spatial distribution of gamma radioactivity levels and radiological hazard indices in the East Coastal sediments of Tamilnadu, India with Statistical approach. Radiation Physics and Chemistry., **103**, 89-98, 2014.

[12] A. El-Taher and Ahmad Al-Turki Soil - to - Plant Transfer Factors of Naturally Occurring Radionuclides for Selected Plants growing in Qassim, Saudi Arabia Life Science Journal., **11(10)**, 965-972, 2014.

[13] UNSCEAR. Sources and Effects of Ionizing Radiation, report to the General Assembly, with scientific annexes, United Nations Sales Publication, United Nations, New York. UNSCEAR Report., **1**, 2000.

[14] M.T. Kaleel and M.J. Mohanad. Natural Radioactivity Levels and Estimation of Radiation Exposure in Environmental Soil Samples from Tulkarem Province-Palestine. Open Journal of Soil Science., **2**, 7-16, 2012.

[15] H. Taskin, M. Karavus, A. Topuzoglu, S.,Hindiroglu and G. Karahan. Radionuclide concentrations in soil and Lifetime cancer risk due to the gamma radioactivity in Kirklareli, Turkey. Journal of Environmental Radioactivity., **100**, 49-53, 2009.

[16] H. Y. Omoboye and I.F. Adeniyi. Primary Productivity of Owalla Reservoir, Osun State, Southwest, Nigeria. New York Science Journal., **10(4)**, 2017.

[17] United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and Effects of Ionizing Radiation, UNSCEAR Report, New York., 1993.

[18] B.A. Almayahl, A.A. Tajuddin and M.S. Jaafar. Effect of the natural radioactivity concentrations and 226Ra/238U disequilibrium on cancer diseases in Peneng, Malaysia. Radiation Physics and Chemistry., **81**, 1547-1558, 2012.

[19] L. I. Nwankwo and O.O. Olubo. Assessment of Terrestrial 40k, 238u and 232th Activities in Soil Within the Basement Complex Terrain of West Central Part of Nigeria. Zimbabwe Journal of Science & Technology., **11**, 1-11, 2016

[20] G.O. Avwiri, J.C. Osimobi and E.O. Agbalagba. Evaluation of Radiation Hazard Indices and Excess Lifetime Cancer Risk Due to Natural Radioactivity in soil profile of Udi and Ezeagu LocalGovernment Areas of Enugu State, Nigeria. Comprehensive Journal of Environmental and Earth Science., **1(1)**, 1 – 10, 2012.