Dutse Journal of Pure and Applied Sciences (DUJOPAS) Vol. 4 No. 1 June 2018

DETERMINATION OF GROSS ALPHA GROSS BETA RADIOACTIVITY IN GROUNDWATER FROM KADUNA METROPOLIS

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Abstract

In this study, the activity concentration of gross alpha and gross beta water samples collected from different wells in Kaduna metropolis were measured. The values of the activity concentrations of the gross alpha and gross beta in the water samples ranged from 0.0008 ± 0.001 Bq/L to 0.90 ± 0.01Bq/L with mean of 0.0313872 Bq/L and 0.004 ± 0.013 Bq/L to 2.97 ± 0.48 Bq/L with a mean of 1.107136889 Bq/L respectively.The specify limit value of World Health Organization is 0.5 Bq/L for alpha and 1.0Bq/L for beta. All values of the gross alpha were lower than the specified limit value 0.5 Bq/L of World Health Organization, while four ground water samples were found to have gross beta activity concentration of greater than 1.0Bq/L which is above World Health Organization Standard.

Keyword: Radionuclide's, gross alpha and gross beta, ground water

INTRODUCTION

The presence of radionuclide in water poses a number of health hazards, especially when these radionuclide are deposited in the human body through drinking. Dissolved radionuclide's in water emit particles (alpha and beta) and photons (gamma) which

gradually serve as exposure pathway to living tissues. Human and animal studies show that radiation exposure at low to moderate doses may increase the long time incidence of cancer. The World Health Organization guidelines for drinking water quality recommended the determination of gross alpha and gross beta activity concentrations in drinking water as the first step of the radiological aspect of the drinking water quality (World Health Organization, 2004). Generally, radiation exposure due to gross alpha is of greater concern than that due to gross beta for natural radioactivity (Gazineu *et al.*, 2005).

Radionuclide's are radioactive isotopes that can occur naturally or result from manmade sources. Natural radiation comes from cosmic rays, naturally-occurring radioactive elements in the earth's crust, and radioactive decay products. Since these radionuclide's are present in soil and rock, they can also be found in groundwater and surface water. Typical radionuclide's found in drinking water sources are isotopes of radium, uranium, and radon, among others. Fission products from manmade nuclear reactions are also of concern today, particularly radioactive cesium and iodine. The three basic types of radiation are alpha particles, beta particles, and gamma rays. Alpha particles are positively charged helium atoms; beta particles are negatively charged electrons, and gamma rays are high-energy electromagnetic waves. Radiation exposure can occur by ingesting, inhaling, injecting, or absorbing radioactive materials. The amount of radiation exposure is usually expressed in a unit called millirem (mR or mrem), which is a measure of energy deposited in human tissue and its ability to produce biological damage. According to the U.S. Environmental Protection Agency (EPA), the average annual radiation dose per person in the U.S. is 620 mrem. Drinking water measurements of radioactivity are typically expressed in picocuries per liter (pCi/L). The relationship between pCi to mrem is complex, because it depends on the type of isotope, its biological half-life, and the material absorbing the radiation. Half-life is the time required for any given radioisotope to decay to one-half of its original quantity, and is a commonly reported measure of the speed with which that isotope undergoes radioactive decay. The half-life is a characteristic of each specific radioisotope, and no physical or chemical treatment will alter the half-life of the isotope. Half-lives of isotopes range from microseconds to millions of years. The March 2011 earthquake in Japan led to a release of radioactive material from the Fukushima nuclear power plant into the atmosphere and ocean. Since the incident, the EPA has been monitoring air, milk, precipitation (rain, snow, and sleet), and finished drinking water for radioactivity. Of the fission products tested, radioactive iodine (specifically I-131) is the only one found in U.S. drinking waters (http://www.epa.gov/japan2011/rert/radnet-sampling-data.html#water). Radioactive iodine can concentrate in the thyroid, and long term exposure to elevated levels can cause thyroid cancer. However, as of April 4, 2011, the levels of I-131 found by EPA range from undetectable to 2.2 pCi/L and, according to EPA, are all well below levels of concern for public health.

Drinking water standards for radionuclide's were first set in 1962 and most recently updated by EPA in the 2000 Radionuclide's Rule. This rule specifically addresses radioactive radium and uranium, and uses measurements of gross alpha and beta activity as screening methods for a broader range of radioactive compounds such as I-131. The standards are set at 5 pCi/L for combined radium (Ra-226 and Ra-228), 30 micrograms per liter (µg/L) for uranium, 15 pCi/L for gross alpha, and 4 millirems per year (mrem/yr) for beta emitters. Several treatment processes can remove various radionuclide's from drinking water sources, as noted in EPA's list of Best Available Technologies for compliance with the Radionuclide's Rule and the 2010 Water Research Foundation report, *Evaluation of Gross Alpha and Uranium Measurements for MCL Compliance* (Project/Order #3028). Because naturally-occurring radionuclide's are the more typical concern for drinking water sources, they are the primary focus.

Treatment options for radon removal are aeration and granular activated carbon (GAC), with aeration being the most cost effective. Options for removal of radium include ion exchange, lime softening, reverse osmosis, nanofiltration, co-precipitation with barium sulfate, greensand filtration, and GAC. Uranium can be removed by many of the same processes as radium as well as by enhanced coagulation/filtration.
Removal of man-made I-131 was the focus of a study by Summers et al. published in 1989. It found that iodine reacted with aquatic humic substances and concluded that flocculation and activated carbon adsorption were effective for removing the iodine-humic substance complexes.

Regardless of whether drinking water utilities are intentionally trying to remove radionuclide's from source waters, they can be concentrated in water treatment processes, and the resulting residuals can possibly require special management methods due to the radioactive content. These materials are sometimes referred to as Technologically Enhanced Naturally-Occurring Radioactive Materials (TENORM). The 2005 Water Research Foundation report, *Management of the Disposal of Radioactive Residuals in Drinking Water Treatment* (Project #2695/Order #91077F), helps address and guide efforts in managing drinking water residuals that might contain enhanced levels of radionuclide's.
This research presents alpha and beta activity in Bq/L for water from wells in Kaduna metropolis, based on reference to USEPA and WHO maximum contaminant limit.

MATERIALS AND METHODS

Materials

The materials used for this work are as follows (1)Gas-flow proportional counting system(2)Stainless steel counting planchets(3)Electric hot plate(4)Drying oven(5)Drying lamp(6)Glass desiccators(7)Glassware(8)Analytical balance

Reagents

Distilled water with a resistance value between 0.5 and 2.0 megohms (2.0 to 0.5 micromhos)/cm at 25^0C Nitric acid, 1N: mix 6.2ml/6N $HN0_3$ (Conc) with distilled water and diluted to 100 ml.

Methods

600mls of the preserved well water sample was gradually evaporated using beakers on a hot plate for days. When the sample is less than 100mls, it is then transferred to petri-dish residue. The dried residue was scraped and put into a stainless steel counting planchet, 0.77g of residue was achieved and counted for alpha and beta radioactivity using MPC 2000.The count rates recorded were reproducible in terms of channels and in terms of mode of measurement. IN20-SYST a proportional counter is not the only detector for low alpha and beta activity measurement in samples. There are other gas filled detectors such as Geiger-Mueller (GM) counters and ionization chambers. Silicon surface barrier, scintillation and semiconductor detectors can also be used for gamma and alpha detection. The choice of gas filled proportional counters was based on availability and the nearly uniform low background level. Low plateaux slope and channel efficiency measured in all the channels simultaneously is an added advantage of using this equipment.

Sampling

The area under study is the Kaduna metropolis area and this investigation is limited to groundwater sources in wells used by people in Kaduna for drinking and domestic activities.The method adopted for the sampling is simple random sampling.

In order to cover the study areas, a survey was done to know the number of wells available in the areas and frequently used by the population for drinking and domestic purpose. The weather condition of the time of sampling was stable. The place where samples were collected were marked by using a global positioning system (GPS) and the temperature of the water were taken at the point of collection.

The procedure involves the following:-

(i) The sample container was rinsed three times with the water being collected, to minimize contamination from the original content of the sample container.

(ii) Each sample were collected into two litres of gallon and the amount of water collected was such that an air space of about 1% of container capacity was created for thermal expansion was left.

(iii) 200mls of concentrated nitric acid were added to the sample immediately after collection to reduce the pH and to minimize precipitation and absorption on container walls.

(iv) The samples were tightly sealed and label with a marker and kept in the laboratory until analysis.

Sample Preparation

Evaporation was done using hot plate without stirring in open 50 ml beaker. It took an average of two and half days to complete the evaporation of a two-litres sample. The residue was washed with distilled water and transferred into a 7.1cm^2 counting planchet, the sample residue was dried in a drying oven at 105^{0}C for two hours, cooled in a desiccator, weighed and counted. The sample residue was stored in a desiccator until it was counted.

Sample preparation efficiency was derived by taking the weight of empty beaker, W_B and weight of beaker plus sample after evaporation, W_{B+S}. The difference between W_{B+S} and W_B gives the weight of sample. The content of the beaker is then transferred to a planchet and the weight of the beaker was taken again, W_{B-S}. The difference between W_{B-S} and W_B gives the total weight of sample unrecovered from the beaker.

$$Sampling\ Efficiency = \frac{(W_{B+S} - W_B) - (W_{B-S} - W_B)}{W_{B+S} - W_B} \times 100\%$$

Sample Analysis

The sample prepared were taking to centre for energy research institute and training Ahmadu Bello University, Zaria, Kaduna, for gross alpha and gross beta analysis with the aid of MPC 2000 machine.

Table 2.1: Sample Coordinate

		GPS			
S/NO	**LOCATION**	**N**	**E**	**HEIGHT**	**TEMP**
1	ZAMFARA ROAD HOUSING ESTATE BARNAWA	10^{0}28.550′	007^{0}25.894′	616m	25^{0}C
2	MALLAM MADORI	10^{0}31.263′	007^{0}25.323′	610m	27^{0}C
3	BYE PASS HOUSING ESTATE BUNGALOW	10^{0}27.610′	007^{0}23.569′	613m	28^{0}C
4	CRESCENT ROAD HOUSING ESTATE	10^{0}32.155′	007^{0}25.343′	625m	26^{0}C
5	LEMU ROAD	10^{0}31.132′	007^{0}25.108′	612m	27^{0}C
6	CASS BYE PASS	10^{0}26.618′	007^{0}25.936	620m	27^{0}C
7	PANTEKA HOUSING ESTATE	10^{0}31.483′	007^{0}25.356′	611m	27^{0}C
8	BYE-PASS HOUSING ESTATE BLOCK OF FLAT	10^{0}27.495′	007^{0}23.514′	606m	26^{0}C
9	CES BARNAWA	10^{0}29.579′	007^{0}25.306′	599M	27^{0}C
10	ENUGU ROAD	10^{0}31.180′	007^{0}25.234′	620M	27^{0}C

RESULTS AND ANALYSIS

Table 3.1: Sample Measurement

S/NO	SAMPLE ID	EVAPORATED VOLUME (ML)	WEIGHT OF RESIDUES (G)	ACTUAL VOLUME (ML)	REQUIRED WEIGHT (G)	ALPHA CPM	BETA CPM
1	ZANFARA ROAD HOUSING ESTATE BARNAWA	980	0.30	0.2498	0.0770	0.24	89.27
2	MALLAM MADORI	2200	1.51	0.1100	0.771	0.27	92.91
3	BYE PASS HOUSING ESTATE BUNGALOW	2300	0.26	0.1426	0.0770	0.47	89.82
4	CRESCENT ROAD HOUSING ESTATE	1000	0.0682	0.0847	0.08818	0.91	86.93
5	LEMU ROAD	1000	0.48	0.1647	0.0770	0.40	81.91
6	CASS BYE PASS	650	0.36	0.1404	0.0772	0.13	92.09
7	PANTEKA HOUSING ESTATE	2400	1.10	0.1684	0.0772	0.24	87.76
8	BYE-PASS HOUSING ESTATE BLOCK OF FLAT	1000	0.0733	0.1674	0.07312	0.62	98.84
9	CES BARNAWA	1300	0.41	0.2390	0.0771	1.04	101.38
10	ENUGU ROAD	1400	0.62	0.1750	0.0770	0.44	91.51

TABLE 3.2 **Sample Location and Result of Activity Concentration for Gross Alpha and Beta** :

S/N	Location	Alpha Activity Bq/L	Beta Activity Bq/L
1	Zamfara Road Housing Estate, Barnawa	0.09 ± 0.01	0.49 ± 0.03
2	Mallam Madori	0.03 ± 0.01	2.32 ± 0.72
3	Bye pass Housing Estate, Bunga low	0.05 ± 0.02	0.98 ± 0.55
4	Crescent Road Housing Estate	0.003 ± 0.0005	0.004 ± 0.013
5	Lemu road	0.03 ± 0.01	BDL
6	CASS Bye pass	0.0027 ± 0.0009	1.64 ± 0.56
7	Panteka Housing Estate	0.015 ± 0.0009	0.35 ± 0.46
8	Bye-Pass Housing Estate Block of Flat	0.06 ± 0.01	2.97 ± 0.48
9	CES Barnawa	0.0008 ± 0.0001	0.027 ± 0.004
10	Enugu Road	0.036 ± 0.001	1.182 ± 0.450

Result Analysis

The results obtained so far were based on the characterization of the detector and measurement of radioactivity (gross alpha and gross beta activity) of ten (10) water samples collected from Kaduna metropolis. The alpha and beta detector efficiency is 87.95% and 42.06% respectively.

Analysis of Alpha and Beta Concentration Data

In order to analyze the activities of alpha and beta measured, statistical analysis employed are the estimation of the graph, frequency histograms and range.

Statistical Analysis

Descriptive Statistics

	Number	Range	Minimum	Maximum
Alpha	10	0.0900	0.0008	0.0908
Beta	10	2.9664	0.0043	2.9707

Examination shows that, percentage of alpha activity measured have lower concentration to the recommended level of 0.5 Bq/L and 60% of the position measured showed lower concentration of beta activity to the recommended level of 1.0 Bq/L. However the maximum concentration of alpha activity is 0.09 Bq/L.

While the minimum concentration is 0.0008 Bq/L. and the maximum concentration of beta is 2.97 Bq/L, while the minimum is 0.0043 Bq/L.

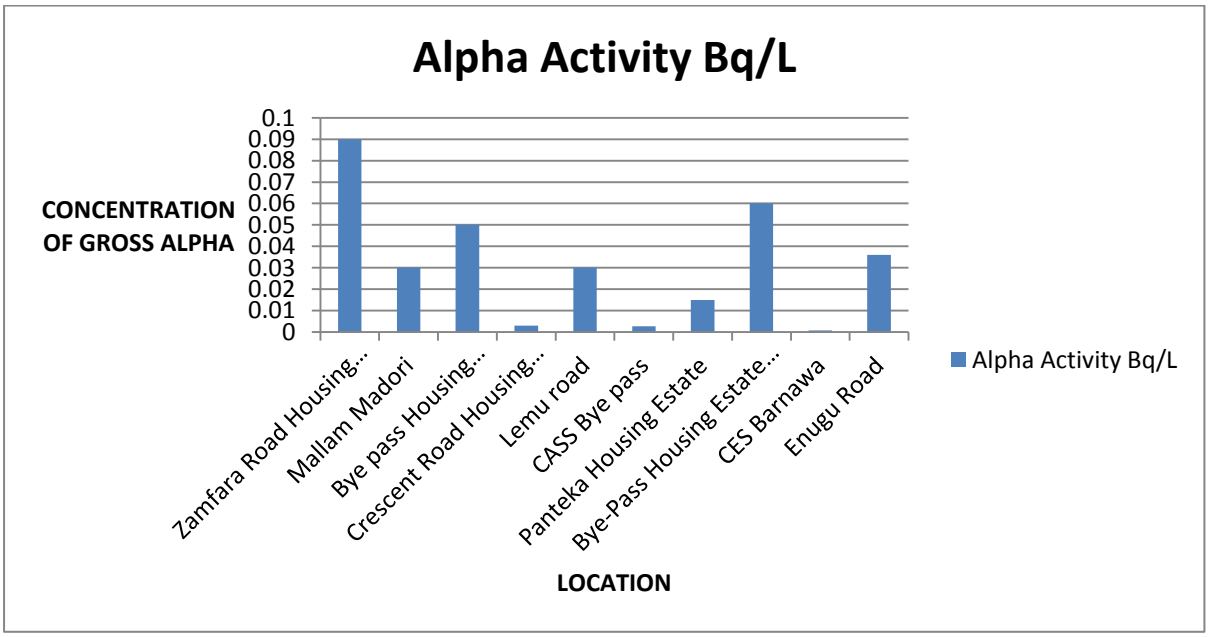

Fig. 3.1: Activities of Gross Alpha Against Location in Well Water in Kaduna Metropolis

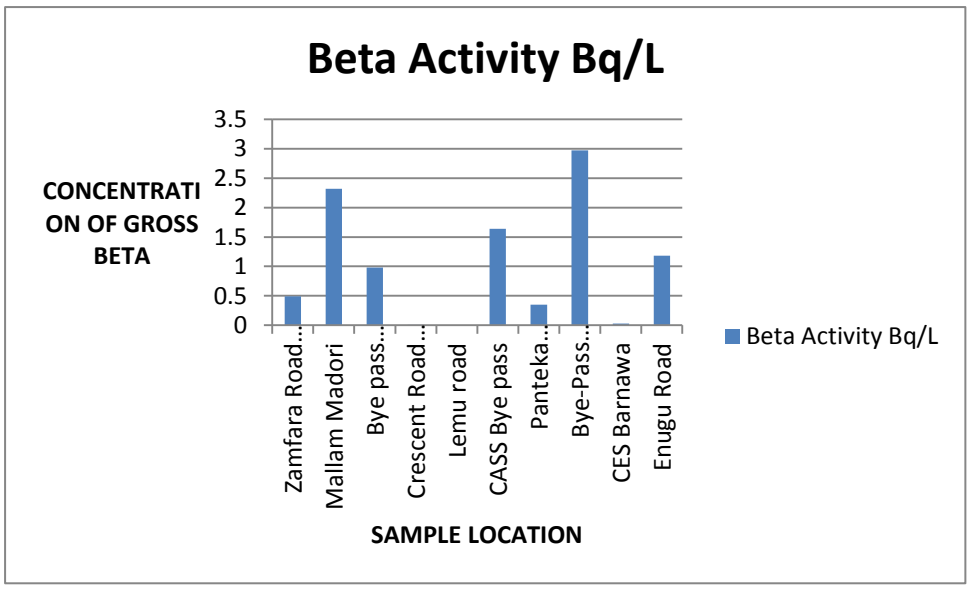

Fig. 3.2: Activities of Gross Beta Against Location in Well Water in Kaduna Metropolis

DISCUSSION

600mls of the preserved drinking water sample was gradually evaporated and the dried residue was scraped, then 0.77g of residue was achieved using MPC 2000 machine. Sample preparation efficiency was derived by taking the weight of the empty beaker, W_B and Weight of beaker plus sample after evaporation W_{B+S}. at the end the alpha and beta detector efficiency is 87.95% and 42.06% respectively.

The counter was used to determine gross alpha and beta activity in well water samples taken from Kaduna metropolis. With alpha activity range from 0.09-0.0008Bq/L and beta activity range from 2.97-0.004 Bq/L.

CONCLUSION

In this work,The graphs above shows the activity of gross alpha and beta, the gross alpha and beta activities in water drawn from utility wells were measured. It was found to be from 0.0009-0.09 Bq/L for alpha and from 0.004-2.97 Bq/L for beta. The level is lower than that recommended by World Health Organization (WHO) for good water quality, which is 0.5 Bq/L for alpha .Therefore, it may be concluded that the quality of well water for alpha in Kaduna metropolis meets the recommendation of the WHO and USEPA. There may not be any need for further screening for radioactivity before the water from the well are used for domestic, industrial and agricultural purpose.

while four ground water samples were found to have gross beta activity concentration of greater than 1.0Bq/L .

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