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DETERMINATION OF GROSS ALPHA/BETA RADIOACTIVITY OF WATER SAMPLES AROUND MINING SITES, DANGE-SHUNI LGA, SOKOTO STATE

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ABSTRACT

Mining activities in the Iullumeden (Sokoto) basin is often heard of due to its prominence in artisanal mode of ransacking the Earth in search of minerals and metal of high economic values. The unabated demand in the growing post-industrial era have decimated any health impact that could be borne by the inhabitants of the mining communities. Dange-Shuni is an enclave of this basin that was covered in a bid to determine the gross alpha and beta radioactivity in domestic water in and around mining points. Water samples were collected and analyzed via Hidex 300 SL system of Liquid Scintillation Counting from a systematic sampling of fifteen mining points. The results indicate that both the gross alpha and beta radioactivity concentrations were in elevation with about 80% and 85% above the global limits of 0.5 and 1.0 BqL^{-1}. The results are good reasons to work hard in order to bring dose of radioactivity exposure to the inhabitants to as low as reasonably achievable (ALARA) being a mandate of WHO.

Keywords: Gamma-rays Spectroscopy, Mining-sites, Dange-Shuni, Environmental Radioactivity

INTRODUCTION

The World Health Organization (WHO) has emphasized serious concerns on the quality of water globally against contamination of different sorts (WHO, 2016 and Ahijjo, 2019). Mining activities in some parts of the world have been implicated to contribute in the contamination of water bodies like streams, rivers, clean ponds, shallow well, stagnant ponds etc. This was found indifferent around mining sites in Dange-Shuni Local Government Area, Sokoto State. Dange-Shuni is an enclave in the famous Iullumeden basin where mining of precious metal and elements such as felspar, phosphate, quarries, limestone, kaolin, gypsum, iron ore etc. have been unabatedly under exploration due to their financial benefits and commercial abundance (Nisti *et al.*, 2009). There is currently insignificant collection of studies conducted on the gross alpha and beta radioactivity concentration in water samples from mining sites on this aspect of studies and these geographical localities. Based on this information, this study is an effort to unveil and determine the level of gross alpha and beta radioactivity concentration which may be due to presence of radionuclides in the form of cosmogenic (^{3}H, ^{7}Be, ^{10}B, ^{14}C, ^{36}Cl and ^{32}Si, ^{22}Na, ^{38}SS and ^{33}P), primordial (^{40}K, ^{87}Rb, ^{50}V, ^{144}Nd, ^{238}U, ^{235}U, ^{232}Th) and anthropogenic (^{137}Cs, ^{90}Sr, ^{89}Sr, ^{131}I, ^{99}Tc, ^{240}Pu, ^{241}Am, ^{65}Zn, ^{54}Mn, ^{55}Fe) radionuclides (Ahijjo, 2019). As such, efforts and resources have been channeled in this direction in order to achieve an assertive knowledge of the gross alpha and beta radioactive safety of domestic water around mining sites in Dange-Shuni LGA. Similarly, endeavors have been taken to address the concern of WHO in ensuring safety of domestic water from potential contaminations. However, this paper is an extraction from a larger scale research of health and environmental radioactivity measurement in some mining sites of communities in Dange-Shuni LGA as earlier stated. Also, this study is timely due to the fact that most mining activities in Sokoto (Iullumeden basin) were carried out in proximity to dwelling places. Some of these gaps shall be addressed in this study.

MATERIALS AND METHODS

Study Area

This study was conducted by collecting water samples from mining communities in Dange-Shuni LGA, Sokoto State. Dange-Shuni lies on the coordinates 12.7956^{o}N, 5.4359^{o}E with headquarter in the town of Dange. It is embedded in a semi-arid climate according to Koppen climate classification. See the Map of Dange-Shuni embedded in the Map of Sokoto State below in Plate 1.

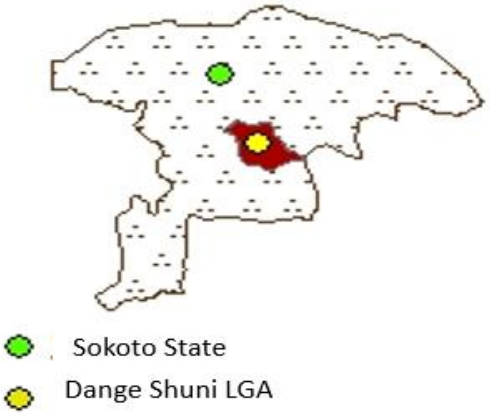

Plate 1. Illustrative Maps of Sokoto State with green dot and Dange-Shuni LGA with yellow dot

Dange-Shuni is an enclave of the famous Iullumeden (Sokoto) basin which is very prominent for its potentials in minerals and precious stones deposits. Its total span in West Africa is estimated to about 500,000Km^2 with an extension of about 60,000 km^2–in Nigeria which is roughly 10% of its occurrence entirely (Okosun and Alkali, 2013). This enclave therefore offers positive and lucrative option of employment to immediate communities inform of mining as well as conventional industrial supports to the inhabitants. Hence, this makes Dange-Shuni one out of other important parts of the basin.

Sampling

Water samples from well, ponds, shallow rivers, slow running streams around mining points were considered for sampling. Those in closer proximities to the mining points were given more priority. The water samples were also considered based on the domestic utility importance attached to the dwelling communities. Correspondingly, due to the dynamics and heterogeneity of the nature of water samples, an approach of mutually exclusive and collectively exhaustive logics was adopted in order to curtail sampling errors and improve collective representativeness of the samples (Singh and Audu, 2013). An equation of stratified random sampling by proportion was coined out as given below in equation (1) below;

$$\Sigma_\sigma = \frac{S_\rho}{\sigma}(N_k) \quad (1)$$

Where, $\Sigma_\sigma$is the sum of the real-world contributions, $S_\rho$is the number of sample points, σ is the sum of the sample points and N_k, is the sum of all the real-world contributions from the inhabitants. The validity of the equation was ensured for its break through and innovative approach to sampling. A measured distribution of interval distances of 25 Km a parts, totaling fifteen different sample points was separately mapped out. This is in order to obtain five homogenized samples so as to optimize representativeness so that at least 95 to 98% of water sample collected at a point. Plastic containers were used in collecting 25 ml of water from the mining sites before transfer to Center for Advanced Study in Physics, G C, University, Lahore, Pakistan for analysis (Ahijjo, 2019). Below is the map of the sampled points displayed on Plate 2.

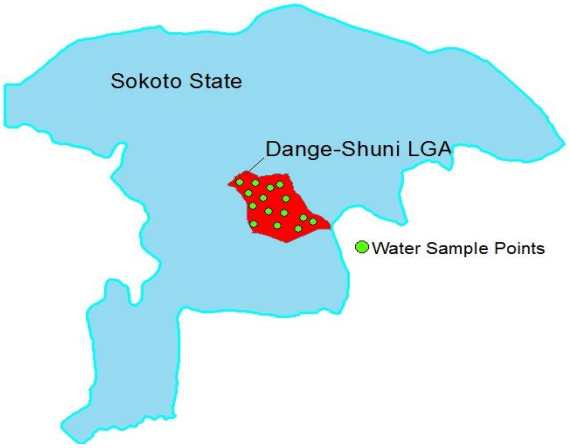

Plate 2. Illustrative Maps of Dange-Shuni showing sample points in green dots

Experimental Procedures

This study was designed to ascertain the gross alpha and beta radioactivity concentration that have been implicated to emanate from Uranium, Radium, and Thorium decay series. The detection system of Hidex 300 SL Liquid Scintillation Counting is excellent in the gross alpha and beta counting. The operation was conducted on a personal Computer (CP) Window based Milkrowin SL software. The procedure was carried out on $^{3}H/^{4}C$ of an efficiency counting between 70-100%. This was able to detect radioactivity of alpha and beta – emitters of the forms; Th, U, Pu, Am, Cm, ^{228}Ra, ^{226}Ra, ^{226}Pb, and ^{210}Po. Forty glass vials designated for counting

were loaded in the sample well at a time. The following procedures were embarked upon; Organic matter decomposition, filtration, instrument calibration, sample measurement and experimental observations.

Organic Matter Decomposition

All the glass vials were weighed initially prior being filled with the water samples collected. They were filled to be 22 ml in volume which represents one-third of the vials. To ascertain the combined weight, the vials were reweighed after being filled. A UV light that operates under a peak emission wavelength of about 225 nm to 235 nm was made to deactivate all the vials contents for about 30×10^{-9} sec. in order to render the inherent organic matter in the samples unretentive. This also offers the deactivated organic matter high degree of immiscibility with the vials content. They were later allowed to settle at room temperature in an hour. They were then cross-examined in case of potential reduction in weight of the empty and filled vials.

Filtration

The vials contents were found out to be in mixture of water sample and immiscible deactivated matter that were allowed to settle at room temperature. They then poured via a funnel with an inbuilt filter under a dark cupboard in order to avert unnecessary light interference on potential volatile radioactivity sources of radioisotopes. This was also noticed to enable perfect separation of particles in solid or near solid state form the liquid samples. After the pouring of the vial's contents via the inbuilt-filter funnel, deionized water and 1 mole of HNO_3 was obtained for washing all the empty vials. Additional 600 sec. was allowed to elapsed until no organic solid was noticeably visible in the samples.

Calibration

The calibration of the system was conducted nearly under self – normalization standard condition containing ^{14}C, ^{3}H, and ^{226}Ra source of 1 BqL^{-1}. Here, the volume of the samples was reduced and gauged at 20 ml for all the vials. This was achieved through careful addition of the source to the sample in the counting vials until the anticipated volume gauge is reached. Secular equilibrium was attained by observing the 30 – day period by storing in a dark cupboard. In other ward, chemiluminescence influence was curtailed to the barest minimum by optimizing the dark effect within the first 2 – 3 quarter of the equilibration period in the dark cupboard. This procedure further enhanced the elimination of false – pulse reading as a result of interference of emission of light due to photo-chemical initiation of reactions between the water sample and the systems cocktail. Region of interest of 0 – 600 was set for energy range and 0 – 20 count per channel number for alpha and beta counting efficiencies. The Minimum Detectable Activity (MDA) was also obtained effectively by setting the background count rate and the counting efficiency of the system.

Sample Measurement

The volume of the vials set for measurement was 20 ml for the counting procedure. LSC measurement was initiated by placing the samples inside the Hidex 300 SL systems' rack. The counting was done in quadruplication of 6,000 sec. timing. The gross alpha and beta radioactivity concentration in the sample was detected when the scintillate is emitted responds to the irradiation due to maximum increased in surface area to contact ratio of the toluene and the flour. A trial procedure was maintained by discarding the first round of the measurement so as to overcome errors from rigorous handling before loading into the systems' rack. The staging tray was later moved to the counting chamber for counting. Hence, the average counting was obtained from three measurement on taking the mean using equation (2);

$$X_{i+j+k} = \frac{x_i + x_j + x_k}{3} \quad (2)$$

Where, X_{i+j+k} is the average counting, x_i , x_j , x_k are the number count per procedure respectively.

Pulse Replication

Alpha and beta radioactivity appears inform of pulse which were detected at the Photomultiplier tube (PMTs) even though they were of different shapes. They appeared at different proportions as alpha and beta pulses in a long and short nature respectively. Kinetic theory observations were deduced in this study, as part of ionizing radiation were transferred to the cocktail and converted to signals being detected by the electronic components of Hidex 300 SL system. Stream of photons was emitted by fast exponential decay of excited singlet states of the gross alpha and beta radioactivity in the sample which too approximately 50 – 70 sec.

System Output

The above procedure led to a longer lifetime that caused the pulse component delay. Greater number of excited molecules in triplet state resulted from higher ionization for alpha particles. This indicates that alpha particles took longer time during outputs. This output delay of alpha pulses was noticed to enhance the entire alpha and beta pulse separation scenarios by the pulse shape discrimination. A storage oscilloscope was set to take the averages of incident signals being produced at the PMTs anode. Since photons were insignificantly consequential, hence, gamma-ray background rejections were ensured via pulse shape discrimination as well as isolation of fission events. Figure of Merit (FoM) was in turn enhanced and optimized which guaranteed statistical qualitative data (results) obtainment in the analysis. An output of 0.03 ± 0.01 and 2.0 ± 0.01 cmp as background of alpha and beta activity concentration was obtained. However, after the successful handling the counting of the samples, the radioactivity of gross alpha and beta were manually calculated using equations (3) and (4) in a similar fashion conducted by Nisti et al. (2009).

$$\alpha(pC_i/L) = \frac{A \times 1000}{2.22 \times C \times V} \quad (3)$$

Where, A is the net alpha count rate (gross alpha count rate minus the background count rate) at the alpha voltage plateau of 1000, C is the alpha efficiency factor from graph of efficiency ($cmp\ /dmp$), V is the volume of sample aliquot in ml , 2.22 is the conversion factor from $Dpm\ /pC_i$.

$$\beta(pC_i/L) = \frac{B \times 1000}{2.22 \times D \times V} \quad (4)$$

Where, B represents the net beta count rate (gross count rate minus the background count rate at the better voltage plateau of 1000), D is the beta efficiency factor from the graph of efficiency ($cmp\ /dmp$), V represents the volume of sample aliquot in ml. 2.22 is the conversion factor from $Dpm\ /pC_i$ but $1\,C_i = 3.7 \times 10^{10}\,Bq$ for conversion of Curie to Baquerel.

RESULTS AND DISCUSSION

Table 1: Results of Gross Alpha and Beta Radioactivity Concentration (BqL^{-1}) in Water Samples from/Around Mining Points, Dange-Shuni, LGA, Sokoto State.

Code	Alpha	Beta
$DANG_{SOK\ 1}$	1.08±0.01	7.088 ± 0.11
$DANG_{SOK\ 2}$	0.131±0.01	9.001 ± 0.21
$DANG_{SOK\ 3}$	2.111±0.02	5.011 ± 0.33
$DANG_{SOK\ 4}$	2.014±0.02	5.016 ± 0.41
$DANG_{SOK\ 5}$	1.021±0.11	8.001 ± 0.5
$DANG_{SOK\ 6}$	1.112±0.02	6.101 ± 0.13
$DANG_{SOK\ 7}$	0.13±0.01	7.002 ± 0.17
$DANG_{SOK\ 8}$	1.071 ± 0.11	8.011 ± 0.03
$DANG_{SOK\ 9}$	2.11 ± 0.11	5.017 ± 0.11
$DANG_{SOK\ 10}$	2.001 ± 0.12	6.022 ± 0.12
$DANG_{SOK\ 11}$	1.121 ± 0.33	9.011 ± 0.03
$DANG_{SOK\ 12}$	0.111 ± 0.41	7.011 ± 0.04
$DANG_{SOK\ 13}$	0.311 ± 0.05	7.111 ± 0.12
$DANG_{SOK\ 14}$	2.101 ± 0.13	8.001 ± 0.31
$DANG_{SOK\ 15}$	1.211 ± 0.17	8.004 ± 0.02
STD	0.761 ± 0.12	1.354 ± 0.14
AVERAGE	1.176 ± 0.10	6.673 ± 0.18
MIN	0.111 ± 0.01	5.011 ± 0.02
MAX	2.111 ± 0.41	9.011 ± 0.5

Table 1 above is the tabulated results of gross alpha and beta radioactivity concentration obtained from water samples around mining sites in Dange-Shuni LGA, Sokoto State. The results are from Seventy-five water samples collected and subsequently aggregated into Fifteen analyzed results based on cluster, homogeneity, geological factors consideration and proximities pits. The results indicates that gross alpha and beta radioactivity concentrations in water sample ranges between $0.111 \pm 0.41\ BqL^{-1}$to $2.111 \pm 0.02\ BqL^{-1}$with an average value of $1.176 \pm 0.10\ BqL^{-1}$respectively. Also, the gross beta radioactivity concentrations in water samples varies from $5.011 \pm 0.33\ BqL^{-1}$to $9.011 \pm 0.02\ BqL^{-1}$ with an average of $6.673 \pm 0.18\ BqL^{-1}$ respectively. The result of the water samples labeled as $DANG_{SOK3}$ has the highest gross alpha radioactivity concentration while the result of water sample labeled as $DANG_{SOK12}$ has lowest respectively.

In order words, the results of water sample labeled as $DANG_{SOK4}$ shows the highest gross beta radioactivity concentration while the one labeled as $DANG_{SOK3}$ indicates the lowest gross beta radioactivity concentration. In contrast, the water sample coded as $DANG_{SOK11}$ has the highest gross beta radioactivity concentration but its corresponding gross alpha radioactivity concentration from the same sample point is fairly low. This trend could be easily accessed gross alpha and beta radioactivity concentration measurement in water samples (Tettey-Larbi *et al.*, 2013).

Interestingly, the results obtained for the gross alpha and beta radioactivity concentrations in this study might be reflecting the significance of radioactive elements capable of emitting alpha and beta particles during their decay since both exist in the formative stage of the soil where water sources are embedded.

However, the results of the gross alpha radioactivity concentration measured in theses water samples shows that the lower range fell below the global threshold of 0.5 $BqL^{-1}$for drinking water of $0.111 \pm 0.41\ BqL^{-1}$while the highest value obtained from the measurement is significantly higher than the global limit of 1.0 BqL^{-1}respectively (WHO, 2011).

Figure 2 below is a graph of combined chart of alpha and beta radioactivity concentrations in the water

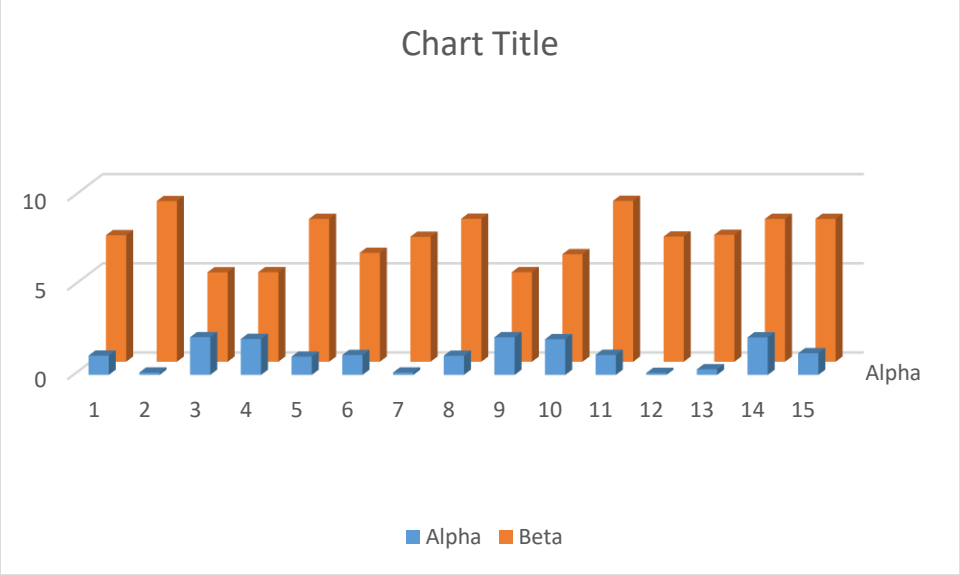

Figure 2. The Combined Chart of Gross Alpha and Beta Radioactivity Concentrations in Water

Samples collected and measured from mining sites in Dange-Shuni LGA. it was found the chart behavior fluctuates with 86.7% elevated gross alpha radioactivity concentrations above world threshold value of 0.5 BqL^{-1}.Similarly, the combined chart displays some dynamics of the values of beta radioactivity concentration over global limit of 0.5 $BqL^{-1}$with about 80% of the results. These trends may not be unconnected with the potential dispersion of soil particles that were dug out of the mining points that subsequently finds their ways into water bodies. An implication that was earlier forecasted in the work of Ahijjo and Umar (2015). This could be monitored and studied in some further endeavors.

Table 2 below is a table of representation of the results of previous studies and the present one for the gross alpha and beta radioactivity concentration in water samples.

Table 2: Comparison of the Present Result and those of Previous Studies

Country/Place	Radioactivity Concentration		Reference
	$\alpha-$ Activity	$\beta-$ Activity	
Sokoto/Dange-Shuni	1.176 ± 0.10	6.673 ± 0.18	This study
Turkey/ East Anatolia	0.118±0.017	0.226±0.012	Sultan et al. (2012)
Ghana	11.73±0.61	124.34±11.28	Tettey-Larbi et al. (2013)
Plateau/Jos	6.64±0.03	–6.68±0.04)	Mangset et al. (2015)
Bangladesh	0.91± 0.18	175 ±4.02	Biswas et al. (2015)

CONCLUSION

The gross alpha and beta radioactivity concentration in water sample in the vicinities of mining points have been ascertained in a bid to determine the safety level of domestic water available for drinking and other domestic utilities in the mining communities in Dange-Shuni LGA, Sokoto State. This study has also been able to unveil plausible basis for its approach in sampling of domestic water for analysis and a baseline scientific analytical methods of Liquid Scintillation Counting system of Hidex 300 SL used.

However, further studies could be directed towards achieving the connections between the level of toxicity and contaminants responsible for the gross alpha and beta radioactivity concentration in water around some mining communities of these localities. Hence, this study may have provided an important aspect of data for scientific endeavors in the path of determining environmental radioactivity in water samples around mining sites in general.

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