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ASSESMENT OF RADIONUCLIDES AND HEAVY MEATALS IN KWAKWACHI IRRIGATION WATER CANAL IN KANO STATE NIGERIA

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ABSTRACT

Investigations were carried out to determine the presence of natural radionuclides and heavy metals in kwakwachi irrigation water canal and evaluate the hazards these toxic pollutants may have on the people living around some locations in Kano metropolis, Nigeria. The gamma-ray spectrometry setup at the Centre for Energy Research and Training, Ahmadu Bello University Zaria, Nigeria, was used to determine the concentrations of radionuclides in the soil samples randomly collected from the study area. The results show that activities of Potassium-40 range from 230.15 to 532.27 Bq/kg,Radium-226 range from 13.75 to 48.24 Bq/kg and that of Thorium-232 range from 25.68 to 131.51 Bq/kg in all the analyzed samples. However, the average values for radium equivalent, external index, internal index and gamma level index are 116.99Bq/kg, 0.381, 0.415 and 0.373, respectively, in all the samples and are lower than the suggested maximal admissible value of 370Bq/kg, 1, 1 and 1, respectively. The average value of the absorbed gamma dose rates to gamma radiations is 79.83(nGy/h) for the samples, which is higher than the recommended world average value of 60 (nGy/h). However, the average annual effective dose is 0.049 (mSv/y) in the samples, and is lower than the world average value of 0.07 (mSv/y). The analysis of the heavy metals concentration using Atomic Absorption Spectroscope (AAS) was conducted at the Department of Soil Science, Faculty of Agriculture Bayero University, Kano, indicate the presence of Chromium, Iron, Zinc, Manganese, Nickel, Lead and Cadmium in lower concentration. Heavy metal toxicity poses a real and substantial danger to the human health, and caused major health issues, heavy metal have negative effects on plant and animal production and also have accumulate in the different organs such as skeleton, liver, spleen and kidney..

Keyward: Activity Concentration, Radionuclides, Heavy Metal, Radium Equivalent, External Index. Internal Index, Gamma Level Index, Absorbed Gamma Dose rates and Annual effective dose.

INTRODUCTION

Human beings are exposed to radiation arising from sources including cosmic rays, natural radionuclides in water, air, soil and plants; and artificial radioactivity from fallout in nuclear testing and medical applications (Bichi, 2022). A radiological dose assessment calculates the amount of radiation energy that might be absorbed by a potentially exposed individual as a result of specific exposure (Smith, 2011). There are external doses and internal doses, the external doses occur when the body is exposed to radioactive materials outside the body; this is primarily concerned for gamma radiation while the internal doses occur from exposure to radioactive materials taken into the body by inhalation or ingestion. This is concerned for alpha (α) and beta (β) radiation, as well as gamma (γ) radiation (Smith, 2011). Radiation is often categorized as either ionizing or non-ionizing radiation depending on the energy of the radiated particle. In ionizing radiation, the energy is more than 10eV, enough to ionize atom and molecules and break chemical bonds Faanu,2011). This is an important distinction, due to the large differences in harmfulness to living organism. Ionizing radiation break important bimolecular structure such as DNA, thereby damaging or killing the affected cell, or in the worst-case causing cancer (Hoong, 2003).

A number of isotopes or elements found in the earth are radioactive. The average of Uranium and Thorium contents of the earth's crust has been estimated to be 1.8 and 7.2 parts per million (Pourimani, Ghahri and Zare, 2014). The environmental problem of naturally occurring radioactive materials (NORM), according to Esmeray and Aydin (2011), is omnipresent on earth and their radioactivity may become concentrated as

a result of human activities. A radionuclide is an atom with an unstable nucleus which, in a bid to become stable, emits energy in the form of rays of high-speed particles. Radioactive minerals however, are minerals that contain Uranium and Thorium as an essential component of their chemical composition. The rapid expansion of unorganized urban, industrial development coupled with inadequate waste management cause significant alterations in the physical environment and increase accumulation of municipal waste (Njagi, 2013).

On the other hand, Heavy metals are naturally occurring elements that have a high atomic weight and a density at least 5 times greater than that of water. Heavy metals also considered as trace elements because of their presence in trace concentration (ppb range to less than 10ppm) in various environmental matrices (Jarup, 2003). The rapid development in industrialization has caused tremendous increase of pollutants. These pollutants are present in concentration that cause harm to human, animal and plant lives and to non-living organisms. Environmental pollution is therefore the presence of toxic substances, naturally or due to man's activities in the environment at a level where acute toxic effect can be recognized (Higgens and Buens, 1979).

Heavy metals can enter water supply from industrial and domestic wastes, or even from acid rain breaking down soils and releasing heavy metals into streams, lakes, rivers and ground water. Anthropogenic activities also affect the natural geological and biological redistribution of heavy metals in the environment (Njagi, 2013). Such alteration often affected the heavy metal toxicity by allowing it to bio-accumulate in plants and animals, bio concentrate in the food chain or attack specific organs of the body (Hawkes, 1997). Heavy metals discharge to the environment may occur as a result of normal geological phenomena such as leaching and ore formation. Metals are released into the environment by burning of fossils, mining and application of pesticides and domestic wastes (Duffus, 1980).

Toxic metals do not occur naturally in soils but are actually carried by waste water flow from industries to rivers, streams and lakes which are used for irrigation purposes in agriculture. These heavy metals are in turn taken up from the soil by plant roots, and passed to stems and leaves, which are eventually consumed by animals and humans (Folaranmi *et al*., 2002). The main sources of heavy metals in soil is the use of urban and industrial waste water, chemical phosphate fertilizers, sludge from waste water treatment plants in cities and metal excreation mines.

The Jakara water channel is a canal which emanates at a point near Goron Dutse and stretches through Jakara community, it extends behind the abattoir area before crossing Kastina road and headed across Zungeru road and the airport road towards the direction of Minjibir. No fewer than 14 smaller drainages empty into it at different points; most significant is the waste water from the abattoir which gives the drainage its characteristic odor. The nature of waste water used for this irrigation practice has raised a lot of health concern over the past two decades considering the stench and odor it emits. The fact that this water is used to irrigate a number of vegetable farms is the problem necessitating this research, especially as products from here are sold in the open market. The reason of this research work will be useful in the determination of Radionuclide and heavy metals in the kwakwachi irrigation stream water samples. It will also disclose the level of heavy metals contaminant in the stream water sample collected from kwakwachi thereby creating awareness on the health implication of using the stream water. Study area is likely to have a severed but localized effect.

Based on the above, the objectives of the study have to do with determining the activity concentration of the natural radionuclides present in the water samples from the sites and to ascertain the absorbed dose rates and the effective dose from the exposure to the natural radionuclides and to determine the elements composition of the water samples and to document on potential toxic elements heavy metals in water sample.

METHODOLOGY

The sample collection was carried out in June, 2024. The length of the canal under consideration is a stretch of about ten kilometers. This was divided into ten sample locations, from each of which water sample and soil samples were collected at a depth of 0-5 cm into container for water and polythene bags for soil sample and labeled as P_1, P_2, P_3, P_4 *and* P_5. The precise geographic coordinates of each sample point is determined using the Global Positioning System GPS handheld device (of GARMIN product with model number: GPS map76S) and is given in table 1.

Table 1: The Geographic Location of Sample Points using GPS Reader

Sample site	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°

The soil samples were dried separately for five days to ensure that they were moisture free, after which 500 g of each soil sample was measured using a scale, and returned back to the plastic bucket and labeled appropriately.

Soil Sample Preparation for Gamma Spectrometry Analysis

The dry soil samples were crushed to fine powder with the help of pulverizer. Some Radon-impermeable cylindrical plastic containers were selected based on the space allocation or geometry (7.6 cm by 7.6 cm dimension) of the sodium Iodide detector to be used. Each container was weighed (empty) using a digital scale and recorded. The containers were each filled to the brim with the fine powder of the soil samples, triple sealed and labeled appropriately. The triple sealing involves first smearing the inner rim of each container lid with vaseline jelly, then the container was covered and the lid assembly gap was filled with candle wax, and lastly, a masking adhesive tape was wrapped round the lid several times. This prevents Radon-222 gas from escaping the container.

Finally, the sealed containers, with their contents were kept in a safe place so as to attain secular equilibrium before taking the gamma spectroscopy measurement (12 weeks and 4 days in this case).

Soil Sample Analysis for Gamma Spectrometry

The evaluation of the soil samples were carried out at the Low Background Counting Laboratory at the Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria. The measurements were made by direct non-destructive instrumental analysis with a computerized gamma spectrometry system made up of NaI(TI) detector and its assessory. The detector system consists of a vertically sealed assembly which includes the NaI(TI) crystal and is coupled to a Photo Multiplier Tube (PMT), an ORTEC Multichannel Buffers (MCBs) for data acquisition and processing using a software program produced by Camberra Nuclear Products. In order to reduce background and scattered gamma radiation from the room in which the detector is installed from entering the samples, a locally fabricated cylindrical lead shield (6 cm thickness) with a fixed bottom and a movable lid to shield the detector encloses it. Within the lead shield are also copper, cadmium and Plexiglas (3 mm thickness each) to absorb X-rays and other photons that might be produced in the lead. The ambient temperature around the detector varied between 20 oC and 27 °C during the period of measurement. The sealed container, with their contents were put into the Sodium Iodide Detector The signal that leaves the detector is made to pass through a module having 1 kilovolt external source, and which amplifies before sending it to the computer with data acquisition software called Maestro -32.

Each soil sample was measures for a period of 29000 seconds, and the signal was displayed in a graphical form on the screen. The peak area for each energy in the spectrum was obtained and used to compute the activity concentrations in each soil sample using the equation

$$c = \frac{c_n}{c_{fk}} \qquad (1)$$

Where; C is the activity concentration of the radionuclides in the samples (BqKg-1) c_n is count rate (counts per second) C_{fk} is calibration factor of the detecting system the background count rate done for 29000 seconds. The identification of individual radionuclides was performed using their gamma ray energies and the quantitative analysis of radionuclides was performed using gamma ray spectrum analysis software, ORTEC MAESTRO-32.

Elemental Analysis Procedure

The main materials used in the determination of the elemental composition of the samples is the flame Atomic absorption spectrometer (AAS) model of series. Soil samples were digested. 1 g of fine particles of dried soil sample from dumpsite was weighed into a 100ml digestion tube. Each of the tubes was labeled to avoid mix-up. 5mL each of nitric acid and hydrogen peroxide were added while SO_4 was added in small amount and the mixture was thoroughly stirred until white fumes evolved. The solution was decanted and diluted with de-ionized water up to all the samples, before metal concentrations were determined,

standard solution were prepared in each case and were used to eliminate sample standard matrix in differences, the instrument was calibrated for all the measurement carried out using de-ionized and standard solution; these standard solution are different for different elements. The concentration of the sample were obtained from the readily of AAS in eqn (1)

$$Concentrationofsample = \frac{AASreadilyx\ 100}{Weightofsample} \quad \text{.....(1)}$$

Theoretical Calculations

1. **Activity**

The activities of the natural radionuclides in the measured samples were computed using the relation (Ibeanu, 1999; Innocent *et al.,* 2014):

$$A_C = \frac{N_c}{Lt}\sigma^{-1} \qquad (2)$$

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.

2. Radium Equivalent Activity

The significance of ^{40}K, ^{226}Ra and ^{232}Th concentrations, with respect to radiation exposure is expressed in terms of radium equivalent activity (Ra_{eq}), which can be evaluated using Equation 2 (Beretka and Matthew, 1985; Innocent *et al.,* 2014). According to (OECD, 1979), the maximum value of Ra_{eq} must be less than 370 $Bq.kg^{-1}$ for the radiological effect to be considered negligible.

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

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).

3. External Hazard Index

External radiation hazard index (H_{ex}) is a widely used hazard index which reflects the external exposure level due to gamma radiation. It was estimated from the relation (UNSCEAR, 2000):

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

4. Internal Hazard Index

In addition to H_{ex}, the internal exposure to radiation was quantified by the internal hazard index (H_{in}) as defined by (UNSCEAR, 2000):

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

5. Gamma Level Index

The representative level of gamma index is (I) was calculated using the following equation (UNSCEAR, 2000):

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

According to UNSCEAR (2000), for radiological effects to be considered negligible, the values of each of H_{ex}, H_{in} and I must be less than 1.

6. Absorbed Dose Rates

The external absorbed dose rates were calculated using the equation (UNSCEAR, 2000):

$$D = 0.0417A_k + 0.462A_U + 0.604A_{Th} \qquad (7)$$

Where A_K, A_U 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.

7. Annual Effective Dose

To estimate the annual effective dose, the conversion coefficient (0.7Sv/Gy) and outdoor occupancy factor (0.2) as proposed by (UNSCEAR, 2000) were used. Therefore, the annual effective dose was calculated from the relation:

$$E_d = D(nGy.hr^{-1})x\ 8760(hr.y^{-1})x0.2x(0.7x10^3mSv)x\ (10^9nGy)^{-1} \qquad (8)$$

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

8. Enrichment Index

A common approach to estimate how much the soil is impacted (naturally and anthropogenically) with heavy metal was to calculate the Enrichment Factor (EF) for metal concentrations above un-contaminated background levels (Fagbote and Olanipekun, 2010):

$$EF = \left[\frac{C_{metal}}{C_{normalizer}}\right]_{soil} \Big/ \left[\frac{C_{metal}}{C_{normalizer}}\right]_{control} \quad (9)$$

Where Cmetal and Cnormalizer are the concentrations of heavy metal and normalizer in soil and in unpolluted control. . Five contamination categories are recognized on the basis of the enrichment factor as follows (Sutherland, 2000; Fagbote and Olanipekun, 2010):

1. EF < 2 is deficiency to minimal enrichment
2. EF 2-5 is moderate enrichment
3. EF 5-20 is significant enrichment
4. EF 20-40 is very high enrichment
5. EF > 40 is extremely high enrichment

As the EF values increase, the concentrations of the anthropogenic origins also increase (Sutherland, 2000; Fagbote and Olanipekun, 2010).

9. Geo Accumulations Index (I_{geo});

Index of Geo-accumulation (Igeo) has been used widely to evaluate the degree of metal contamination or pollution in terrestrial, aquatic and marine environment (Tijjani and Onodera, 2009). The Igeo of a metal in soil was calculated with formula (Medolla *et al.,* 2008; Fagbote and Olanipekun, 2010):

$$I_{geo} = Log_2\left[\frac{C_{metal}}{1.5 \times C_{metal\ (control)}}\right] \quad (10)$$

Where Cmetal is the concentration of the heavy metal in the enriched sample and Cmetal(control) is the concentration of the metal in the unpolluted sample or control. The factor 1.5 is introduced to minimize the effect of the possible variations in the background or control values which may be attributed to lithogenic variations in the soil (Medolla *et al.,* 2008; Fagbote and Olanipekun, 2010). The degree of metal pollution is assessed in terms of seven contamination classes based on the increasing numerical value of the index as follows (Huu and Damme, 2010; Fagbote and Olanipekun, 2010):

Igeo <0	means unpolluted
0≤Igeo<1	means unpolluted to moderately polluted
1≤Igeo<2	means moderately polluted
2 ≤ Igeo<3	means moderately to strongly polluted
3 ≤ Igeo<4	means strongly polluted
4 ≤ Igeo<5	means strongly to very strongly polluted
Igeo ≥ 5	means very strongly polluted.

RESULTS AND DISCUSSION

The concentration of radionuclides in the soil sample is showing in the table 2

Table 2: Concentration (Bq $Bq\ kg^{-1}$) of radionuclide in the soil sample of kwakwachi irrigation water canal.

Sample code	***K-40 (Bq/kg)***	***Ra-226 (Bq/kg)***	***Th-232 (Bq/kg)***
P_1	328.27 ± 3.84	28.24 ± 3.10	32.12 ± 0.82
P_2	230.15 ± 3.89	25.10 ± 3.16	25.68 ± 0.91
P_3	532.27 ± 5.30	48.24 ± 4.63	52.67 ± 0.19
P_4	510.50 ± 3.27	12.75 ± 2.55	50.08 ± 1.25
P_5	321.70 ± 3.58	13.75 ± 2.09	131.51 ± 1.12
Range	230.15 – 532.27	12.75 – 48.24	25.68 – 131.51
Average world range	140 - 850	17 - 60	11 - 64
World average	100	35	30

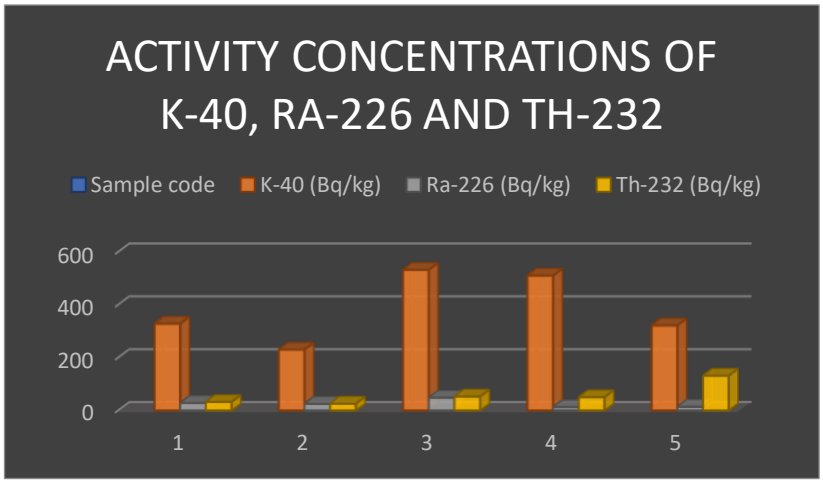

Figure 1: Activity of ^{40}K, ^{226}Ra and ^{232}Th of the samples

Table 3: ***Radium Equivalent, External Index, Internal Index and Gamma Index***

Sample code	***Ra(eq) (Bq/kg)***	***Hex***	***Hin***	***I***
P_1	99.45 ± 4.60	0.268	0.316	0.364
P_2	81.08 ± 4.76	0.215	0.282	0.288
P_3	164.54 ± 6.17	0.444	0.590	0.600
P_4	136.32 ± 4.59	0.369	0.648	0.512
P_5	226.58 ± 3.84	0.612	0.240	0.810

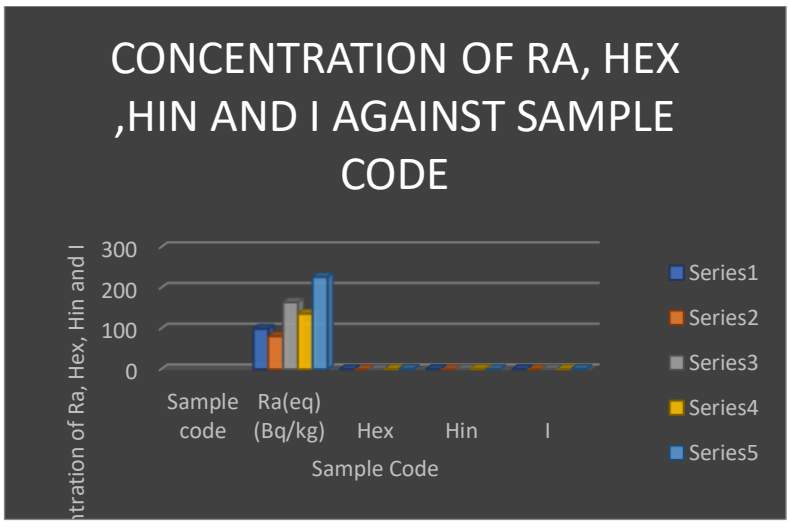

Figure 2: ***Radium Equivalent, External Index, Internal Index and Gamma Index***

Table 4: The Absorbed Dose Rate Annual Effective Dose

Sample code	*D (nGy/h)*	*Ed mean (mSv/y)*
P_1	44.44 ± 2.10	0.054
P_2	121.57 ± 2.17	0.014
P_3	73.04± 2.84	0.089
P_4	61.75 ± 2.07	0.075
P_5	98.37 ± 1.74	0.012

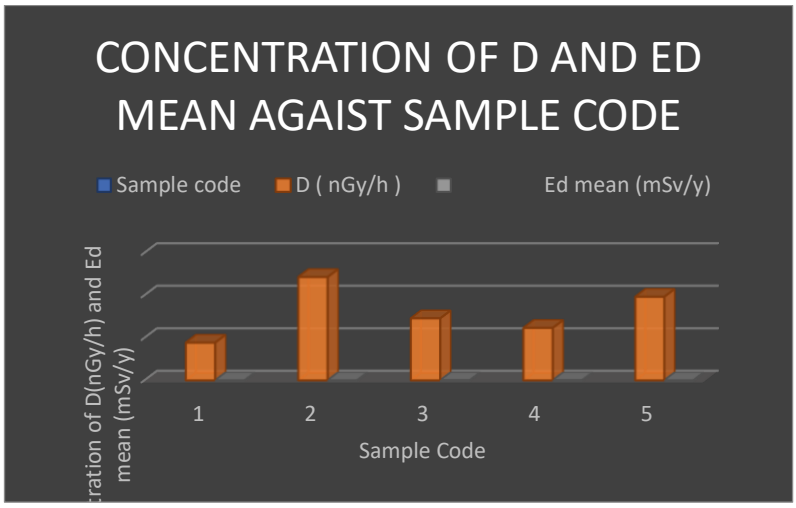

Figure 3: The Absorbed Dose Rate and Annual Effective Dose

Table 5: pH, EC_{et}, Concentration of heavy metals in Water Analysis Results

Description	Sample Code	**EC (ms/cm)**	**Cd (mg/l)**	**Cr (mg/l)**	**Cu (mg/l)**	**Ni (mg/l)**	**Pb (mg/l)**	**Zn (mg/l)**	**Fe (mg/l)**
Katsina road a	P_1	2.41	0.01	0.31	0.02	0.05	0.05	0.04	0.22
Katsina road b	P_2	2.33	0.01	0.16	0.02	0.02	0.10	0.04	0.21
Jakara police st a	P_3	2.58	0.01	0.30	0.00	0.05	ND	0.02	0.17
Jakara police st b	P_4	2.21	0.01	0.23	0.60	0.06	0.04	0.16	0.24
Zangero road a	P_5	2.31	0.01	0.29	0.06	0.07	ND	0.06	0.33
Zangero road b	P_6	2.17	0.02	0.28	0.02	0.04	0.02	0.03	1.09
Kwakwachi c a	P_7	2.58	0.01	0.16	0.02	0.03	0.16	0.03	0.27
Kwakwachi c b	P_8	2.13	0.02	0.21	0.05	0.05	0.13	0.02	0.25
Aboittoir a	P_9	2.38	0.02	0.24	0.06	0.03	0.25	0.04	0.21
Aboittoir b	P_{10}	2.61	0.01	0.17	0.05	0.03	0.09	0.04	0.21

Table 6: The enrichment factor of heavy metal in kwakwachi irrigation water irrigation canal

Sample Location	Sample Code	Cd	Cr	Cu	Ni	Pb	Zn
Katsina Road A	P_1	1.3637	8.4548	0.0273	0.9740	1.3636	0.0191
Katsina Road B	P_2	1.4286	4.7514	0.0285	0.4682	2.8571	0.0114
Jakara Police Station A	P_3	1.7647	10.5886	0.0000	1.2605	0.0000	0.0071
Jakara Police Station B	P_4	1.2500	5.7500	0.7500	1.0716	1.0000	0.0100
Zangero Road A	P_5	0.9092	5.2727	0.0545	0.9091	0.0000	0.0109
Zangero Road B	P_6	0.5505	1.5413	0.0055	0.1573	0.1101	0.0016
Kwakwachi Market A	P_7	1.1111	3.5555	0.0222	0.4762	3.5555	0.0067
Kwakwachi Market B	P_8	2.4002	5.0400	0.6600	0.8572	3.1200	0.0048
Abattoir A	P_9	2.8574	6.8574	0.0857	0.6123	7.5003	0.0115
Abattoir B	P_{10}	1.4286	4.8372	0.0714	0.6123	2.5714	0.0114

Table 7: Geoaccumulation index of heavy metal in kwakwachi irrigation water canal

Sample Location	Sample Code	Cd	Cr	Cu	Ni	Pb	Zn	Fe
Katsina Road A	P_1	1.0473	2.0473	-6.2288	-1.0703	-0.5851	-7.5616	-1.0327
Katsina Road B	P_2	-3.9070	0.0931	-6.2288	-1.0703	0.4150	-7.5516	-1.0997
Jakara Police Station A	P_3	-3.9070	1.999	0.0000	-1.0703	0.0000	-8.5543	-1.4000
Jakara Police Station B	P_4	-3.9070	1.6163	-1.3219	-0.8073	-0.9068	-5.5509	-0.9668
Zangero Road A	P_5	-3.9070	1.9510	-4.6438	-0.5849	0.0000	-6.9657	-0.4475
Zangero Road B	P_6	0.4150	1.9510	-6.2288	-1.3923	1.0931	-7.9657	1.2762
Kwakwachi Market A	P_7	0.4150	1.0931	-2.9669	-1.8074	1.0931	-7.9657	-0.7360
Kwakwachi Market B	P_8	-3.9070	1.4854	-4.9070	-1.0704	0.7935	-8.5511	-0.8481
Abattoir A	P_9	0.4150	1.6781	-4.6438	-1.8074	1.7369	-7.5508	-1.0995
Abattoir B	P_{10}	0.4150	1.1802	-4.9070	-1.8074	0.2630	-7.5508	-1.0995

CONCLUSION

Based on our findings, the average activity concentration of Potassium-40, Thorium-232 and absorbed gamma dose rate to gamma radiation observed in this study is lower suggesting it may have a reduced impact on the residents living in those areas. However, the overall findings of the research are indicating a degree of radiological concern in the area, while the calculated hazard indices are low, there is a possibility that extended period of daily exposure could lead to chronical biological effects for the general public over time., The impact of anthropogenic heavy metal pollution in the sampling site was evaluated using Enrichment factor concentration and Geoaccumulation index this show that the study area fails under nil to very low contamination calculation of Enrichment factor and Geoaccumulation indices the study area is regarded as non-polluted.

Recommendation

Based on the conclusion drawn, the researcher made the following recommendations:

1. The radiations (^{40}K, ^{232}Th and absorbed gamma dose rates) must be reduced by limiting the time spent in the sites.
2. Monitoring the accumulation of these radionuclides (^{40}K, ^{226}Ra and ^{232}Th) and heavy metals in the soil and water from the sites is very important.
3. The practice of cultivating the land around these sites for planting legumes and vegetable by farmers must be discourage to prevent the carrying of these toxic metals into human system.
4. As a result of the above, the government should put in place certain monitoring processes and empower relevant institutions such as the ministry of environment and REMASEB that deal with solid waste disposal at the metropolis level, to be able to assess solid waste disposal practices and impose penalties if good practices are not followed in the disposal of solid waste.

The following areas are recommended for future research:

1. Samples of water sources (tap water, borehole) in this study area should be taken for analysis to ascertain the level of radionuclides and heavy metals.
2. Samples of Building materials in this study area should be taken for analysis to determine the radionuclides and heavy metal levels.
3. Vegetables, Legumes, Crops samples such as tubers and cereals grown around dumpsites should be analysed to assess the level of radionuclides and heavy metal levels.

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