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Evaluation of Radioactivity Concentration in Drinking Water Collected from Local Wells and Boreholes of Dutse Town, North West, Nigeria

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Abstract: Water is necessity to human and other life, human uses water for drinking, agricultural activities, domestic activities and so on. Therefore, it become necessary to study the level of radiation in our drinking water, because it poses many biological risks to human and other life when exceeded the maximum contamination level. This study examined the level of radioactivity of drinking water collected from local hand-dug wells and boreholes in Dutse town of Jigawa State. A total of 24 samples were collected and analyzed using MPC-2000, a Low Background alpha and beta counter. The equipment is a gasless proportional counter with ultra-thin window. The results showed that the alpha activity ranges from 0.006 to 0.485 Bq/l with a geometric mean of 0.060 Bq/l for borehole water samples and 0.003 to 1.08 Bq/l with a geometric mean of 0.094 Bq/l for well water samples and that of beta activity ranges from 0.009 to 84.68 Bq/l with a geometric mean of 5.288 Bq/l for borehole water samples and 6.830 to 6284.50 Bq/l with a geometric mean of 29.70 Bq/l for well water samples. Most of the sampling areas were above the maximum recommended level set by World Health Organization (WHO) of 0.5 Bq/l for alpha and 1.0 Bq/l for beta and United State Environmental Protection Agency (USEPA) of 0.55 Bq/l for alpha and 1.85 Bq/l for beta activity. An attempt has been done to examine the correlation between the alpha and beta activity and a very poor correlation was obtained. It was further observed that well water samples recorded higher activity compared to borehole water samples. The lower activity in the borehole water samples may be due to the absorption of the activity in the pipes unlike the well water samples that was drawn directly from it source. The overall results showed that many of the sampling areas are not suitable for drinking, agriculture and other domestic activities. It is therefore, recommended that more studies should be carried out to ensure the safety of the general public in these locations.

Keywords: Gross Alpha, Gross Beta, Radioactivity, Boreholes, Wells, Dutse Town

1. Introduction

Radioactivity in water is relatively easily measured, given the appropriate equipment and radio-analytical expertise, the interpretation of the significance of the measured radioactivity to the domestic water user is beset with uncertainties and imponderables, especially when it comes to evaluating the actual risk to the consumer. Water is a necessity to man and his environment; it has existed throughout the history of the earth crust even before the existence of man. Man uses water for the following activities: irrigation, power generation and domestic activity. There are two sources of water: rain and ground waters. It is found in rivers, wells, lakes and streams. The activities of human and natural phenomena constantly pollute the sources of water and affect water quality. Water pollution arises as a result of waste and sewage disposal into the environment and rivers by industries, hospitals and use of materials such as fertilizers by farmers. These disposed materials often contain radio nuclides [1]. In developing countries like Nigeria, lack of good drinking water is one of the serious threats to the human health as a result of that, rivers, streams, well and borehole waters are often used as supplement for the scarce pipe-borne water for drinking and domestic activities without any treatment [2].

Water bodies are also polluted from Naturally Occurring Radioactive Materials (NORM) that emits alpha, beta and gamma radiation. These usually have elements in the uranium and thorium series whose radioactive cause an appreciable airborne particulate activity and contribute to the radioactivity of rain and ground waters. It also affects drinking water from deep wells which are expected to have a higher concentration of radioactive elements compared to surface water. Furthermore, man-made alpha emitters, such as plutonium and americium could be transported into springs or wells there upon extending the activity level of the water [1].

Radioactivity in drinking water is an important mode of transfer of radio nuclides from the environment to man. The most important natural radio nuclides in drinking water are tritium, potassium-40, radium and their decay products, which are in essence beta and gamma emitters [1].

There is evidence of widespread contamination of water resources in many areas of our country. The Environmental Protection Agency's National Water Quality Inventory of 1994 has identified agriculture, urban runoff/storm water, and municipal point sources as the largest pollutant sources for rivers, lakes, and estuaries. Contaminants from these sources include pesticides, metals, nitrates, solvents, and other wastes. More than 200 chemical constituents have been documented in groundwater alone. But it should be noted that not all contamination events pose a threat to our health. The National Water Quality Inventory 1994 Report to Congress states that 40% of flowing river and stream miles can be used for drinking water after conventional water treatment, and 37% of lake and reservoir acres meet the designated use criteria for drinking water. Pollutant concentrations become diluted when they enter water sources and are further reduced by biological degradation, filtration, and adsorption to soil. Some chemicals, such as the man-made chlorinated hydrocarbons, are very stable in the environment. Some of these compounds accumulate in living organisms and are not readily metabolized and excreted.

The impacts of contamination events to lakes and reservoirs are more severe and persistent than streams and rivers because there is no natural flushing process as is characterized by the flow in streams and rivers. Contamination is even more persistent in groundwater due to lack of biological degradation. The most biologically active bacteria live within the soil above groundwater supplies. Inflow of waste-water from industries and rainwater flowing over farmland into the rivers and other water bodies constitute a source of pollution to drinking water in a particular area. The pollution may constitute heavy elements as well as radioactive elements whose existence could prove to be hazardous to health. Data on radioactivity in drinking water is therefore important in determining the quality and health impact on the populace. In Dutse town there is yet no established data on the radioactivity level in drinking water sources. Most of the rural inhabitants of the area depend on water from boreholes and local dug wells for drinking, household activities and irrigation. It may be possible that the water they used contain excess of naturally occurring radioactive elements and Heavy metals which may be harmful to human and other life. The aim and objectives of this study is to evaluate the gross alpha and beta activity in the sample locations and to establish the distribution pattern of the radioactivity measured in the locations in order to identify areas with elevated activity if any.

2. Materials and Methods

2.1. Counting Equipment

The gross alpha and beta counting equipment used in this work was MPC-2000, a Low Background alpha and beta counter. The equipment is a gasless proportional counter with ultra-thin window. The sample was placed in a planchet and later placed in a sample carrier and the carrier was then placed on the sample drawer and closed for the purpose of gross alpha and beta counting, the counting was done automatically according to the selected count mode when the appropriate sample parameters were entered [3].

2.2. Sampling

a) Sampling Frame.

The area under study is the Dutse metropolis and this investigation is limited to underground water sources in local boreholes and wells used by people for drinking, domestic activities, irrigation and animal husbandry. The method adopted for the sampling is stratified random sampling [2].

b) Sampling Procedure.

The sampling procedure involves the following:

- The sample container was rinsed three times with the water being collected, to minimize contamination from the original content of the sample container.
- An air space of about 1% in the container of water collected was left for each sample to give room for thermal expansion. There was marked on each container indicating two liters of volume corresponding to the air gap. 20 ml of diluted nitric acid was added to the sample immediately after collection to reduce the pH and to minimize precipitation and absorption on container walls.
- The samples were tightly covered with container cover and masking tape and kept in the laboratory for analyses
- Two samples were collected per sampling point which gives the total of 48 samples from 24 different sampling points.

2.3. Sample Preparation

The specified volume of each sample was measured into a beaker and evaporated on a hot plate to 50 ml volume and then transferred to a clean dry planchet. The samples were evaporated to dryness on hot plate. The residues were transferred onto to a clean, dry and previously weighed planchet and the difference between the mass of empty planchet and that of the empty planchet plus residue gives the mass of the residue. The residues were uniformly spread on the planchet by dropping a few drops of ethanol. The residues were allowed to dry and then covered with Mylar film ready for counting.

$$\text{Sample efficiency} = \frac{(w_2 - w_1) - (w_3 - w_1)}{w_2 - w_1} \times 100\% \quad (1)$$

where w_1= weight of empty planchet, w_2 = weight of planchet plus residues obtained after evaporation and w_3 = weight of empty planchet – weight of residue

2.4. Counting and Analysis

The counting equipment is automated. The protocol involves entering preset time, counting voltage and number of counting cycles. Also, the counter characteristics (efficiency and background) volume of sample used and sampling efficiency specified. Results are displayed as raw count, (count/min) count rate, activity, and standard deviation [4]. The calculation formulae for count rate activity and other parameters for a given sample are shown below:

a) Count Rate

$$\text{Rate}(\alpha,\beta) = \frac{Raw\ (\alpha,\beta) Count}{Count\ Time} \quad (2)$$

In all modes except mode alpha then beta:

b) Activity

$$\text{Activity}(\alpha,\beta) = \frac{Rate\ (\alpha,\beta) - Bgd\ (\alpha,\beta)}{Sample\ Efficiency \times Channel\ Efficiency \times Volume} \times \frac{1}{60} \quad (3)$$

The statistical precision is calculated for each channel, on each measurement and it depends only on the preset count whose value is declared indirectly. Assume N measurements are made during a time T, the average is given by $x = \frac{\sum xi}{N}$ and the standard deviation is given by

$$\sigma = \sqrt{[\frac{R_s}{t_s} + \frac{R_b}{t_b}]} \quad (4)$$

R_s = Sample counting rate
R_b = Background counting rate
t_s = Sample counting time
t_b = Background counting time

$$CR = 1.96\sigma \quad (5)$$

Where CR = Counting Error

c) Statistical Analysis

In order to analyze the activity measured, statistical analysis employed are estimation of the central tendencies and deviations, correlation analysis and histograms. The correlation coefficient (r) is given by the expression below [5]:

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \quad (6)$$

and the geometric mean is given by as:

$$\text{Geometric Mean} = \sqrt[n]{(x_1, x_2 \ldots x_n)} \quad (7)$$

Where μ is the population mean and σ is the standard deviation. All statistical analyses were made using the Microsoft Excel.

3. Result and Discussion

3.1. Measured Activity for Boreholes and Wells Samples

In this section we shall discuss the measured activity for the samples collected from boreholes and local dug wells. It was observed that the average alpha activity measured from boreholes and wells were 0.09 and 0.33 Bq/l respectively and the average beta activity measured for boreholes and wells samples were 18.6 and 508 Bq/l respectively. In addition, the geometric mean for both alpha and beta activity was also computed, for the samples collected from local dug wells and boreholes: the geometric mean of alpha activity were 0.09 and 0.06 Bq/l respectively and 29.70 and 5.29 Bq/l respectively for beta activity.

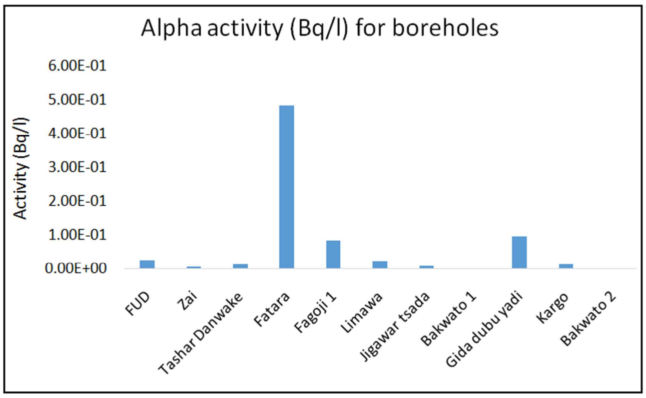

Fig. 1. Plot of Alpha Activity for Boreholes Water.

Figure 1 shows an alpha activity for boreholes water samples collected from Dutse town and the chart behavior fluctuates with some elevated activity and low activity at some other areas. The maximum and minimum recorded activity at fatara and Zai with corresponding values of 0.485 and 0.0062 Bq/l respectively. It could be seen that Bakwato 1 and 2 were recorded as 0 Bq/l in the plot above but they were below detection limit (BDL) of the system.

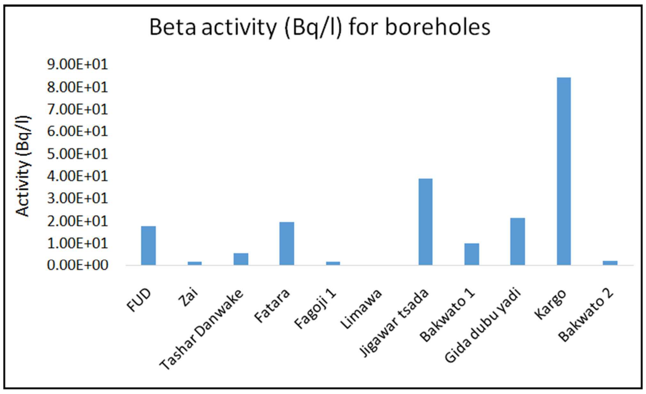

Fig. 2. Plot of Beta Activity for Boreholes water.

Figure 2 shows the plot of beta activity for boreholes water samples collected from Dutse town. The chart indicated a fluctuating behavior with some elevated activity and low activity in some other areas. The maximum and minimum activity were recorded at Kargo and Limawa with corresponding values of 84.68 and 0.0089 Bq/l respectively. Further observation was made almost all the sampling area exceeded the maximum permissible limit set WHO and USEPA except for Fagoji 1 and Zai which were below the maximum contamination level set by USEPA of 1.85 Bq/l and only Limawa comply with the recommended level set WHO of 1.0 Bq/l.

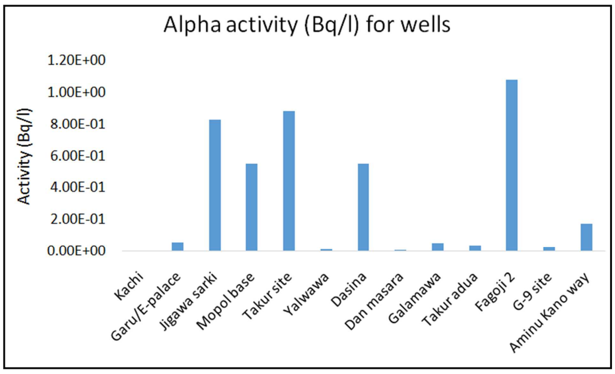

Fig. 3. *Plot of Alpha Activity for Wells water samples.*

Figure 3 shows the bar chart of alpha activity for wells water samples collected from Dutse town. The chart indicated a fluctuating behavior with some elevated activity and low activity at some other areas. The maximum and minimum activity were also recorded at Fagoji 2 and Kachi with corresponding values of 1.08 and 0.0031 Bq/l respectively.

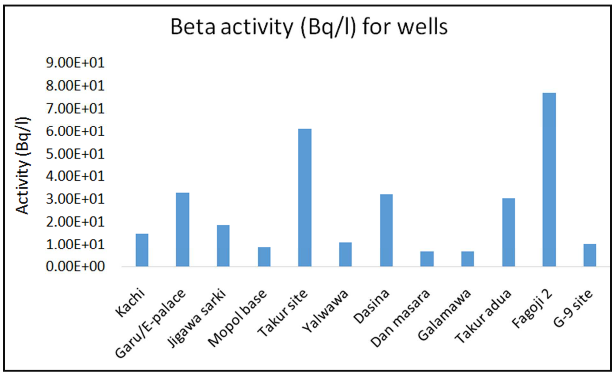

Fig. 4. *Plot of Beta Activity for Wells water samples.*

Figure 4 shows the beta activity for wells water samples collected from Dutse town. The chart indicated that the activity varies across the sampling areas. However, all sampling areas exceeded the maximum recommended limit set by WHO and USEPA for safe drinking of values 1.0 and 1.85 Bq/l respectively. The maximum and minimum activity were recorded at Aminu Kano way and Galamawa with corresponding values of 6284.5 and 6.83 Bq/l respectively.

3.2. Alpha and Beta Activity for the Combined Boreholes and Wells Water Samples

Below illustrated the alpha and beta activity for Dutse town it could be seen that the maximum and minimum alpha activity observed at Fagoji 2 and Kachi with corresponding values of 1.08 and 0.0031 Bq/l respectively. Similar observation was made for beta activity at Aminu Kano way and Limawa with corresponding values of 6284.50 and 0.0083 Bq/l respectively. It would be observed that Aminu Kano way dose not captured in the plot for beta activity due its magnitude which would make it difficult to observe the other activities as shown in the figures 5 to 6.

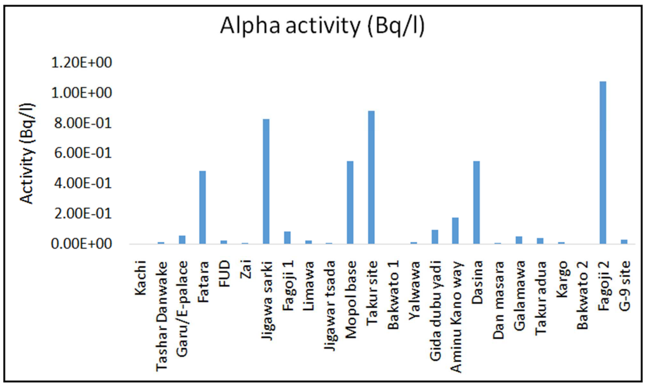

Fig. 5. *Plot of Alpha activity (Bq/l) against Sampling Points.*

Figure 5 shows the plot of alpha activity against sampling points for Dutse town. The results indicated that Jigawa sarki, Mopol base, Takur site, Dasina and Fagoji 2 showed elevated activity which is above the maximum recommended level set by World Health Organization (WHO) of 0.5 Bq/l. Apart from Jigawa sarki, Takur site and Fagoji 2 which displayed very high activity, all other sampling areas comply with maximum recommended level set by United State Environmental Protection Agency (USEPA) of 0.55 Bq/l. the average alpha activity computed was 0.229 Bq/l which was below the maximum permissible limit set by WHO and USEPA for safe drinking water.

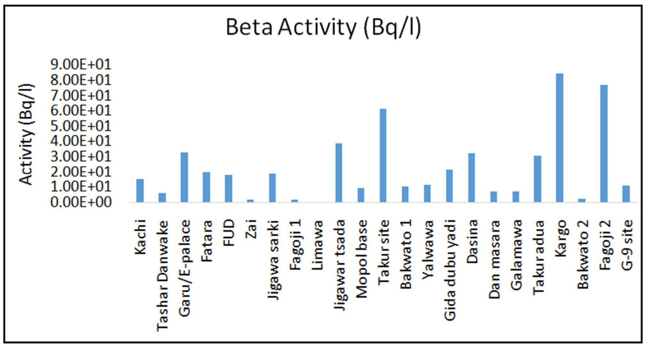

Fig. 6. *Plot of Beta activity (Bq/l) against Sampling Points.*

Figure 6 shows the plot of beta activity against sampling points for Dutse town. The results indicated that almost all the sampling sites showed elevated activity except for Fagoji 1 and Zai which are below maximum recommended level set by USEPA which is 1.85 Bq/l and only Limawa comply with the recommended level set by WHO which is 1.0 Bq/l. The mean value computed was 283.00 Bq/l which exceeded the maximum permissible limit set by WHO and USEPA for safe drinking water.

3.3. Comparison Study Between Alpha and Beta Activity

Below is the correlation between the measured alpha and beta activity in Dutse town of Jigawa State, Nigeria.

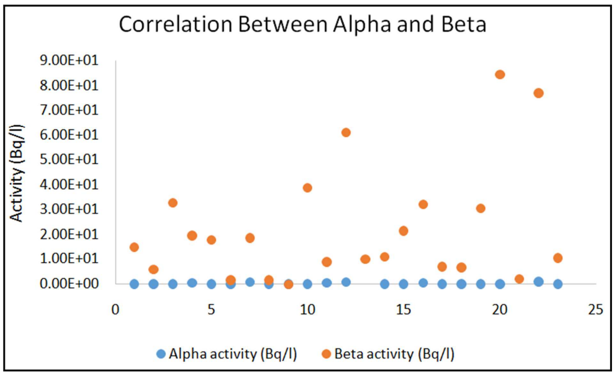

Fig. 7. *Plot of Correlation between Measured Alpha and Beta Activity.*

Figure 7 shows the correlation study between measured alpha and beta activity for Dutse town. The correlation between alpha and beta gave the coefficient of determination (R^2) value of 0.0046 and a Pearson regression coefficient (r) of 0.068 showing that there is no significance statistical relationship between alpha and beta activity as indicated from the correlation, that only 6.8% of the alpha activity is correlated with beta activity.

3.4. Comparison of Measured Activity in Dutse with Other Locations

The results of measured gross alpha and beta activity in Dutse were compared with other locations within and outside Nigeria. The maximum and minimum recorded in China were compared with the results measured in Dutse town and the following were observed: the maximum alpha activity measured in China was 88% less than that of Dutse town and the minimum measured was three times that of Dutse town. Similar comparison was conducted for beta activity, the maximum beta activity measured in China was negligible compared to the one measured in Dutse and the minimum activity measured in China was almost eight times that of Dutse town. Other comparisons were described in the table 1 below.

Table 1. *Comparison of Measured Activity in Dutse with Other Locations.*

Location	Measured Activity (Bq/l)								Source
	Alpha				Beta				
	Min	Max	Gm	Mean	Min	Max	Gm	Mean	
Gombe	0.001	0.063	0.01	-	0.132	3.828	0.526	-	[2]
KUST, Wudil	0.0005	0.022	-	0.006	0.008	0.345	-	0.048	[6]
Sokoto	0.01	6.00	0.26	-	-	-	-	-	[7]
Bayelsa	-	-	-	4.02	-	-	-	54.23	[8]
Turkey	0.08	0.38	-	0.192	0.12	3.47	-	0.579	[9]
China	0.009	0.20	-	-	0.067	0.32	-	-	[10]
Zaria	0.035	0.01	-	0.015	0.06	0.91	-	0.33	[11]
Dutse	0.003	1.08	0.006	0.229	0.008	6284.5	13.48	283.0	This work

Table 1 above shows the comparison between the measured alpha and beta activity in Dutse town with other places including Gombe, Wudil, Sokoto, Bayelsa, Turkey, China and Zaria. It was observed that the alpha activity measured in Gombe was 0.4% greater than that of Dutse town and that of beta activity was extremely less than that of beta activity measured in Dutse town. For Wudil; it was 22.3% less than that of Dutse for alpha and extremely less than that of beta activity measured in Dutse. For Sokoto; it was 25.4% greater than that of Dutse for alpha activity. For Bayelsa, it was extremely greater than that of Dutse for alpha and extremely less than that of Dutse for beta activity. For Turkey; it was 3.7% less than that of Dutse for alpha and extremely less than that of Dutse for beta activity. For Zaria, it was 21.4% less than that of Dutse for alpha and extremely less than that of Dutse for beta activity.

It could be seen that arithmetic and geometric mean computed indicated that the alpha activity measured was less than maximum contamination level set by WHO of 0.5 Bq/l and for beta activity, it was above the maximum contamination level set by WHO of 1.0 Bq/l. The elevated activity recorded for beta may be due to the nature of the sample locations and geological activities in these areas.

Water samples were collected from both local dug wells and boreholes in Dutse town. The samples were studied and analyzed for gross alpha and beta activity.

The first study was to examine alpha and beta activity for the samples collected from boreholes and wells respectively. In the study the maximum and minimum alpha activity recorded for boreholes water samples were 0.485 and 0.006 respectively and the corresponding beta activity were 84.68 and 0.009 Bq/l respectively. Similar results were obtained for wells water samples of values 1.08 and 0.003 Bq/l respectively for alpha activity and 6284.5 and 6.83 Bq/l respectively for beta activity. Among the study areas, only two sampling points namely: Bakwato 1 and 2 were below detection limit of the system.

Study for the combined boreholes and wells water samples has been done and the following observations were made as shown in the table 2 below:

Table 2. *Arithmetic and Geometric Mean of Alpha and Beta Activity.*

Observations	Alpha Activity (Bq/l)	Beta Activity (Bq/l)
Overall Maximum	1.08	6.28×10^3
Overall Minimum	3.09×10^{-3}	8.29×10^{-3}
Arithmetic mean	0.23	283.00
Geometric mean	5.84×10^{-3}	13.48

Finally, a correlation between alpha and beta activity was also determined and a Pearson regression coefficient of value 6.8% was obtained which implied that there is no significant relation between alpha and beta activity.

4. Conclusion

The level of gross alpha and beta radioactivity in drinking water samples drawn from local hand-dug wells and boreholes in Dutse town were examined using MPC-2000, a Low Background alpha and beta counter. The results showed that most of the sampling areas showed elevated activity. The overall maximum and minimum activity concentrations were 1.08 and 0.0031 Bq/l respectively with mean value of 0.23 Bq/l for alpha activity and 6284.5 and 0.0083 Bq/l respectively with a mean value of 283.0 Bq/l for beta activity. The result obtained was compared with other locations within and outside Nigeria. A study was made to determine the correlation between the alpha and beta activity and a Pearson correlation coefficient of 6.8% was obtained which implied very poor correlation. It was also observed that the study area was covered with rocks mostly metamorphic type which was believed to have affected the level radioactivity in the sample locations especially the well water samples. The reason of having lower activity in the borehole water samples was due to the absorption of some part of the radiation by the wall of the pipes. Therefore, it is recommended that further studies to investigate the level of radioactivity and radionuclides concentration in these locations need to be carried out.

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