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Material Analysis of Gross Alpha and Beta activity in Drinking Water and Untreated Sewage Soil in Hanwa, Sabon Gari, Zaria, Kaduna State

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Abstract
*Radioactivity measurement was carried out in water and sewage soil in Hanwa, Sabon-gari LGA, Kaduna State. Sewage soil and water samples each collected from **six** (6) different locations of the area were analyzed using proportional counter technique. The six (6) soil samples were analyzed for gross alpha and beta activity with an average values of 0.04041±0.01124, 0.03757±0.01114, 0.02093±0.01022, 0.02736±0.010710.03475±0.01110 and 0.0210±0.0088Bq/g for gross alpha and 0.00676±0.01324, 0.07515±0.01591, 0.04826±0.01486, 0.03503±0.01459, 0.05392±0.01531 and 0.0543±0.0131Bq/g for beta, for the six different locations, respectively. Also thesix (6) water samples were analyzed for gross alpha and beta activity with an average values of 0.10934±0.01370, 0.07645±0.01985, 0.00496±0.00506, 0.01108±0.00784, 0.07303±0.01085 and 0.062913±0.00975Bq/L for alpha and 0.09054±0.02345, 0.00000±0.02686,0.00000±0.00684, 0.01235±0.01134, 0.03225±0.01833, 0.03473±0.01724 Bq/L for beta, for the six different locations, respectively. The overall results showed that the activity concentrations of all locations are within the typical world average values of 0.5Bq/L and 1.0Bq/L for alpha and beta respectively, although some extreme values are obtained in some locations. Therefore, the area has very low significance radiological health burden on the environment and the populace.*

Keyword: Radioactivity, Alpha, Beta, Activity Concentration, Hanwa Sabon-Gari Zaria

INTRODUCTION

Water is an indispensable component in our lives, an essential substance to man, animal and all that surrounds them. It has been in existence right from the origin of the universe itself. Water forms greater percentage of human and animal's blood and tissue. The use of water cuts across industrial agricultural and domestic uses (H. T. Abba, 2013). The two main sources of water are rain and ground water sources. The ground water can be deep ground water like wells and boreholes, or surface ground water, like rivers, seas, oceans, lakes and streams. This

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surface water can also be collected, passed through purification processes and channeled through pipes as tap water. This is the most portable source of drinking water in Nigeria. However, water sources are constantly polluted by some human activities and natural phenomena; thus adversely affecting the quality of water. Water pollution arises from wastes and sewage disposals into rivers and streams from industries, hospitals and rain wash out from fertilizers used for farming. Some of these pollutants are radionuclides. Another source of water pollution arises from the secondary particles of cosmic radiation, which release radionuclides into the atmosphere, and these radionuclides, are washed down by rain into ground and surface water bodies (J. P. Longfin, 1988,). Water sources are equally polluted by naturally occurring radioactive materials (NORM) of the earth's crust (terrestrial radioactivity); which emits alpha, beta and gamma radiations. These materials normally elements in the uranium and thorium series and are more concentrated in deep ground water than in surface water (N. N. Rabiu, 2008). They contaminate the water body directly with their radionuclide products; and indirectly, through the radon and Thoron gaseous products which can solidify and attach themselves as aerosols to the air particles and are washed down by rain into water bodies. Furthermore, flowing water encounters shelves, sedimentary rocks, igneous rocks and phosphate rocks all of which are also radioactive (Santchi and Honeyman, 1989). All these contribute to the level of radioactivity in water. The radioactivity of drinking water is an environmental factor which contributes to the population exposure to ionizing radiations and the activity of monitoring the water radioactive content is the responsibility of the national public health systems by ensuring the maintaining of the effective dose by ingestion in the provided limits. The population usage of drinking water represents a way of the population exposure to the ionizing radiations by ingestion the radionuclides existing in it. UNSCEAR estimates that the natural sources contribution to the effective dose is 2.4 mSv y^{-1} (in this dose value being contained the value of 0.3 mSv y^{-1} due to the usage of food and water) (UNSCEAR, 2000). Hence, it is necessary to perform regular measurements of radioactivity parameters of different types of drinking water in each region using simple, low-cost and reliable methods (D. Calmet *et al*, 2013).

HANWA is one of the areas in Sabon-Gari local government area of Kaduna, Kaduna state, Nigeria, with a population of around 398,684 inhabitants according to NPC data of 2006 census, and its geological studies indicate that it is rich in granite deposits. Thomas et, al. (1987), reported that majority of areas with high radon concentrations are those areas underlain by granite rocks that contain higher levels of radon precursors (E. J. Baratta, 1990). Hanwa area is close to the Nigerian Research Reactor 1 (NIRR-1) (a source of radiation) about 3km away and one of the major sources of water in the area is wells,and boreholes. Most of the inhabitants of the area are farmers/herdsmen and as such pollutants such as fertilizer on farms, cow dungs etc. are washed into the sources and affect the quality of the water. Also, there are abundant waste disposal around the area. Some of these pollutants are radioactive and their deposition into the human body can be hazardous to health.

There is yet no established data on gross alpha and beta concentrations in drinking water sources in Hanwa, despite the fact that most of the inhabitants of the country, especially those in the rural areas, depend solely on ground water and surface water sources for drinking, household activities, agricultural purposes; and it may be possible that the water they use contain high concentrations of gross alpha and beta emitters.

The aim of the present study is to measure and analyze the level of radioactivity (gross alpha and beta activity) in well, borehole waters and sewage soil that are used as manure in Hanwa, compare the results with acceptable levels and ascertain the possible radiological effects on

the populace, livestock and the environment, also to assess the effective doses due to water ingestion by adult members of the public.

MATERIALS AND METHOD

The protean MPC 2000- DP is a convenient and versatile "bench top" alpha/beta radiation sample counter detector. The detector is supplied with an aluminum window. The assembly is coupled to a photomultiplier tube and encased in a light tight enclosure. The dual phosphor detector provides excellent alpha-beta efficiency, although not at the same performance level of the gas flow detectors, only voltage is required to count a sample (M. Eisenbud and A. S. Paschoa, 1989). Other materials used for the various experimental stages of this work include: 2-litre plastic containers to collect the water samples; conductivity meter in order to measure the conductivity of the water samples; global positioning system (GPS) for acquiring accurate geographical co-ordinates of the wells and boreholes; stainless steel planchettes; glass beakers; hot plate; weighing balance (accurate to ±0.1mg); agate mortal; hydraulic press; die. Also, the following reagents were used: nitric acid, acetone, liquid binder (toluene and PVC) and vinyl acetate (F. O. Ogundare and O. I. Adekoya, 2015). The International Standard Organization procedure (ISO9696 and ISO9697:1992E) for the measurement of gross alpha and beta activities in water was employed in this analysis. This procedure provides a screening technique to determine the gross alpha and beta radioactivity in water and soil samples. The procedure is highlighted below:

Samples which includes SEWAGE A-E, IRRIGATION CLAY and KW 1-2, BR 1-2, BK IW were collected at various locations in the area for soil and water respectively. This area is situated within Sabon-Gari LGA as shown in Figure 1. The exact geographical location will be determined by hand held GPS (Global positioning system) devices.A total number of 12 samples were collected six waters and six soils: the area was divided roughly into sections, in order to obtain widely spread and representative samples. The water Samples were collected in clean 2-litres plastic containers with tight covers. The volume of the sample collected was such that an air space of about 1% of the container was left for thermal expansion. To avoid contamination, the boreholes were allowed to run so as to evacuate the existing water in the pipe before collection. The containers were also rinsed thoroughly with water. The specific conductivity of the water was measured on collection, and the water samples were preserved with 20ml of concentrated HNO_3 per liter of water in order to minimize precipitation, bacterial growths and absorption on container walls; also, in case there are chloride salts in the samples, the HNO_3 will convert these salts to nitrate salts (chlorides will attack stainless steel and increase the sample solids, and no corrections can be made for those added solids). Soil samples were collected in a clean polythene bags. The samples were collected from the soil beneath the sewage disposal and are well dried.

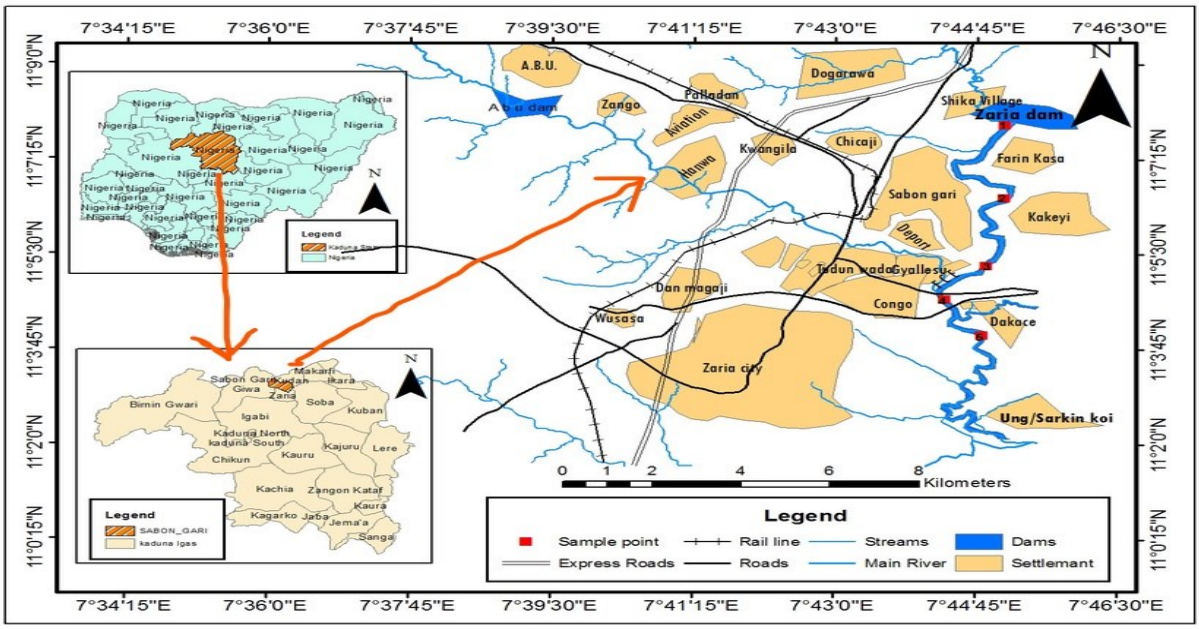

Figure 1. Map indicating the case study area (www. Researchgate.net).

Procedure/Preparation of samples

Soil samples are grinded manually using an agate mortar and pestle to a grain size of 125µm after which a three (3) drops of liquid binder (a solution of toluene and PVC) and grinded again until the fine grain size is attained. The sample is then transfer into a die of 19mm in diameter and placed in a hydraulic press where a pressure of 10tons is exerted to it to produce a pellet. See figure 3.4-3.9 (Tukur, 2014).

Water sample: The beakers, ceramic petri-dishes, planchettes and spatula should be properly washed and rinsed with distilled water and then sterilized using acetone. A little quantity of the sample should be used to rinse the beaker twice to ensure that cross contamination is properly avoided. 1000ml of the sample should then be measured in the beaker and set on the hot plate. The water sample should be evaporated gradually i.e. below the boiling temperature (to avoid excessive loss of the residue) without stirring in the open beaker until it is reduced to a very little quantity (about 50ml).It should then be transferred into the sterilized ceramic or petri-dish where the sample is being evaporated to dryness under the infra radiator lamp.

Having taken the initial weight of the dish (empty dish), the weight of the dried residue and the dish should be measured using the analytical weighing balance. The weight of the residue obtained from 1000ml of the sample evaporated can then be obtained by subtracting the weight of empty dish from the weight of the residue and the dish as shown in the equation 1

$W_{(d+s)} - W_d = W_r$(Tukur, 2014) (1)

Where $W_{(d+s)}$ is the weight of the dish with sample, W_d is the weight of the empty dish and W_r is the weight of the residue.

If the weight of the residue is more than 0.077g, 0nly 0.077g of the residue should be transferred into the sterilized planchet using the weighing balance and the sterilized spatula, and the volume of the sample that produce 0.077g could be calculated using equation 2:

$0.077g \times V_r = W_r V$(Tukur, 2014). (2)

Where, V_r is the volume that produce the residue, W_r is the weight of the residue and V is the volume that will give 0.077g. If the weight of the residue is exactly 0.077g, the whole residue should be transferred into the planchette by rinsing the residue with distill water into the planchette and evaporate to dryness. This implies that the volume that gives 0.077g is 1000ml. If the weight of the residue is less than 0.077g, more of the sample should be added until 0.077g could be obtained (Tukur, 2014).

Determination of total solid

The total solid concentration in the samples was determined in order to know the appropriate volume of water to evaporate for each sample so as to avoid unnecessary sample thickness which may lead to self-absorption. The volume of water required is such that it can produce a mass of solid residue slightly in excess of 0.1Amg (where A is the area of the Planchette in mm^2) Appropriate volume of the sample that can produce a mass of solid residue slightly in excess of 0.71mg was evaporated to near dryness using hot plates. The evaporation was done at a temperature less than 100^0C until the volume was reduced and allowed to cool. It was then transferred to a glazed porcelain dish of mass M_d and evaporated to dryness under an infrared lamp. The mass of evaporating dish and dried residue M_c was obtained. Total dissolved solids (TDS) for each sample was calculated in mg/l using the formula (ISO 9697, 1992) of equation 3.

$TDS = \frac{M_c - M_d}{V_p} \times 10^6$(Juliet, 2006) (3)

The value of the TDS for each sample was used to calculate the volume of sample Vp which when evaporated will give a mass of residue corresponding to 0.1A mg using equation 4

$V_p = \frac{0.1A}{TDS} \times 10^6$(Juliet, 2006). (4)

The residue was further allowed to cool in a dessicator and later transferred to Planchets and evenly dispersed with a spatula, to which small quantities of acetone were added. This is in order to reduce moisture; too, a small amount of vinyl acetate was added, to further dry the samples on the Planchets. The residues were taken for counting of gross alpha and beta activity using gasless proportional counter (Juliet, 2006).

Counting

The counting equipment is automated. The procedure involves entering the present time, number of cycles and the counting (operational) voltage. Also, the counter characteristics (efficiency and background count rate), volume of sample used and sampling efficiency were entered. The sampling efficiency was calculated using equation 5

$Sample\ efficiency = \frac{(W_{B+S} - W_B) \times 100\%}{W_{B-S} - W_B}$ (5)

Where: W_{B+S} is weight of empty planchet plus sample after evaporation; W_B is weight of empty planchet; W_{B-S} is weight of empty planchet – sample (M. Waziri, 2009).

$Sample\ efficiency = \frac{Residure\ size\ obtained}{Required\ residure} \times 100\%$ (6)

Channel efficiency is given by equation 7:

$E_C = \frac{cpm(\alpha,\beta) \times 100\%}{A}$ (7)

Where cpm(α, β)= background count per minute A = activity of the source used (Pu-239 for alpha and Sr-90 for beta) (Abdu Ibrahim et al, 2016).

Expression of results

Gross alpha counting: The high voltage for gross alpha counting was set at 1,600V, and samples were counted for 30 minutes in alpha only mode. Then the results were displayed as raw counts; (counts/minutes). The count rate and the activity were calculated using the formula of equation 8:

$$\text{Activity A} = \frac{\text{count rate(cpm)} - \text{Background count rate(cpm)}}{\text{D.E x sample volume x sample efficiency x 60}} \quad (8)$$

Where, D.E is the detector efficiency. The reciprocal of 60 seconds is the conversion factor of activity to Bq/L from cpm (Abdu Ibrahim et al, 2016).

Gross Beta counting: The high voltage for gross beta counting was set at 1,700V, and samples were counted for 30 minutes in beta only mode. The count rate and the activity were calculated using the formula of equation 9:

$$Activity\ \beta = \frac{\text{count rate (cpm)} - \text{Background count rate (cpm)}}{\text{D.E x sample volume x sample efficiency x 60}} \quad (9)$$

Where, D.E is the detector efficiency. The reciprocal of 60 seconds is the conversion factor of activity to Bq/L from cpm (Abdu Ibrahim et al, 2016).

Effective Dose

The annual alpha and beta effective dose due to intake of water was determined by averaging the individual annual committed effective doses contributed by the major alpha and beta emitters in the U-238 and Th-232 series of the naturally occurring radionuclides using equation 10

$$\boldsymbol{E_{avg}(\alpha/\beta) = \sum_{i}^{R(\alpha/\beta)} A_{i(\alpha/\beta)} \times DCF_{i(\alpha/\beta)} \times 730} \quad (10)$$

Where, $E_{avg}(\alpha/\beta)$is the average gross annual alpha or beta committed effective dose in the drinkable water, $A_{i(\alpha/\beta)}$ is the gross alpha or beta activity concentration of individual radionuclides present in the water sample and $DCF_{i(\alpha/\beta)}$ is the dose conversion factor for ingestion of the individual natural radionuclides for an adult taken from UNSCEAR (2000) report. A daily water intake of 2L/day is assumed (EPA, 2000-05) thus resulting in annual consumption rate of 730 L/year (A. I. Olanrewaju et al, 2018). Following the procedure of Fernandez, Lozano, and Gomez (1992) and Damla, Cevik, Karahan, and Kobya (2006), it is considered that more than 50% of the annual dose from intake of water corresponds to radium (gross alpha radium). This was assumed in this work since the component radionuclides in the gross alpha and beta activities could not be determined due to the limited functions of the machine used. According to Görùr, Keser, Akcay, As, and Dizman (2011) the major contributors to the gross β activities are ^{210}Pb and ^{228}Ra. For calculations, the dose conversion factors of 2.80×10^{-4}mSvBq^{-1} for ^{226}Ra and $6.90 \times 10^{-4}\ mSv$Bq^{-1} for both ^{210}Pb and ^{228}Ra, published by the WHO (2004) were used (A. I. Olanrewaju et al, 2018).

RESULTS AND DISCUSSION

Alpha and beta activity concentration in water sample

Gross alpha and beta activity concentration analysis for six (6) water samples is presented in Table1. The alpha activity concentration has an average value of 0.05630±0.01117 and the beta activity concentration has an average value of 0.02831±0.01734 in all the locations. The mean gross alpha and beta activities in water samples were between 0.00496±0.00506-0.10934±0.01370 Bq/L and 0-0.18250±0.01629Bq/L respectively.

Table 1 Alpha and Beta Activity Concentration in Water Samples collected

S/N	SAMPLE ID	Geographical Coordinate	Alpha activity in Bq/L	Beta activity in Bq/L
1	KW1	N11°6'50.436" E7°42'0.3528"	0.10934±0.01370	0.09054±0.02345
2	KW2	N11°6'50.5728" E7°42'0.1908"	0.07645±0.01985	0.00000±0.02686(BDL)
3	BR1	N11°6'48.2508" E7°42'14.922"	0.00496±0.00506	0.00000±0.00684(BDL)
4	BR2	N11°6'51.9408" E7°42'16.5348"	0.01108±0.00784	0.01235±0.01134
5	BK	N11°6'46.5732" E7°42'1.7208"	0.07303±0.01085	0.03225±0.01833
6	IW	N11°6'50.7132" E7°41'49.0848"	0.062913±0.00975	0.03473±0.01724
Mean			0.05630±0.01117	0.02831±0.01734
Max			0.10934±0.01370	0.09054±0.02345
Min			0.00496±0.00506	BDL

KEY: KW1= kaje well-1, KW2= kaje well-2, BR1=borehole riga-1, BR2=borehole riga-2, BK=borehole kaje, IW=irrigation water

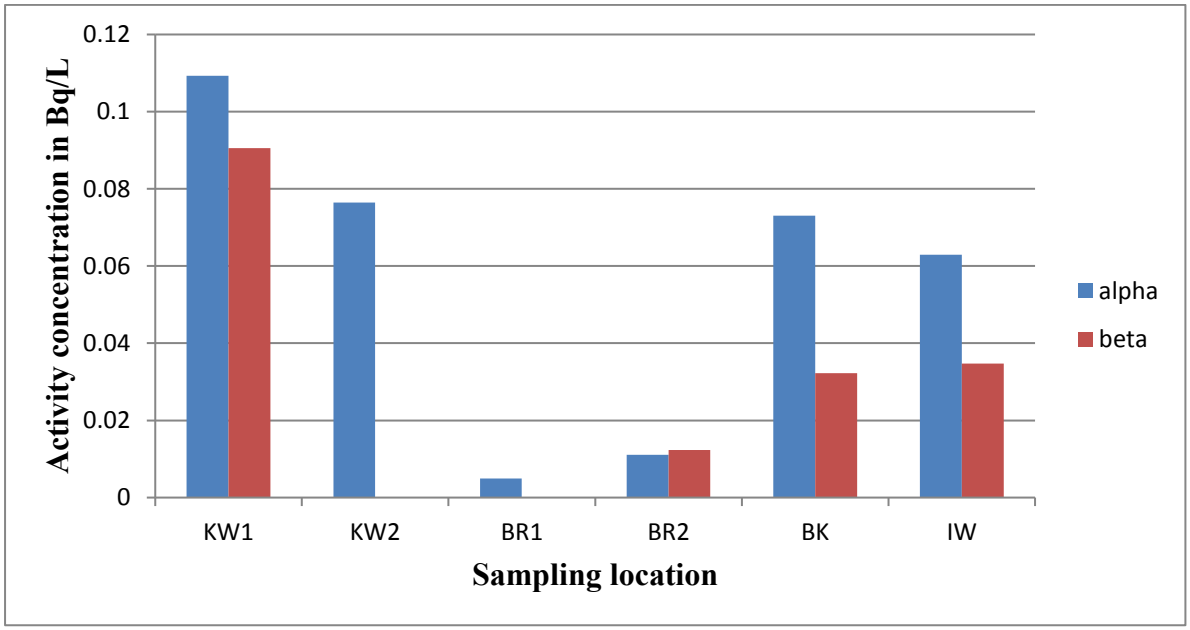

Figure 2 Gross alpha and beta activity (Bq/L) in water in the locations

It is obviously seen from Figure 2 that the gross alpha activity is generally higher than the corresponding gross beta activity in all locations except for BR2 where beta activity concentrations is slightly high. It was determined that the total α and total β activity concentrations for all water samples are lower than 0.5 Bq /L and 1 Bq/L respectively. These levels are recommended by the world health organization (WHO). Water from these locations is used by people of that area as a source of drinking water for their livestock, farming, as well as domestic activities. Hence, water taken from the locations in the area is suitable for drinking and other usage.

Alpha and beta activity concentration in sewage soil sample

Gross alpha and beta activity concentration analysis for the six (6) collected sewage soil samples are presented in Table 2. The alpha activity concentration has an average value of 0.03034±0.01054 and the beta activity concentration has an average value of 0.04557±0.0145 in the locations of the area under study. The mean gross alpha and beta activities in soil samples were between 0.02093±0.01022-0.04041±0.01124 Bq/g and 0.00676±0.01324-0.07515±0.01591 Bq/g respectively.

Table 2 Alpha and Beta Activity Concentration in Sewage Soil Samples Collected

S/N	Sample ID	Geographical Coordinate	Location	Alpha activity in Bq/g	Beta activity in Bq/g
1	SEWAGE A	N11°6'51.12" E7°41'59.6652"	Danmadami street	0.04041±0.01124	0.00676±0.01324
2	SEWAGE B	N11°6'55.0728" E7°41'58.542"	Rafinsidi	0.03757±0.01114	0.07515±0.01591
3	SEWAGE C	N11°6'48.924": E7°42'20.0952"	Riga lake	0.02093±0.01022	0.04826±0.01486
4	SEWAGE D	N11°6'58.2948" E7°42'15.4332"	Riga LEA1	0.02736±0.01071	0.03503±0.01459
5	SEWAGE E	N11°6'56.8332": E7°42'17.0568"	Riga LEA2	0.03475±0.01110	0.05392±0.01531
6	IRRIGATION CLAY	N11°6'50.7132": E7°41'49.0848"	Irrigation site	0.0210±0.0088	0.0543±0.0131
Mean				0.03034±0.01054	0.04557±0.0145
Max				0.04041±0.01124	0.07515±0.01591
Min				0.02093±0.01022	0.00676±0.01324

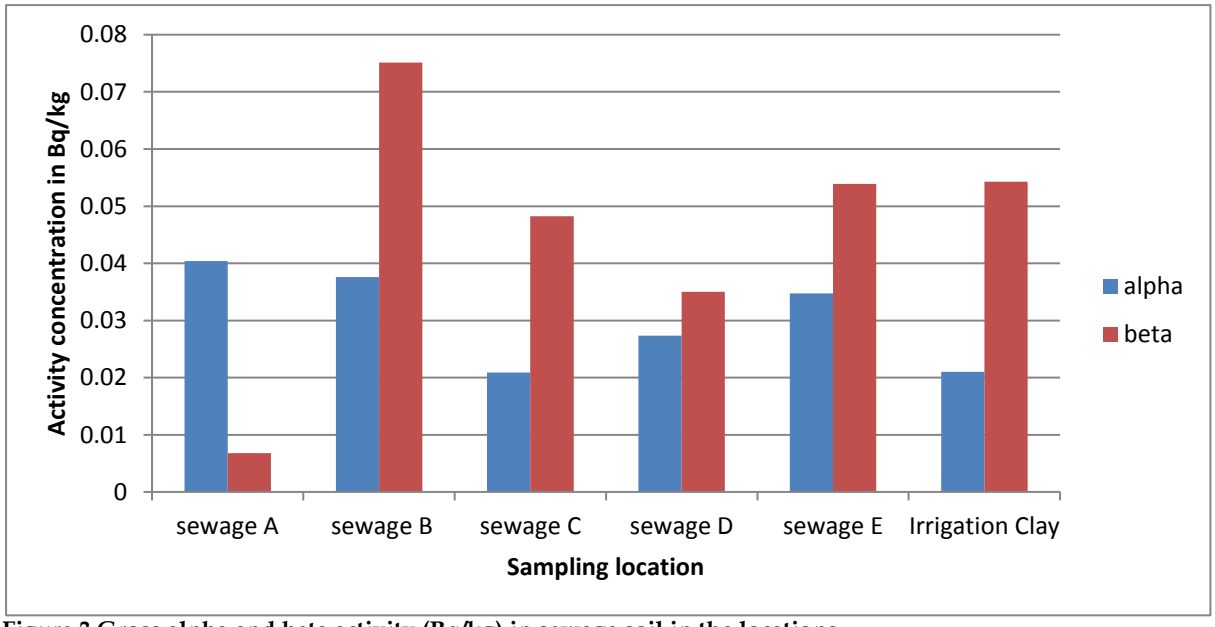

Figure 3 Gross alpha and beta activity (Bq/kg) in sewage soil in the locations.

The above Figure 3 shows that the gross beta activity is generally higher than the corresponding gross alpha activity in all samples except for sample sewage A where alpha activity concentration is highest. The total α and total β activity concentrations for all soil

samples are found to be within reasonable limit. Although the radioactivity in soil depends on the composition or constituents of the soil. Comparison is made with the (WHO) standard of water since soil contributes to the radioactivity in water. Hence, sewage soils from the locations are safe.

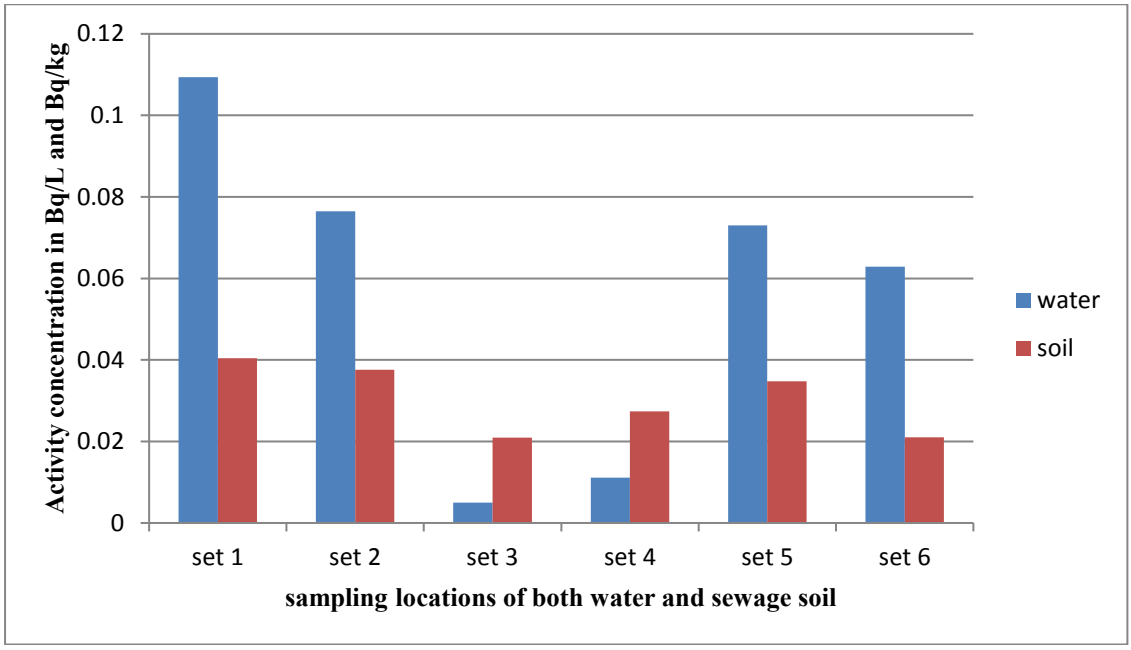

Figure 4 Correlation between gross alpha activities in soil and water samples.

From the Figure 4 above it is observed that alpha activity is higher in the water than in the sewage soil in almost all the sets (comparison between the water and the sewage soil) except for set3 and set4 as shown in Figure 4 On the other hand beta activity is greatest in sewage soil than in the water in all the sets with the exception of set1 as shown in Figure 5. This implies that the sewage disposal contributes to the increase in beta activity in the area.

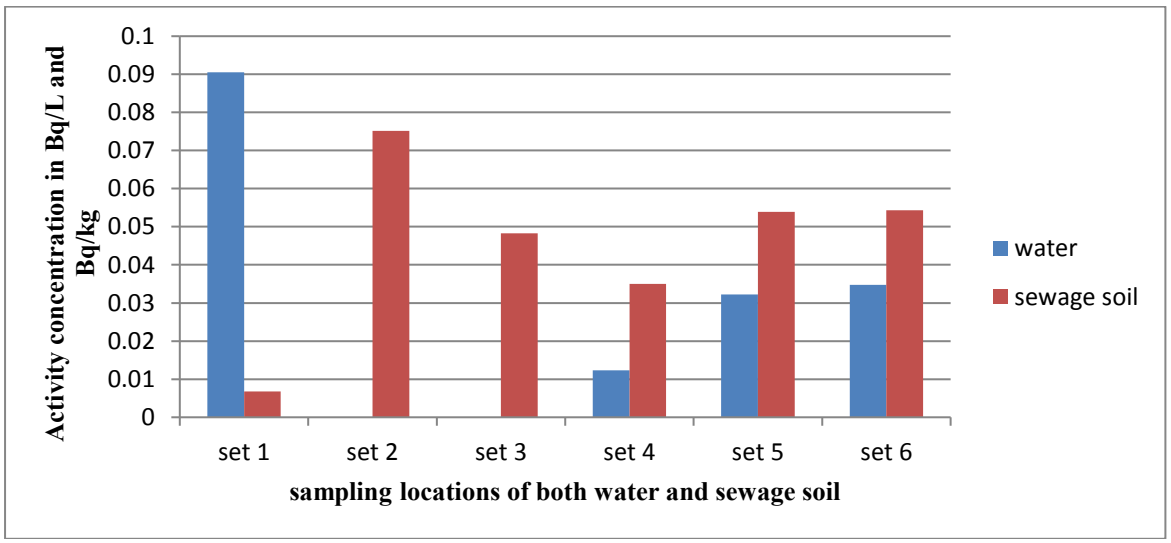

Figure 5 Correlation between gross beta activities in soil and water samples.

Table 3 Effective equivalent dose in all the sampled locations (Errors ignored)

S/N	Location	Effective equivalent dose due to radium-226 (mSv)	Effective equivalent dose due to beta radionuclides (mSv)	Total effective equivalent dose (mSv)
1	KW1	0.0447	0.0456	0.0903
2	KW2	0.0313	0	0.0313
3	BR1	0.0020	0	0.0020
4	BR2	0.0045	0.0062	0.0107
5	BK	0.0299	0.0162	0.0461
6	IW	0.0257	0.0175	0.0432

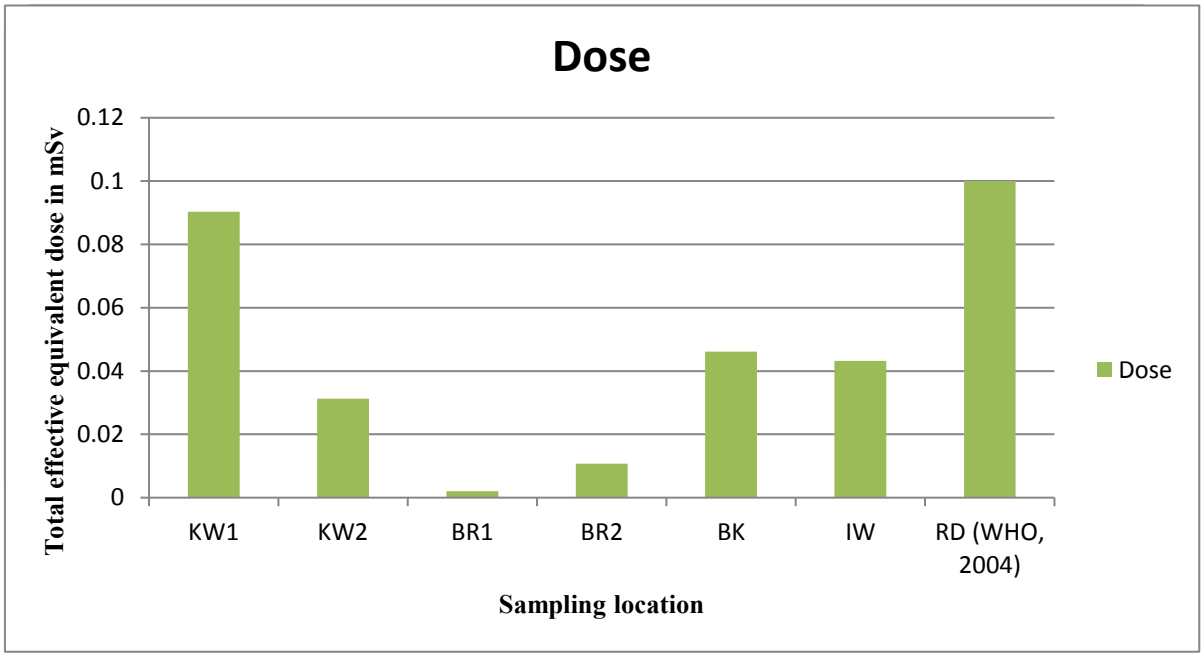

Figure 6 Total effective equivalent dose due to alpha and beta radionuclide in drinking
KEY: RD= Recommended dose (WHO, 2004)
Recommended dose (WHO, 2004)

Figure6 shows the total effective equivalent dose due to both alpha (radium-226) and beta emitting radionuclides in drinkable water. The total effective equivalent dose was greatest at KW1 and least at BR1. It thus follows that greater risk is associated with drinkable water from KW1 than at the BR1and BR2. The recommended reference dose level (RDL) of the committed effective dose, equal to 0.1 mSv from 1 year's consumption of drinking-water was however not exceeded in all of the locations, thus making the water in all the locations safe for consumption.

CONCLUSIONS

The gas proportional counter used for this research responded positively to the alpha and beta radioactivity, the counting modes employed gave alpha efficiencies of 87.95%, for alpha. Similarly, the beta efficiency obtained is 42.06% for beta.The mean gross alpha and beta in sewage soil and drinkable water samples were measured and the effective dose computed.

Drinkable water from the sampled locations pose no risk to both animals and dwellers in and around the area though there is little or no radioactive contamination of the water arising from the radioactive wastes being discharged into the air or deposited on ground. Also the sewage soils are safe and can be used even as manure. Also, the committed effective dose, 0.1 mSv from 1 year's consumption of drinking-water was however not exceeded in all of the locations, thus the waters are safe for consumption.

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