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Full Length Research Article

DETERMINATION OF GROSS ALPHA AND BETA RADIOACTIVITY CONCENTRATION ALONG JAKARA WASTE WATER CANAL, KANO METROPOLIS, KANO STATE, NIGERIA.

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ABSTRACT
This research undertook an assessment of the radioactivity level along the Jakara waste water canal. Six soil samples and five water samples were taken for gross alpha and beta activity concentration using the gas–flow–proportional counter (IN20). Results for gross alpha activity concentration for the soil samples range from 4.597E-03 Bq/g to 1.425E-02 Bq/g, while that of gross beta activity for soil has the range from 3.341E+01 Bq/g to 8.092E+01 Bq/g. In the same vein, results for gross alpha activity concentration for the water samples have the range from 6.035E-03 Bq/L to 1.433E+00 Bq/L while the value for the gross beta activity concentration ranges from 5.038E+00 Bq/L to 2.853E+01 Bq/L for the same water samples. These results show that the alpha and beta activity concentration in the analysed samples are higher than the minimum permissible concentration by World Health Organisation (WHO, 2003). This may pose health risk because the waste water is used by people to irrigate vegetables along the waste water canal.

Keywords: Background Radiation, Activity Concentration, Gross Alpha, Gross Beta

INTRODUCTION

The human environment is radioactive. Consequently, human beings are constantly exposed to radiation arising from sources including cosmic rays, natural radionuclides in water, air, soil and plants: other sources include artificial radioactivity from fallout in nuclear testing and medical applications.

While radiation is the transfer of energy via electromagnetic waves travelling at the speed of light and requiring no medium, ionizing radiation consists of energetic subatomic particles, ions or atoms carrying enough energy to liberate electrons from atoms or molecules of the medium thereby ionizing them. According to Avwiri and Agbalagba (2007), there is a continuous bombardment of man and his environment by these ionizing radiations. Some of these radiations reach the earth's surface, with most entering near the poles where shielding by the earth's magnetic field is weakest, and at high altitudes where the earth's atmosphere is thinnest (Health Physics Society, 2012). Three major types of ionizing radiation are alpha particles, beta particles and gamma rays. They are invisible and not directly detectable by human senses; hence, radiation detection instruments are required. A gross alpha test is the first step in determining the level of radioactivity in drinking water (Fasae, 2013). Alpha and beta emission are often accompanied by gamma emission, as an excited nucleus drops to a lower and a more stable energy state (Helmenstine, 2015).

From the beginning, life has evolved in the presence of natural background ionizing radiation. Bavarnegin *et al*. (2013) stated that life evolved in an environment with higher radiation levels than exist today, and background radiation levels today are lower than at any time in the history of life on earth.

Radioecology is the study of the fate and effects of radioactive materials in the environment. An important component of radioecology is concerned with the assessment and prediction of the movement and concentration of these radioactive contaminants in the environment in general, and particularly in food chains that may lead to humans. Primary concern is focused on agricultural pathways through which a radionuclide may enter the human food chain through crop plants or other products of domestic livestock (Encyclopedia of Science and Technology, 2007).

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) noted that this may not appear until many years after the radiation dose is received, typically 10 – 40 years.

Alpha and beta emitters are considered the most important with respect to the potential internal radiation exposure to humans (Faanu *et al*., 2016). According to Avwiri *et al*. (2011), over 60 radionuclides can be found in nature and they are classified into three general categories:

- **Primordial:** formed before the creation of the earth
- **Cosmogenic:** formed as a result of cosmic ray interactions
- **Artificial Radionuclide:** enhanced or formed due to human actions or activities

Also, Canadian Nuclear Safety Commission (2013) identified four major sources of natural radiation: Cosmic radiation, Terrestrial radiation, and intake from naturally occurring radionuclides through inhalation and ingestion. Background radiation is said to be the radioactivity level from natural radionuclides, especially as it depends on the amount of radioactive materials in the

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environment. Mohammed and Mazunga (2013) stated that the background radiation can be high if the environment is polluted either from man-made or natural activities. It can also be high in regions with deposits of mineral resources.

Very large quantity of waste water is being discharged into this Jakara canal all along its length, making the water in the canal very polluted and having an offensive odor. The fact that water from this channel is used to irrigate a number of vegetable farms beside it, and those vegetables harvested there are being sold to the general public at the open market necessitates this research in order to assess how radioactively safe the crops produced here are.

MATERIALS AND METHODS

Materials

The materials used for this investigation include; a plastic cup with handle, plastic funnels, masking tape, five plastic jars, six plastic buckets, polythene bag, a GPS reader, a hand trowel, a shovel and a cutlass, beaker, concentrated trioxonitrate (v) acid, distilled water, Acetone, Vinyl acetate, hot plate, thermometer, Ceramic dish, electronic weighing scale, desiccators, and a gas-flow-proportional counter (Eurysis Measure – IN20),

Sample Collection

The sample collection was done in two batches; the first batch was carried out in October 2015. The length of the canal under consideration was a stretch of about ten kilometers. This was divided into five sample locations, from each of which water samples were obtained and labeled as W_1, W_2, …W_5 for the water samples respectively. Each sample was placed in a polythene bag and tied as soon as it was collected.

Each water sample was fetched from the canal using a plastic cup, poured into a plastic jar using a plastic funnel, then firmly covered and labeled appropriately and put in a polythene bag.

The second batch of sample collection took place in February, 2016. Here, six soil samples were collected and labeled S1A, S1B, S3A, S3B, S5A and S5B with their sample locations described in table 3.1 accordingly. The samples with "A" labels were all collected at a depth of 50cm below the soil surface, while all samples with "B" labels were fetched at a depth of 100cm. This brings to 10 the total number of samples analysed.

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 the table below.

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

DESCRIPTION	SOIL		WATER	
	SAMPLE CODE	GEOGRAPHICAL LOCATION	SAMPLE CODE	GEOGRAPHICAL LOCATION
Near Goron Dutse	S1A &S1B	N11.99453° E008.50012°	W1	N11.99412° E008.50036°
Near Jakara Police Station			W2	N12.00109° E008.5093°
Beside the abattoir	S3A&S3B	N12.01135° E008.52213°	W3	N12.0111° E008.52223°
Beside Kastina road bridge			W4	N12.01457° E008.52485°
Beside airport road bridge	S5A&S5B	N12.03449° 008.53587°	W5	N12.03444° E008.5358°

20ml of concentrated trioxonitrate (v) acid was added to 2 litres of each water sample in the jar. It was then covered and properly shaken, after which it was kept for onward transport to the laboratory at CERT, Ahmadu Bello University, Zaria for further procedures.

Water Sample Preparation

At the instrumentation laboratory, the beakers were properly washed and rinsed with distil water, after which they were sterilized using Acetone. Each beaker is again rinsed twice with a little quantity of the water sample to be analysed, then 1000ml of the water sample was poured into the beaker, which is in turn set on a hot plate in a fume cupboard and allowed to evaporate at a temperature of 50°C to 60°C. The beaker is left open without stirring to avoid excessive loss of the residue.

Plate I. Picture of the Jakara Water Canal at the Peak of Dry Season

Plate II. An Irrigation Farm beside the Canal near the Airport Road Bridge

When the water in each beaker remained about 50ml, it was transferred to a pre-weighed ceramic dish where the sample was finally evaporated to dryness using a hot plate. The ceramic dish is weighed again after cooling and the weight of the residue is obtained by subtracting the previous weight of the empty dish. A few drops of Acetone were added to the dry residue in order to sterilize it. It was then stored in a desiccator and allowed to cool, thereby prevented from absorbing moisture.

The volume of water which gave the total residue was obtained from the relationship:

$$V = \frac{V_w}{TR \times RP} \quad (1)$$

Where: V_w is the volume of water evaporated
TR is the total residue obtained
RP is the residue transferred to the planchet

Water Sample Analysis

The procedures for the water samples were carried out at the Gross Alpha and Beta Laboratory. Exactly 77mg of the dry residue is fetched and weighed, then spread on the stainless - steel planchet to have a uniform surface. A few drops of Vinyl acetate were put on the samples to make them stick to the planchets and prevent scattering of the residue during counting. Those planchets were then set on the eight channeled gas-filled proportional counter which counts for the Gross alpha and beta radioactivity concentration in the sample.

Counting: The counting equipment is an eight channel gas-flow-proportional counter (Eurysis Measure – IN20). Each counter channel has a window thickness of 450μgcm^{-3} and a diameter of 60mm. The chambers are covered with Lead whose thickness can be varied. The detectors are operated within the radiation environment of < 101μradh^{-1}. The system is connected to a microprocessor loaded with a spread sheet program (Quarttro-pro) and graphic programme (multiplan).

The system can be operated at a bias voltage of ~1100V with P10 gas (Argon-methane mixture in the ratio of 90% to 10%). The operational modes used for the counting were the α-only mode for the alpha counting and the β (+α) mode for the beta counting. The alpha standard was ^{239}Pu with a half-life of 24110 years, while the beta standard was ^{90}Sr with a half-life of 28 years.
The procedure involves entering the present time, number of cycles and the counting (operational) voltages. Also the counter characteristics (channel efficiency and background count rate), volume of sample used and sample efficiency were entered. The sample efficiency was calculated as:

$$Sample\ Efficiency = \frac{Mass\ of\ residue\ transfered\ to\ planchet}{0.077g} \times 100\% \quad (2)$$

Gross alpha counting: For gross alpha counting the high voltage was set at 1600 volts and samples were counted for 3 cycles of 3600 sec per cycle. The results were displayed as raw counts, count rate (count/min) activity and standard deviation. The data were acquired for alpha only mode and the alpha count rate as well as alpha activity were calculated using the formula:

$$Count\ rate\ of\ \alpha(countsec^{-1}) = \frac{Raw\ \alpha\ count \times 60}{count\ time\ (sec)} \quad (3)$$

$$Alpha\ activity = \frac{(\alpha\ count\ rate - Background\ count\ of\ \alpha) \times \alpha\ unit\ coefficient}{\alpha\ Channel\ efficiency \times \alpha\ sample\ efficiency \times sample\ volume} \quad (4)$$

Where, (α) unit coefficient (1.67×10^{-2}) is the conversion factor from cpm to cps as 1cps = 1Bq.

Gross beta counting: The high voltage for gross beta counting was set at 1700 volts and samples were counted for 3 cycles of 3600 sec per cycle in beta only mode. The count rate and the activity were calculated using the formula

$$Count\ rate\ of\ \beta(countsec^{-1}) = \frac{Raw\ \beta\ count \times 60}{count\ time\ (sec)} \quad (5)$$

$$Beta\ activity = \frac{(\beta\ count\ rate - Background\ count\ of\ \beta) \times \beta\ unit\ coefficient}{\beta\ Channel\ efficiency \times \beta\ sample\ efficiency \times sample\ volume} \quad (6)$$

Alpha-activity: The alpha activity is expressed as activity concentration C in Becquerel per liter (Bq L^{-1}). The activity concentration C is calculated using formula.

$$C = \frac{R_b - R_o \times a_s \times m \times 1.02}{R_c - R_o \times 1000 \times V} \quad (7)$$

Where, R_b is observed sample count rate (s^{-1}), a_s is the specific activity of the alpha standard, V is the volume of the sample evaporated in liter and m is the mass in mg of the residue from volume V and the factor 1.02 is included to correct for 20ml of nitric acid added per liter as a stabilizer.

Beta-activity: The gross beta activity is expressed as activity concentration C in Bq L^{-1} calculated as:

$$C = \frac{R_b - R_o \times a_s \times m \times 1.02}{R_c - R_o \times 1000 \times V} \times \frac{14.4}{1000} \quad (8)$$

Where, $\frac{14.4}{1000}$ represent the specific activity of ^{40}K in KCl, all other terms have their usual meanings.

Soil Sample Preparation

Both soil and sediment samples were dried in an oven at 80^{o}C for 12 hours until the moisture could not be further removed as constant weights were attained, then grinded with mortar. The samples were sieved through a stainless steel sieve (75 μm) and reduced to powder for palleting. Each pallet was transferred into a 2 inch diameter stainless steel planchete in the detector and then counted for gross alpha and beta radioactivity.

Soil Sample Analysis

The sample efficiency for the soil samples was computed using;

$$Sample\ Efficiency = \frac{recovered\ mass\ after\ pallet\ was\ formed}{Initial\ mass\ of\ the\ sample\ in\ powdery\ form} \times 100\% \quad (10)$$

The error associated with the sample activity was computed using;

$$E_r = \frac{\left(B + \frac{(100000)^2}{T_{bgd}} \times G\right)^{\frac{1}{2}}}{100000} \times \frac{U}{H \times S \times V} \quad (11)$$

Where;
B is the sample raw count.
T_{bgd} is the background count time
U is the unit coefficient (1.67 × 10^{-2})
H is the channel efficiency,
S is the sample efficiency
S is the sample volume or mass
G is the background count of Alpha or Beta particles
All these are programmed in the computer system software which converts the count into activity and it is printed as the result.

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RESULTS

The results obtained from the analysis of the Gross alpha and beta radiation for water samples as well as that of soil samples are displayed below in table 2 and table 3 respectively.

Table 2: Results of Gross Alpha and Beta Radioactivity of Water Samples

Table 3: Results of Gross Alpha and Beta Radioactivity of Soil Samples

Sample ID	Alpha Activity Bq/g	Error ±	Beta Activity Bq/g	Error ±
S1A	1.425E-02	6.33E-03	1.107E+01	3.51E-01
S1B	1.122E-02	5.91E-03	3.652E+00	3.15E-01
S3A	1.047E-02	4.19E-03	3.341E+01	3.38E-01
S3B	1.202E-02	5.78E-03	4.882E+01	5.02E-01
S5A	4.597E-03	4.05E-03	8.092E+01	5.62E-01
S5B	1.351E-02	6.75E-03	1.362E+01	4.33E-01
Average	1.10111666666E-02	5.50166E-03	3.19153333333E+01	4.16833333E-01

Background Detector

	cpm	Efficiency
Beta:	92.70	42.06%
Alpha:	0.07	87.95%

DISCUSSION

The results of the sample surveys displayed in the tables above are discussed in this session. This discussion made use of graphical charts where necessary in order to give a pictorial view of those variables tested.

Gross Alpha and Beta Results for Water Samples

Water samples from the canal exhibit gross alpha activity concentration values which range from 0.006035Bq/L near the bridge along the Airport road to 1.43297Bq/L near the abattoir and having a calculated average value of 0.504399Bq/L as shown in table 2 above. The gross beta activity concentration ranges from 5.03812Bq/L near the bridge along Kastina road to 28.53Bq/L at the beginning point of the canal not far from Goron Dutse with an average value of 16.237624Bq/L. The chart in figure 1 below compares the activity concentration result for alpha with the WHO (2003) limit for drinking water.

Two out of the five water samples analysed (W2 and W5) tested lower in activity concentration values than the WHO (2003) recommended level while the remaining three samples have shown to have higher values. In the case of gross beta radioactivity, test results show that the activity concentrations of all the water samples are higher than the WHO limit. The average gross alpha activity concentration in the water sample is 504.399% higher than the WHO (2003) 0.1Bq/L recommended level, while the mean gross beta activity concentration is 1623.7624% higher than the WHO (2003) recommended level of 1.0Bq/L.

Generally, radiation exposure due to gross alpha is of greater concern than that due to gross beta for natural radionuclide. This is due to the high Linear Energy Transfer (LET) nature of alpha particles which gives them the ability to deposit larger amount of energy within a small distance in a medium.

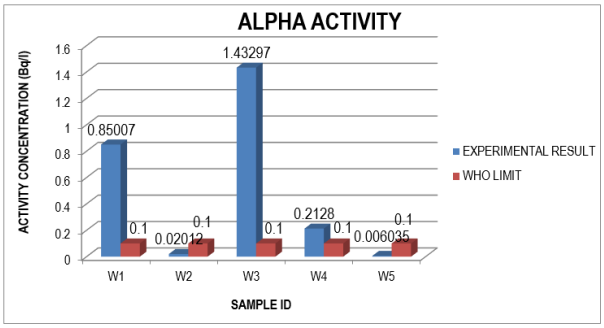

Figure1: Comparison of Alpha Activity Concentration of Experimental Results of Water Samples with WHO Limit

A similar comparison was also made for activity concentration of beta radiation with WHO limit for water in figure 2 below. Hence, it could be inferred from the column Charts of figure 1 and figure 2 that some alpha activity concentrations as well as all the beta activity concentrations for the water samples are far beyond the WHO (2003) limit.

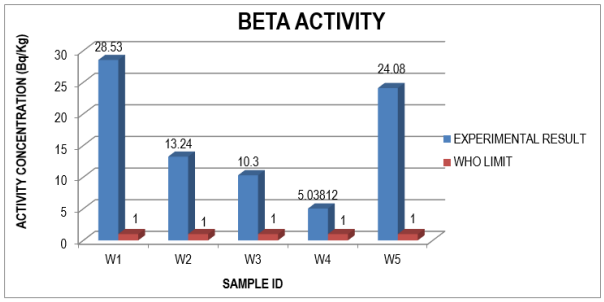

Figure 2: Comparison of Beta Activity Concentration of Experimental Results of Water Samples with WHO Limit

Gross Alpha and Beta Results for Soil Samples

The values of gross alpha radioactivity originating from these alpha emitters in the soil depends on the geological characteristics of the area, the content of mineral component and the type of human activities in the area. The analysis of Gross alpha and beta activity concentration for the soil samples gave rise to table 3 above.

It has been observed from these results that in most cases, the values of alpha activity concentrations for samples collected with sample ID of A; at a depth of 50 cm below soil surface are higher than values for samples collected with sample ID of B, fetched at a sub - surface depth of 100cm. This could possibly indicate that the contaminant alpha emitters in this study area may not have originated from the geological formation of the area but rather brought along by the polluted water whose level varies with the season and can overflow during the raining season and also is used to water the vegetable farms beside the canal.

A comparison of the gross alpha activities between the water and the soil samples were done with the aid of another chart below.

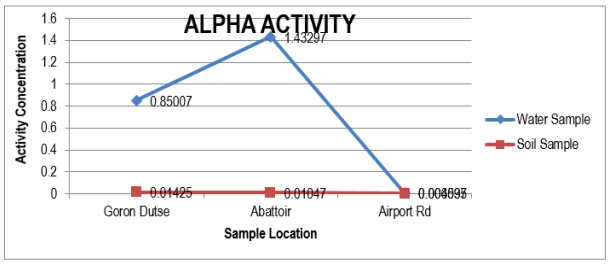

Figure 3: Comparison of Alpha Activity Concentration of Water Samples with that of Soil Samples

It becomes clear from the above line graph that the Alpha activity concentrations for water samples are far higher in this study area than for soil samples. This could also imply that most of the alpha emitters are more present in the water than in the soil. The gross alpha radioactivity concentration in soil is the total radioactivity of all alpha emitters, which in this case could mainly be due to Uranium, Radium and Thorium isotopes.

The gross beta radioactivity in soil is due to the natural long lived isotopes like ^{40}K, ^{210}Pb and ^{228}Ra. Others are artificial isotopes, such as ^{90}Sr and^{137} Cs.

Another comparison is of the beta activity concentration between the water and the soil sample. The line graph below shows this information. Here it becomes clear that the Beta activity concentrations for soil samples are higher than that of water samples except for near Goron Dutse where the value for water sample is higher.

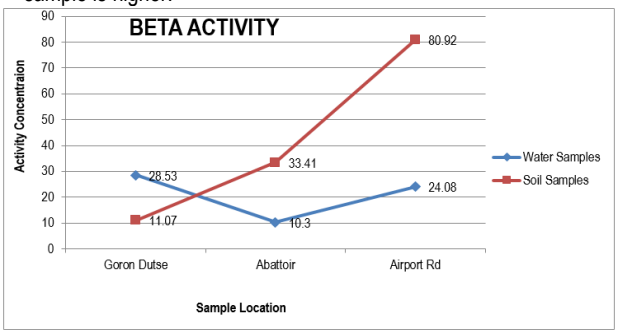

Figure 4: Comparison of Beta Activity Concentration of Water Samples with that of Soil Samples

Lastly, we also compared the Gross Alpha activity concentration with the Gross Beta activity concentration for water sample as shown in the line chart below.

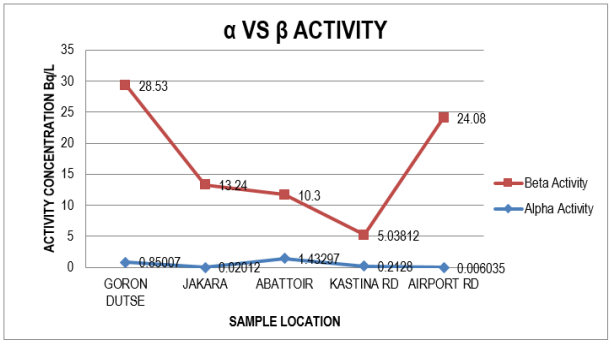

Figure 5: Comparison of Alpha versus Beta Activity Concentration of the Water Samples

Figure 4 above shows that the alpha and beta activity concentration of the samples are not uniformly distributed. This none – linear distribution of alpha activity and beta activity along the canal could be an indication that the cause of the elevated naturally occurring radioactive metals is not strictly from the geological constituent, but may have been due to modification and degradation due to human activities in that area. This can be explained by the human activities of discharging their waste directly into the canal. Such human activities might include use of fertilizer, drilling, burning of fossil fuel and dumping of large amount of waste materials in sites without adequate soil protection measures (Ogundare and Adekoya, 2015).

Conclusion

The main target of this study was to determine the gross alpha and beta activity level of this Jakara canal. The method adopted in the analysis is the gross alpha and beta radioactivity measurement for water and for soil samples using the eight channel gas-flow-proportional counter called Eurysis Measure – IN20.

The result reveals a higher level of gross alpha and gross beta activity than the WHO (2003) standard limit in many of the sample locations. More so, the fact that the alpha activity concentration for water samples are far higher than for soil samples, as revealed in figure 3, is a pointer that the alpha emitters are more abundant in the polluted water than in the soil. The overall result of this research shows a level of radiological pollution of the area. This has become an issue of serious concern because the polluted water from the canal is being used on daily basis to water a long stretch of vegetable irrigation farms along the edge of the canal. Likewise, the several herds of cattle which follow the edge of this canal on daily basis as their grazing route might possibly have been ingesting contaminated plants, soils or water. Hence, those vegetable products of the farms which are sold in the open market may not be radioactively safe. Therefore, The Jakara water canal, if left the way it is, could pose a severe radiological burden to the entire populace

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