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Radiological Assessment of Natural Radionuclide in Kwakwachi Irrigation Water Canal in Kano State Nigeria.

Isma'il Usman Dahir[1*], Nafiu Sani Abbas[2], Adamu N. Baba-Kutigi[3] & Emmanuel Joseph[4]

[1&2]Department of Physics Sa'adatu Rimi College of Education Kumbotso Kano State Nigeria
[3&4]Department of Physics, Faculty of Physical Sciences Federal University Dutsin-Ma Katsina State Nigeria
[*]Corresponding Author Email: idusman1985@gmail.com

ABSTRACT
This study examines the levels of natural radionuclides in soil samples from the Kwakwachi irrigation canal, assessing potential radiological risks to the local population. Using gamma spectrometry at the Centre for Energy Research and Training, Ahmadu Bello University, Zaria, we analyzed randomly collected soil samples for radionuclide content. Results showed that potassium-40 activity ranged from 28.43 to 85.01 Bq/kg, radium-226 from 12.70 to 31.12 Bq/kg, and thorium-232 from 21.78 to 45.22 Bq/kg. The mean concentrations for these radionuclides were all below their respective global averages (400 Bq/kg for 40K, 35 Bq/kg for 226Ra, and 30 Bq/kg for 232Th). Calculated indices—including radium equivalent, external and internal hazard indices, and gamma index—were also within internationally recommended safety limits. The average absorbed gamma dose rate was 55.20 nGy/h, below the global mean of 60 nGy/h. However, the annual effective dose for soil samples slightly exceeded the worldwide average of 0.07 mSv/y.

Keywords:
Radionuclide, Hazard, Activity Concentration, Radium Equivalent, Hazard Index, Gamma Dose, Annual Effective Dose.

INTRODUCTION

Radiological dose assessments estimate the amount of radiation energy individuals may absorb from environmental sources, helping to gauge potential health impacts. Exposure can be external (from sources outside the body, primarily gamma radiation) or internal (from inhaled or ingested radioactive materials, including alpha, beta, and gamma emitters) (Smith, 2011). Human activities along the Kwakwachi stream, such as the release of hazardous chemicals, have raised concerns about environmental contamination. This research aimed at measuring the activity concentrations of potassium-40, uranium-238, and thorium-232 in soil using gamma spectrometry, evaluate associated radiological hazards, and estimate absorbed and effective dose rates for both soil and crops.

This work establishes a baseline for environmental radioactivity, informs policy, guides safe waste management, and raises awareness among local residents about radiation risks.

MATERIALS AND METHODS

Description of the Study Area

The research was conducted in Kano Metropolis, northwest Nigeria, located between latitudes 12°682'N and 12°028'N and longitudes 8°257'E and 8°203'E. Kano is the third largest city in Nigeria, with a population of over 2.8 million (Ayila*et al*., 2014). It is a commercial hub, with urban agriculture relying heavily on wastewater irrigation. The study covered 10 sites within Kano municipal and Fagge local government areas, each with over 15 years of existence.

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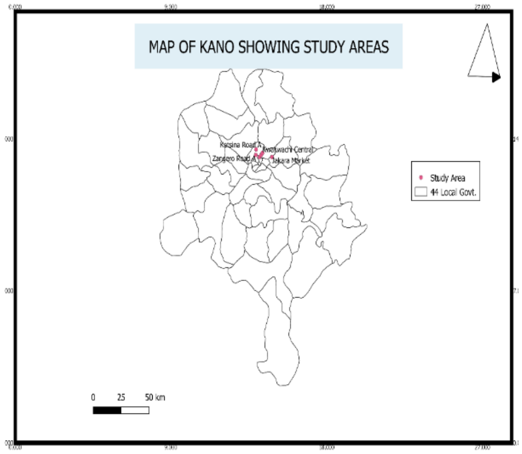

Fig.1: Kano Map Showing research areas

Sample Collection

Soil samples were taken in April 2024 from a 10 km section of the canal. At each of the 10 designated points, soil was collected from a depth of 20 cm and sealed in labeled polythene bags. GPS devices ensured accurate location recording. Samples were then transported to the Centre for Energy Research and Training (CERT) at Ahmadu Bello University for analysis.

RESULTS AND DISCUSSION

Table 1: The Geographic location of sample points using GPS Reader

Description	Sample code	Geographical Location
Jakara Police Station	P_1	N12.658° E8.515°
Jakara market	P_2	N12.682° E8.349°
Abattoir A	P_3	N12.125° E8.564v
Abattoir B	P_4	N12.028° E8.448°
Kwakwachi Central A	P_5	N12.148° E8.372°
Kwakwachi Central B	P_6	N12.320° E8.554°
Zangero Road A	P_7	N12.194° E8.555°
Zangero Road B	P_8	N12.138° E8.205°
Katsina Road A	P_9	N12.590° E8.203°
Katsina Road B	P_{10}	N12.509° E8.587°

Soil samples were collected from 10 sites using an Auger at a depth of 20 CM. For analysis, the samples were delivered to the environmental laboratory within Ahmadu University Centre for Energy, Research and Training (CERT) in Zaria, Nigeria, after being secured in labeled, airtight plastic containers.

Sample Preparation for Gamma ray Spectrometry

Collected soils were air-dried, ground to a fine powder, homogenized, and packed into cylindrical plastic containers (7 cm height, 6 cm diameter) for measurement. Containers were sealed with petroleum jelly, candle wax, and masking tape to prevent radon loss, then stored for at least 30 days to reach equilibrium between 226Ra and its decay products before gamma counting (Olomo*et al.*, 1994 and Innocent *et al.*, 2014). The NaI(Tl) detector at CERT was used, with energy calibration and background correction performed according to standard protocols Table1: indicated the spectra energy windows used in the analysis and table 3 also indicated the energy calibration for quantitative spectra analysis both obtained from CERT, Zaria.

Table2: Spectra energy windows used in the analysis (obtained from CERT, Zaria)

Isotopes	Gamma energy (KeV)	Energy window (KeV)
K-40	1460.00	1380 – 1550
Ra-226	1764.00	1620 – 1820
Th-232	2614.50	2480 – 2820

Table3: Energy calibration for quantitative spectra analysis (obtained from CERT, Zaria)

Isotope	Calibration factor $cps/Bq-kg^{-4} \times 10^{-4}$	Conversion factor	Detection limit Bq/kg
^{40}K	6.43	10^{-4}	14.54
^{226}Ra	8.63	10^{-4}	3.84
^{232}Th	8.77	10^{-4}	9.08

Laboratory Background Measurement

The results of the net count rates obtained from the system included that contributed by the natural radionuclide in the laboratory. Therefore, to obtain that due to the samples alone, the laboratory background was measured and later subtracted from the net counts rates obtained from the system. The laboratory background measurement was made by counting an empty detector without any sample for 29000s. From the spectrum obtained, only the naturally occurring radionuclides produced observable measurement.

Method of Measurement and Data Interpretation

Each sample was counted for 29,000 seconds using a calibrated detector setup. Activity concentrations for 226Ra, 232Th, and 40K were determined using their characteristic gamma lines (214Bi at 1764 keV, 208Tl at

2614 keV, and 40K at 1460 keV, respectively). Calibration factors derived from previous studies were applied to convert raw counts to Bq/kg. The extended counting time was chosen to ensure a sufficient number of counts in the photo peak providing acceptable statistical accuracy, data acquisition and gamma spectra analysis were performed using a computer based MCA system with the maestro II software (kugbere *et. al*., 2025). Activity concentrations for 226Ra, 232Th, and 40K were determined using their characteristic gamma lines (214Bi at 1764 keV, 208Tl at 2614 keV, and 40K at 1460 keV, respectively). Calibration factors derived from previous studies were applied to convert raw counts to Bq/kg. The measured counts per second (cps) were converted to standard units using a calibration factor (CF_k, $CF_{Ra}$and CF_{Th}) derived by (Boyang., *et al*, 2024) to determine the activity levels of the radionuclide. The calibration factors and their corresponding values are listed below:

$$CF_K = \frac{cps(^{40}K)}{Bq(^{40}K)/Kg} = 6.431 \times 10^{-4} cps/Bqkg^{-1} \quad \ldots\ldots(1a)$$

$$CF_{Ra} = \frac{cps(^{226}Ra)}{Bq(^{226}Ra)/Kg} = 8.632 \times 10^{-4} cps/Bqkg^{-1} \quad \ldots\ldots(1b)$$

$$CF_{Th} = \frac{cps(^{232}Th)}{Bq(^{232}Th)/Kg} = 8.768 \times 10^{-4} cps/Bqkg^{-1} \quad \ldots\ldots\ldots(1c)$$

Dose Assessment and Radiological Effects

In this paper, the radiological parameters including activity, radium equivalent activity, and radiation exposure indices, were calculated to assess the potential health risks associated with radiation exposure.

Activity

Activity levels for 40K, 226Ra, and 232Th were calculated for each sample (Ibeanu, 1999; Innocent *et al.*, 2014):

$$A_c = \frac{N_C}{L_t}\sigma^{-1} \quad (2)$$

Where L_t is the lifetime of counting, $N_c$is the net count rate, σ is a conversion factor which is constant for each radionuclide at constant geometry and is a characteristic of efficiency of the NaI(Tl) detector assembly used at CERT Zaria. All the raw data obtained from the detector will be converted to conventional units using the calibration factors to determine the activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th, respectively.

Radium Equivalent Activity

Radium equivalent (Raeq) was computed to represent the combined gamma output from 40K, 226Ra, and 232Th, ensuring comparability to safety thresholds (should not exceed 370 Bq/kg) (OECD, 1979),

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_k \quad (3)$$

Where A_{Ra} ,A_{Th} and A_k are the activity of ^{226}Ra,^{232}Th and ^{40}K, respectively. Equation 3 is based on the estimation that 1 Bq.kg^{-1} of ^{226}Ra, 0.7 Bq.kg^{-1} of ^{232}Th and 13 Bq.kg^{-1} of ^{40}K generate the same gamma-ray dose rate (Siak *et al.*, 2009; Innocent *et al.,* 2014).

External Hazard Index

The External radiation hazard index (H_{ex}) is a commonly utilized measure that indicates the level of external exposure to gamma radiation. This index was calculated using the formula provided byUNSCEAR (2000):

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \quad (4)$$

Internal Hazard Index

External and internal hazard indices (H_{ex}, H_{in}) and gamma index were calculated to evaluate potential exposure risks. All indices were below the recommended limit of 1 UNSCEAR (2000):

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \quad (5)$$

Gamma Level Index

The formula by UNSCEAR (2000) was used in calculating gamma index

$$I = \frac{A_{Ra}}{300} + \frac{A_{Th}}{200} + \frac{A_k}{3000} \quad (6)$$

According to UNSCEAR (2000), radiation exposure is considered safe if the external hazard indexH_{ex}, internal hazard indexH_{in}, and gamma index I are all below 1.

Absorbed Dose Rates

Absorbed dose rates were calculated using UNSCEAR (2000) coefficients.

$$D = 0.041A_K + 0.462A_{Ra} + 0.604A_{Th} \quad (7)$$

Where A_K, A_{Ra} and A_{Th} are the activity concentrations of ^{40}K, ^{238}U and ^{232}Th respectively in Bq.kg^{-1} and D is the value of the absorbed dose rate.

Annual Effective Dose

The annual effective dose was estimated using a conversion factor of 0.7 Sv/Gy and an outdoor occupancy factor of 0.2 as recommended by UNSCEAR (2000), using a specific formula.

$$E_d = D(nGy.hr^{-1}) \times 8760(hr.y^{-1}) \times 0.2 \times (0.7 \times 10^3 mSv) \times (10^9 nGy)^{-1} \quad (8)$$

Where E_d is the annual effective dose rate in ($mSv.y^{-1}$) (Harb *et al*., 2010).

Gamma Spectroscopy Analysis

The results obtained for Activity concentration for the soil samples (table 4) are presented. Also, the calculated value for the following Radium equivalent, external index, internal index, gamma index, absorbed dose rate and annual effective dose using Gamma Spectrometry are presented.and annual effective dose using Gamma Spectrometry are presented.

Activity

Table below displays the results of the activity level of the Naturally Occurring Radionuclides (^{40}K ^{226}Ra, ^{232}Th,) in Soil samples as determined by using gamma ray spectrometry and were expressed in Bq/kg.

Table 4:		***Activity concentration of soil samples***				
Sample ID		***K-40 (Bq/kg)***		***Ra-226 (Bq/kg)***		***Th-232 (Bq/kg)***
JPS		41.8834 ± 3.8637		16.7863 ± 2.2977		36.7617 ± 2.7530
JMK		65.3188 ± 4.9300		28.9273 ± 2.2139		25.596 3± 2.1197
ABA		28.4292 ± 3.5303		16.1793 ± 1.6381		45.2223 ± 3.8928
ABB		72.5661 ± 4.3390		26.4863 ± 2.6761		24.6134 ± 2.2576
KCA		85.0078 ± 4.8833		12.7039 ± 1.1364		26.3044 ± 2.6344
KCB		83.0699 ± 3.6594		28.4836 ± 2.7792		17.8905 ± 1.4941
ZKA		71.4930 ± 3.5769		31.1203 ± 2.1807		19.9737± 1.6168
ZRB		64.0855 ± 4.0193		18.2994 ± 1.8575		21.7787 ± 1.6110
KAA		95.2431 ± 5.5054		16.9845 ± 1.6601		26.2371 ± 2.2748
KRB		79.6909 ± 3.7860		21.6126 ± 2.1976		25.2818 ± 2.0273
Range		28.4292 - 95.2431		12.4836 – 31.1203		17.8905 – 45.2223
Average		68.3788		21.7583		26.9559
World range		140 – 850		17 – 60		11 – 64
World average (UNSCEAR,2000)		400		35		30

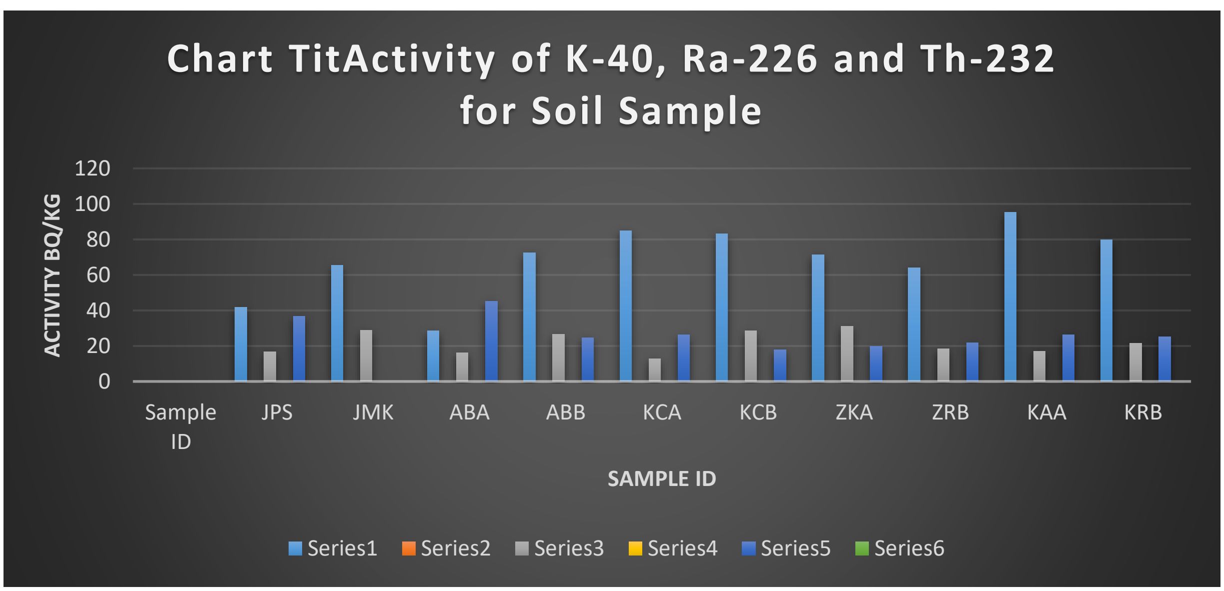

Figure 2: Activity concentrations of ^{40}K ^{226}Ra, ^{232}Th in Soil Sample

Radium equivalent, external index, internal index and gamma index

Below is the table of Radium equivalent, external index, internal index and gamma index.

Table 5: ***Radium equivalent, external index, internal index and gamma index for Soil Samples***

Sample ID	***Ra(eq) (Bq/kg)***	***Hex***	***Hin***	***I***
JPS	72.5806	0.1728	0.2414	0.2537
JMK	70.3600	0.1906	0.2688	0.2462
ABA	82.9763	0.2242	0.2679	0.2095
ABB	67.2711	0.1817	0.2533	0.2355
KCA	56.8648	0.1536	0.1879	0.2089
KCB	60.6195	0.1633	0.2463	0.2121
ZKA	65.1877	0.1761	0.2602	0.2275
ZRB	54.3775	0.1468	0.1963	0.1915
KAA	61.8373	0.1670	0.2129	0.1895
KAB	63.9013	0.1758	0.2309	0.1829
Range	54.3775 – 82.9763	0.1468 - 02242	0.1879 - 0.2688	0.1829 - 0.2537
Average	65.5973	0.1585	0.2366	0.1948
World average(UNSCEAR,2000)	< 370	< 1	< 1	< 1

The absorbed dose rate and annual effective dose

The absorbed gamma dose rates to gamma radiation in air at the ground surface for the uniform distribution of the Naturally Occurring Radionuclides (^{40}K ^{226}Ra, ^{232}Th), and Annual effective dose were calculated in Table 6

Table 6: ***The absorbed dose rate and annual effective dose for Soil samples***

Sample ID	***D (nGy/h)***	***AEDE (mSv/y)***
JPS	59.2319	0.07264
JMK	59.9945	0.07357
ABA	66.9036	0.08201
ABB	57.2475	0.07021
KCA	47.4231	0.05816
KCB	52.5878	0.06448
ZKA	56.4255	0.06918
ZRB	45.9992	0.06541
KAA	52.1060	0.06390
KAB	54.0768	0.06631
Range	47.4231 – 66.9036	0.05816 - 0.08201
Average	55.1995	0.06859
World average(UNSCEAR,2000)	60.0000	1.0000

The computed gamma dose rates ranging from 47.4231 to 66.9036(nGy/h) with all samples exhibiting values below this range except for ABA, which registered 66.2319(nGy/h). The meangamma dose rate for the soil sample was 55.15995 (nGy/h) slightly less than the55.6 (nGy/h), reported by Ademola*(*2021) and the values noted by (Innocent *et al.*, 2014) with 59.70 (nGy/h), (Sivakumar*et al.*, 2014) with 32.91(nGy/h). Additionally, this average is lower than the global recommended average of 60 (nGy/h) (UNSCEAR, 2000) aspresented in Table 6 and illustrated in figure 3. These differencescould be contributed to variations in cosmic ray levels at different sites, differences in activities, and the geochemical characteristic of the studied locations. Additionally, the annual effective dose rate, presented column 3, varied between 0.05816 to 0.08201 (mSv/y) with an average of 0.06859 (mSv/y) in the samples, this average is higher than that reported by (Usikalu*et al.*, 2014), which is 0.05 (mSv/y), and notably exceeds the global average of 0.07 (mSv/y) (UNSCEAR, 2000).

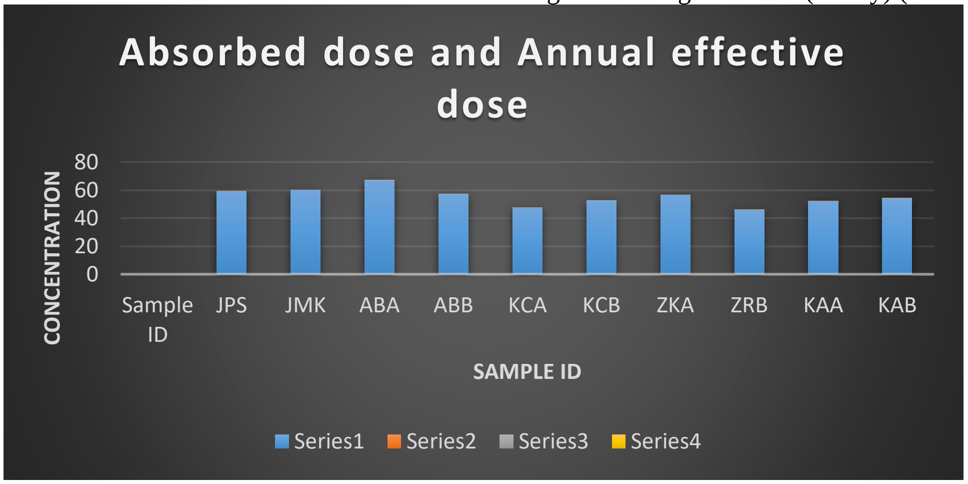

Figure 3: Absorbed dose rate and annual effective dose of the soil samples

Table 4.7 Average Activity concentration in some ountries

Country	**^{40}K(Bq/kg)**	**^{226}Ra(Bq/kg)**	**^{232}Th(Bq/kg)**
Algeria	41.00	27.00	422.00
Autralia	51.00	48.10	114.70
Austria	26.70	14.20	210.00
Bangladash	61.00	80.00	1133.00
Brazil	61.70	58.50	564.00
China	51.70	32.00	207.70
Egypt	35.00	19.00	93.00
Finland	40.20	19.90	251.00
Ghana	35.94	25.44	251.00
Greece	92.00	31.00	310.00
Italy	46.00	42.00	316.00
Japan	36.00	21.00	139.00
Malaysia	81.40	59.20	203.50
Netherlands	27.00	19.00	230.00
Norway	29.60	18.50	259.00
Pakistan	26.10	28.70	272.90
Turkey	41.00	26.00	267.00
Nigeria	44.65	13.07	227.18
Nigeria (present work)	68.38	21.76	26.98
World Average	410.00	32.00	45.00

(Ernest, 2016).

The current study compares the average activity concentration of potassium with finding from other researchers across various countries, as shown in ^{40}K, ^{226}Ra and ^{232}Thin this present work with studies

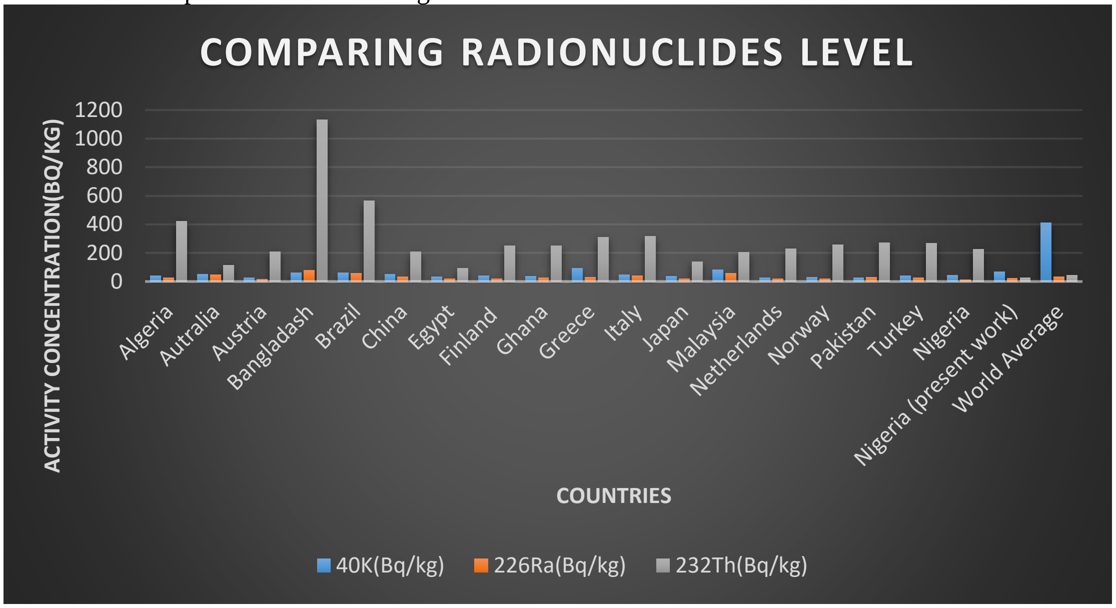

Figure4: Comparing Radionuclides level in some countries

This study evaluated the Natural Occurring Radioactive Materials (NORMs) in soil. Soil samples were collected, purified, and analyzed using gamma ray spectroscopy to detect radionuclides, and the results were then assessed to determine their levels. The average concentration of the results indicates the average activity concentration of ^{40}K in soil samples is 68.4978 Bq/Kg, which are below the global average value of 400 Bq/Kg,The average concentration of ^{226}Ra in soil samples is 21.7583 Bq/Kgwhich is below the global average value of 35 Bq/Kg,furthermore, The average concentration of ^{232}Th in soil samples is 26.9559 Bq/Kgwhich is below the global average value of 30 Bq/Kg. However ,Soil analysis revealed mean values of 54.3775 Bq/Kg, radium equivalent , 0.159 external index , 0.137 internal index, and 0.195 gamma level index for radiation hazard indices. The average dose rate of the absorbed gamma, which is below the 60 global recommended value. The average annual effective dose is 0.06859 (mSv/y) for soil samples which are lower than the world average of 0.07 (mSv/y) for all the samples type (UNSCEAR, 2000).

CONCLUSION

The radiological assessment of soils in the Kwakwachi canal area indicates that natural radionuclide concentrations and associated radiation doses are generally below international safety standards. However, continued monitoring is recommended to track any

changes due to ongoing human activity and environmental factors.

In accordance with the research conclusions, the following recommendations are suggested:

1. Exposure radiations from^{40}K, ^{232}Th and absorbed gamma dose rates can be reduced by eliminating time spend at the sites.
2. Monitor Radionuclides building in soil is essential.
3. Farmers should be advised against planting crops in areas surrounding these sites

REFERENCE

Ademola, A. K., and Adejumobi, C., (2021). Assessment of natural radionuclides and some toxic metal in vegetables cultivated around ibese and ewekoro cement industries in Ogun state, southwest Nigeria. Journal of Science and Technology Vol.13910: 57-65.

Ayila, A.E., Fabiyi, O.O., Bello, Y. and Anas, (2014). Statistical Analysis of Urban Growth in Kano Metropolis, Nigeria Journal of Environmental Monitoring andAnalysis 2(1): 50-56.

Ayodele Olumuyiwa Owolabi, Sunday Olabisi Daramola. (2025) "Assessment of the radiological health hazards around mine sites in Jos Area, Nigeria", Environmental Geochemistry and Health.

Boyang, H., Yuxinliu.,Xiaoyan, S., Lei, H., Shipeng, D and Liang, m., (2024). Risk assessment and management of Radionuclide leakage in nuclear power plants. International journal of Earth and Environmental Sciences. Vol. 4

Chijioke M Amakom, Chikwendu E Orji,Kelechukwu B Okeoma, Obi K Echendu. (2023)"Radiological Analysis of Cassava SamplesFrom a Coal Mining Area in Enugu State, Nigeria", Environmental Health Insights.

Ernest I.E., Tijjani. S.B., Dahiru G. D., Rose.A.O., and Inuwa. A. F (2016). Assessment of naturally occurring radiactive materials (Norm) along Jakara waste water canal, Kano state, Nigeria. *Dutse journal of pure and applied sciences. Vol 2:2*

G. Gurbuz (2007) "Radiological signifi cance ofcement used in building construction inTurkey", Radiation Protection Dosimetry.

Harb S., Salahel D.K, AbbadyA.andMostafa M., (2010). Activity concentration for surface Soil samples collected from Armant, Qena, Egypt. Proceed. 4thEnviron. Physics Conference 4: 10-14.

Ibeanu, I.G.E., (1999): Assessment of Radiological Effects of Tin Mining Activities in Jos Environments. PhD Thesis, Ahmadu Bello University, Zaria, Nigeria. Unpublished.

Ibeanu. I.G., Futua, I.I., Adeyemo, D.I., Bappah, A.I and Umar. I.M., (2000). Radiation monitoring programme for the Centre for Energy Research and Training (CERT) Nuclear research reactor site and environs.

Igwe, J.C., Nnorom, I.C and Gbaruko. B.C. (2019). Radionuclides and Heavy metals in soils in connection to Soil contamination and their effect on plant growth. African journal of soil science.

www.internationalscholarsjournals.org.

Innocent A. J., John O., Ali H., Onimisi M. Y., John S. A. and Nwodo N. A., (2014). Radiolgical Safety Assessment of some mine site at Gusau and envrons, Nigeria, *Advancement inScientific and Engineering Research,* 2(2): 23 – 28.

Jibiri, N.N. (2007) "Estimation of annual eff ectivedose due to natural radioactive elements iningestion of food stuffs in tin mining area ofJos-Plateau, Nigeria", Journal of Environmental Radioactivity.

Khandoker Asaduzzaman, Farhana Mannan, Mayeen Uddin Khandaker, Mohideen SalihuFarook et al.(2015) "Assessment of Natural Radioactivity Levels and Potential Radiological Risks of Common Building Materials Used in Bangladeshi Dwellings", PLOS ONE.

Kareemah, A.L., Usman, M.I., and Faiza, A. (2025). Health risk assessment of radiation exposure to radionuclides in quarry soil at Dawakin kudu Kano, Nigeria. Dutse journal of pure and applied sciences. Vol.11 doi.org/10.4314/dujopas.

Kugbere, E., Isi, Pretly, O., Amitu,O, M., Adwole. M.G and Victor, M. (2025). Assessment of Activity concentrations of Radionuclides (226-Ra, 232-Th and 40-K) and Annualmeffective dose in water and minig pits, Osun state, Nigeria. *International journal of life science research*. Vol.13 p41-47.

Laith. A.N., Zakariya, A.H., Sardar, Q.O., Taha. Y.W., Mostafa, Y.A, and Howaida, M. (2024). Radiological Impacts of Natural Radioactivity and Heavy metal of tobacco plants in Iraq Kurdistan Region. Iraq. A Journal of Pollution. DOI:https:doi.org/10.22059/ poll.2024.37522.2353

Malgorazota, W., Karol, W., and Maldelena, D (2022). Assessment of heavy metals and Radionuclides concentration in selected mineral waters available on the polish market. Journal of Applied Sciences Vol. 12, 1-17.

Mohamed, H.M.S., Heba, A.A.E., and Ahmed, M.H.I . (2024). Assessment of Radionuclides and some Heavy Metals in Environmental samples along Abuzenima, Redis coastline in Eqypt. Arab Journal of Nuclear Science And Applications.vol.589 (1), p83-97. alnsa.journals.ekh.eg.

Muhammad S. M., Bichi. T. S., and Diso. D.G. (2016). Radiological safety assessment of soil sample from some waste dumpsites in Kano metropolis. *Dutse journal of pure and applied sciences. Vol.2:2*

Namadi, A,Z., Agu, M.M and Ugbe, R.U (2925). Dosimetric Evaluation of terrestrial Gamma radiation andAssociated cancer risk in Federal University Dutsin-ma Nigeria. *Journal of Basic and Applied sciences research.* DOI:10.4314/jobasr. v312.2

Nuraddeen Nasiru Garba, Nasiru Rabi'u,Alhassan Sa'ad Aliyu, Usman Musa Kankara etal. (2023) "Evaluation of radiological risk associatedwith local building materials commonly usedin Northw estern Nigeria", Heliyon.

OECD, (1979). Exposure to radiation from natural radioactivity in building materials. Report by group of experts of Organization for Economic Cooperation, Nuclear Energy Agency, Paris – France.

Orgun, Y. (2007) "Natural and Anthropogenic radionuclides in rocks and beach sands fromEzine region (Canakkale), Western Anatolia,Turkey", Applied Radiation and Isotopes.

Olomo, J.B., Akinloye, M.K., and Balogun F.A., (1994). Distribution of gamma-emitting Radionuclide in soil and water around nuclear research establishment, Ile-Ife Nigeria, *Nuclear Instruments and Methods in Physics Section A, 353,553–557.*

Suleiman I, M Agu, M Onimisi. (2018)"Evaluation Of Naturally Occurring Radionuclide in Soil Samples from Erena Mining Sites in NigerState, Nigeria", Current Journal of Applied Science and Technology.

Seref, T., Ergin, M.A., Aytac. A., Ferhat. G., Aybaba. H., Asli. K and Muhammad. K. (2024). Dispersion of oxides, Heavy metals, and Natural radionuclides in phosphogypsum stockpiles of the phosphate industries in Turkiye. A journal of Environmental Sciences and Pollution Research. https://doi.org/10.1007s11356-36180-2.

Siyakumar. S., Chaudrasekaran. A., Ravisankar. R., Raviskumar. S.M., Prakash. J.J., Vijayagopal. P. (2014). Measurement of Natural Radioactivity and evaluation of radiation hazards in coastal sediments of east coast of Tamilandu using statistical approach. Journal of Talibah University for Science, 8(2014):375-384.

Smith, K.P., (2011): *Overview of Radiological Dose and Risk Assessment* Illinois: Environmental Science Division National Laboratory, Argonne

UNDP, (2006). Practical Action Technology Challenging Poverty. United Nation Development Programme Report. https://www.undp.org.

UNSCEAR, (2000). Radiological Protection Bulletin, United Nations Scientific Committee on the Effects of Atomic Radiation, No. 224, New York. http://www.unscear.org/report.htm.

Usikalu. M.R., Akinyemi. M.L., Achuka. J.A. (2014). Investigation of Radiation levels in Soil samples collected from selected locations in Ogun state, Nigeria. *International Conference on Environment Systems Science and Engineering,* 9 (2014) 156-161.

Z. Wang. (2011) "Natural and artificial radionuclide measurements and radioactivity assessment of soil samples in eastern sichuan province (CHINA)", Radiation Protection Dosimetry,"