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# RADIOACTIVITY LEVEL IN WATER AROUND A CEMENT FACTORY IN NORTH CENTRAL NIGERIA

[1,2]Bello, I.A., [2]Zakari, Y.I., [2]Garba, N.N., [2]Vatsa, A.M. and [3]Kure, N.

*[1]Division of Agricultural Colleges, Ahmadu Bello University Zaria, Nigeria
[2]Department of Physics, Ahmadu Bello University Zaria, Nigeria
[3]Department of Physics, Kaduna State University, Kaduna, Nigeria

*E-mail of the corresponding author: dbell1066@yahoo.com

**ABSTRACT**
In recent times, there has been consistent demand for drinkable water to meet the growing population of Obajana environs, where cement factory is situated. The mean gross alpha and beta activities in drinkable water around the communities of the cement factory, following a continuous exposure of workers and habitants was determined using a low background Gas-less counting system with solid state silicon detector for alpha and beta detection. The average activities for gross alpha and beta water ranged between 0.002871±0.00957 to 0.05335±0.0253 Bq/l and 0.2937±0.0588 to 39.96±11.3000 Bq/l, respectively. The alpha and beta geometric mean of the whole samples were found to be 0.0156±0.01487 Bq/l and 10.9±13.8373 Bq/l, respectively. The correlation coefficient (R), was found to be R = 0.8181, which shows there is a good relationship between the measured gross Alpha and Beta (activity). The average annual committed effective dose for water intake was between 0.149 mSv to 20.100 mSv, the recommended reference level for ingested dose for drinkable water was however exceeded in most locations, thus making the water in most locations not quite safe for consumption.

**Keywords:** Water, Cement Factory, Effective dose, Gross Alpha and Gross Beta.

## 1. INTRODUCTION

Globally, cement production undergoes different processes such as quarrying and handling of raw materials, grinding the clinker, blending, packing and shipping of the finished products. A crucial process in cement production is the quarry process. Research has shown that this process increases the activity concentration of possible natural radionuclides in the production environment (Gbadebo, 2011). In Obajana Environment where quarrying and mining activities are high due to cement production from the factory, it is possible to have underground water contamination due to gamma, beta and alpha radiation emitters.

The presence of radionuclides in water poses a number of health hazards, especially when these radionuclides are deposited in the human body through drinking. Dissolved radionuclides in water emit particles (alpha and beta) and photons (gamma) which gradually affect living tissues (Gruber et al., 2009). In radioactivity research, attentions are most often given to gamma emitters detection and quantification even in an environment where it is possible to have alpha and beta emitters (Mehade *et al.*, 2014). Gamma rays have the highest penetrating power compared to alpha and beta particles within the body either through inhalation or ingestion compared to alpha and beta particles, the effects of alpha and beta particles within the body either through inhalation or ingestion are far more detrimental because of their ionizing power.

The world health Organization guidelines for drinking water quality recommended the determination of gross alpha and beta activity concentrations in drinking water as the first step of the radiological aspect of the drinking water quality (WHO, 2004). The essence of the evaluation gross alpha and gross beta activities is to ensure that the reference dose level (RDL) of 0.5 Bq/l for gross alpha,1.0 Bq/l for gross beta and 0.1 mSv for committed effective dose for 1 year's consumption of drinking water is not exceeded as recommend (WHO, 2004).
Data available reveals that the geology of Obajana and its environs contains significant amount of marble deposits within the Basement Complex geology of the area (Etu-efeotor et al., 1989). High rate of cement production in Obajana cement factory, increases the exploiting rate of Obajana marble deposit through mining, there is need to assess the environmental impact of mining on the environment. This includes the assessment of gross alpha and beta activities in underground water as well as the effective dose to the dwellers in the environment.

### 1.2 The Study Area

Obajana lies within longitude $6^0$24'E to $6^0$27'E and latitude $7^0$54'N to $7^0$56'N (Musa *et al*, 2012). It can be accessed through Lokoja-Kabba road. The establishment of Dangote cement factory increase the population of the community, from about 400 to 5000. The community is rich in large deposits of limestone and other minerals needed for production of cement. The area falls within the Kabba-Jakura Formation, which consists of five rock units. These are Obajana gneiss member, garnetiferous biotite-gneiss, schists, quartzites, and limestone/marble. Marble is basically a metamorphic rock formed essentially from sediment and composed mainly of a crystalline aggregate of calcite and/or dolomite (Iqab *et al.*, 2000). It may, therefore, contain appreciable amounts of radioactive materials leached out from porous uranium-rich rocks. The limestone/marble in the study area occurs within the schist quartzite series overlying the Obajana gneiss member. It is generally a white coarse-grained rock, with other varieties being fine-grained and grayish in color. The limestone/marble contains appreciable amounts of calcium carbonate, with the content of magnesia below the limit for cement manufacturing. Due to mining activities of cement raw materials, farm practices around the mining area and ground water that serve as major source of water, it becomes necessary to establish a baseline radioactivity level in the study area.

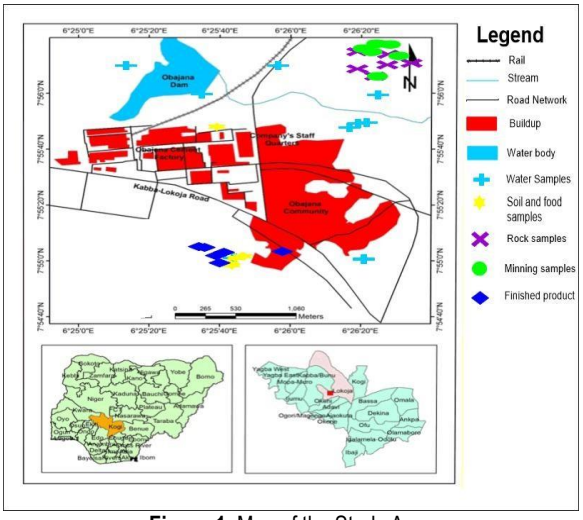


**Figure 1**: Map of the Study Area

## 2.0. MATERIALS AND METHODS

An initial Survey to ascertain the level of gamma radiation was carried out within the Cement Factory and the sampling point, using a portable Survey meter (Rados Model RDS 120) having sensitivity range of 0.05μSvh$^{-1}$-10Svh$^{-1}$. The Survey meter was Calibrated at the Instrumentation Laboratory, at Center for Energy Research and Training, Ahmadu Bello University, Zaria.

### 2.1 Sample Collection

Drinkable water Sampling comprising of 7 hand dug wells, 1 borehole and 2 stream channels spread all over the Obajana community where randomly selected. At each sampling point, 1.5L plastic container was used for the collection of the water sample from source with about 1% air space of the container left for thermal expansion. Sample containers were rinsed three times with sample water being collected to minimize contamination from the original content of sample container. Hand dug shallow well water samples were collected at the early hours of the day from host community wells of varying depths (5 to 10m). The water samples were collected directly from the wells, by dipping a clean container on a rope long enough to reach the water level in the well. For the borehole waters, before samples were collected the taps was first turn on at full capacity for few minutes to purge the plumbing system (Tchokossa *et al.*, 1999). The samples of river/stream waters were collected from the host community domestic water fetching spot in the early hours of the day using the grab sampling method as reported by Avwiri and Agbalagba (2007).

### 2.2 Sample preparation and evaporation

The water was acidified immediately after collection with nitric acid solution ($HNO_3$) in order to prevent the growth of micro-organisms. Evaporation was done in the laboratory using hot plates, without stirring and at moderate heat in an open 600 ml beaker. It took an average of about 16 hrs to complete the evaporation of one liter of each sample. During evaporating process, the sample was transferred into petri dish, when level of sample in the beaker was about 50 ml. The sample was later placed under infrared source to completely dry the residue.
The sample was allowed to cool before weighing.

### 2.3 Sample Analysis

The prepared samples were counted to determine alpha and beta activity concentration using the low background Gas-less Alpha/Beta counting system (Protean Instrument Corporation (PIC) MPC 2000DP), calibrated with alpha (239Pu) and (90Sr) standards. The system used a solid state silicon (passivated implanted Planar Silicon, PIPS) detector for alpha and beta detection. The samples were counted for 200 min. the alpha and beta efficiency were determined to be 87.95% and 42.06%, respectively. The detection limit of the alpha and beta activity concentration were 0.16 and 1.47 cpm, respectively. The background reading of the alpha and beta activity concentration were 0.14 and 77.82 cpm. All the measurements were done at the Low Background Laboratory, at Center for Energy Research and Training, Ahmadu Bello University, Zaria, Nigeria.

### 2.4 Statistical Analysis

There are many softwares used for statistical analysis in various disciplines but the most versatile and widely used is (Excel, 2016), which was used to analyze measured data in this study. Descriptive statistics, Correlation and Analysis of variance (ANOVA) single factor were the statistical analysis performed in this study.

## 3.0 Results and Discussion

The measured sample locations using global positioning system (GPS) and equivalent dose rate at different sampling points using portable Survey meter (Rados Model RDS 120) around the Obajana cement factory were recorded and shown in table 1. Sample Location identifications (WW = hand dug wells, BH = Borehole and STRM = flow Stream channels).

**Table 1:** Insitu measured dose rate and sample location.

| Sample Location | Gamma Dose rate (μSv/h) | Geographical Coordinate | |
|---|---|---|---|
| | | Longitude | Latitude |
| WW1 | 0.13 | 6$^0$26'35.71"E | 7$^0$58'10.99"N |
| WW2 | 0.12 | 6$^0$26'30.03"E | 7$^0$58'12.33"N |
| WW3 | 0.1 | 6$^0$26'26.44"E | 7$^0$58'11.72"N |
| WW4 | 0.12 | 6$^0$26'26.55"E | 7$^0$58'05.96"N |
| WW5 | 0.1 | 6$^0$26'21.88"E | 7$^0$58'06.31"N |
| WW6 | 0.15 | 6$^0$26'28.83"E | 7$^0$55'20.94"N |
| WW7 | 0.11 | 6$^0$25'25.73"E | 7$^0$55'16.15"N |
| BH | 0.1 | 6$^0$26'28.71"E | 7$^0$55'20.42"N |
| STRM 1 | 0.11 | 6$^0$26'35.66"E | 7$^0$58'11.02"N |
| STRM 2 | 0.12 | 6$^0$25'27.16"E | 7$^0$55'21.77"N |

In Table 2., the mean dose rate values ($1.16x10^{-4}$ mSv/h) compared favorably with those measured at other factory in different parts of the country i.e. Delta Steel company (Adekoya *et al*., 2015), Ikot Akpaden, Uyo (Esen *et al*., 2013) and Ughelli, Delta state (Avwiri *et al*., 2007).

**Table 2**: Comparison of measured Insitu equivalent dose rate in Obajana with related national studies

| Location | Mean equivalent dose rate (mSv/h) | References |
|---|---|---|
| Delta Steel | $1.88 \times 10^{-3}$ | Adekoya *et al*., 2015 |
| Ikot Akpada, Uyo | $1.65 \times 10^{-4}$ | Esen, *et al*., 2013 |
| Ughelli, Delta State | $1.48 \times 10^{-4}$ | Avwiri, *et al*., 2007 |
| Obajana, Nigeria | $1.16 \times 10^{-4}$ | Present Study |

The Aerial Dose Rate Value (ADV) was determined from equation (1), in order to estimate annual dose rate value of public and occupational exposure of (1 $mSvy^{-1}$) and (20 $mSvy^{-1}$), respectively recommended by ICRP.

$ADV$ ($^{mSv}/_{y}$) = EDR ($^{mSv}/_{y}$) x 24 ($^{h}/_{day}$) x 365 ($^{day}/_{y}$) ------ (1)

Where: ADV is Aerial Dose Rate Value, EDR = Equivalent dose rate, 24 hrs = 1 day and 365days = 1 year.

Aerial dose rate was shown in table 3. ADV was highest at point WW6 and lowest at (WW3, WW5 and BH). Fig. 1 shows the calculated ADV.

**Table 3**: Aerial dose rate value around sample location

| Sample Location | Aerial Dose rate Value (mSv/yr.) |
|---|---|
| W1 | 1.139 |
| W2 | 1.051 |
| W3 | 0.876 |
| W4 | 1.051 |
| W5 | 0.876 |
| W6 | 1.314 |
| W7 | 0.964 |
| BH | 0.876 |
| STRM 1 | 0.964 |
| STRM 2 | 1.051 |

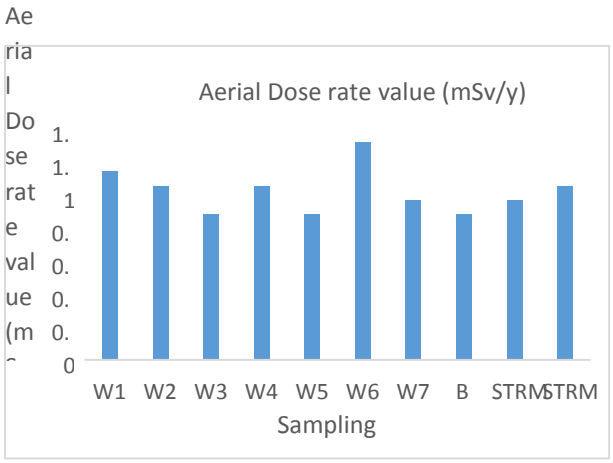


**Figure 2**: Aerial dose rate value around sample location

It was observed that 50% of the sampling points were slightly above the public exposure limit and all the sampling points were below the occupational exposure limit recommended by ICRP. It thus follows that greater risk is associated with sampling areas with high ADV above the public exposure limits. Thus, proper area monitoring should be done at regular base intervals in the area with high ADV, in order to limit public exposure to the smallest possible dose, so that the ALARA principle can be achievable.

The alpha (α) /beta (β) count rate and alpha/beta activity were calculated using the equation below.

$$\text{The alpha or beta count rate } (\alpha/\beta)\,(count/s) = \frac{Raw\,(\alpha/\beta)\ count \times 60}{count\ time\ (\text{time})} \quad \text{----------}$$

$$\text{The alpha or beta activity } (Bq/l) = \frac{\alpha/\beta\ count\ Rate\ - \text{bkg count rate (cpm)}}{detector\ efficiency \times sample\ efficiency \times sample\ vol.} \times 0.0167 \text{ --- (3)}$$

The alpha activity measured ranged from 0.002871±0.00957 to 0.05335±0.0253Bq/l, while the beta activity is in the range of 0.2937±0.0588 to 39.96±11.3000Bq/l as shown in table 4. The alpha and beta geometric mean of the whole samples were found to be 0.0156±0.01487 and 10.9±13.8373, respectively.

The error quoted in the table represents the standard deviation from repetitive measurements. In Fig 3., the mean beta activity in all the analyzed water samples was lower than the alpha activity, this agreed with many related experiments in other literatures (Adekoya *et al*., 2015, Onoja *et al*., 2011).

**Table 4**: Alpha and Beta Radioactivity concentration (Bq/l) of water samples around the Factory.

| Sample Location | Sample Gross Radioactivity Measurement (Bq/l) | |
|---|---|---|
| | Alpha Activity | Beta Activity |
| W1 | 2.220E-02 ± 1.97E-02 | 3.555E+00 ± 6.94E-01 |
| W2 | 1.784E-02 ± 1.34E-02 | 3.223E+01 ± 7.30E-01 |
| W3 | 7.896E-02 ± 7.01E-03 | 6.856E+00 ± 3.36E-01 |
| W4 | 7.400E-03 ± 2.17E-03 | 8.188E-01 ± 2.28E-01 |
| W5 | 7.900E-03 ± 2.49E-03 | 6.070E+00 ± 2.78E-01 |
| W6 | 9.796E-03 ± 4.64E-03 | 5.058E+00 ± 1.94E-01 |
| WW7 | 5.335E-02 ± 2.53E-02 | 3.996E+01 ± 1.13E+00 |
| BH (Bore hole) | 2.124E-02 ± 8.12E-03 | 1.233E+01 ± 3.38E-01 |
| STM1 (Stream1) | 2.871E-03 ± 9.57E-03 | 2.937E-01 ± 5.88E-02 |
| STM2 (Stream2) | 5.400E-03 ± 1.19E-03 | 1.964 E+00 ± 4.44E-01 |

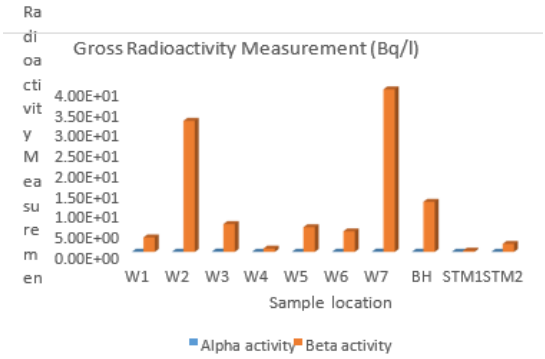


**Fig 3:** Alpha and Beta Radioactivity concentration (Bq/l) of water samples around the Factory.

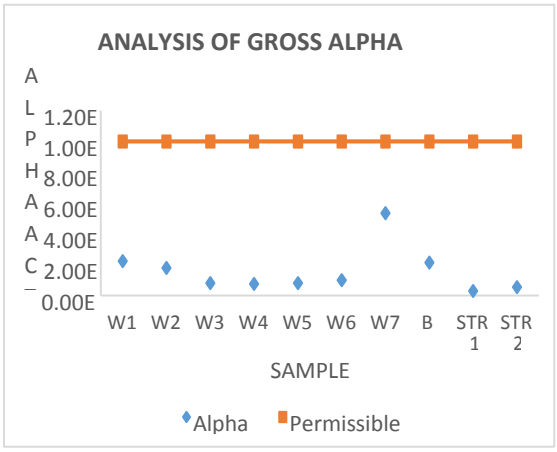


**Fig 4**: Gross Alpha Radioactivity Data with reference dose level (RDL)

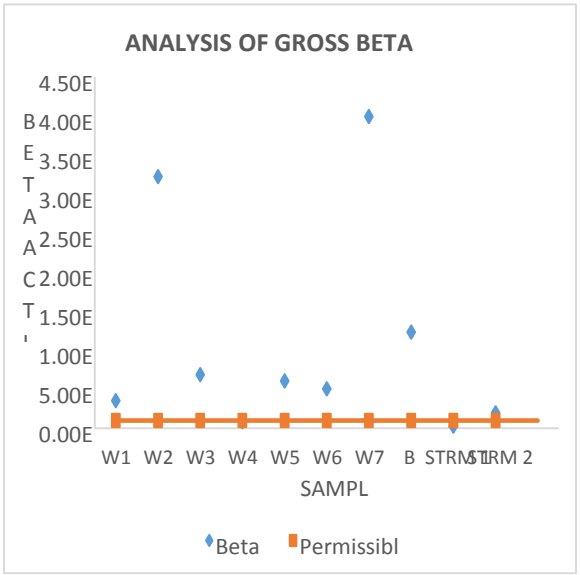


**Fig 5: Gross Beta Radioactivity Data with reference dose level (RDL)**

In comparison with the national primary drinking water regulation stated by the United States Environmental Protection Agency (USEPA), the results in Fig. 4, show that all the samples were below the regulation for gross alpha activity in portable water. Also, in Fig. 5, about 40% of the samples were below and 60% of the samples have violated regulation for gross beta activity in portable water as recommended by ICRP (1997).

The results of the gross alpha and beta analysis of the well water shows that the activities of alpha emitters in all the samples were lower than the recommended limits of 0.1Bq/L (ICRP,1991). Also most of the Beta-emitters were above the recommended level of 1.0Bq/L with exception of Sample Identified as WW4 and Stream 1. The higher activity varies with location and could be the due to geological characteristics of the soil in the area. The high level of Beta activities around the area might be as a result of percolation of beta-emitting radionuclides (e.g. $^{210}$Pb and $^{228}$Ra) through the soil into the ground water. Sample identified as WW7 has the highest concentration of both alpha and beta emitters, it might be due to the location of the well which is the closest to the company and presence of natural radionuclides. Stream 1 has the lowest concentration because the stream is situated at a far distance from the company and has a steady follow of water.

The mean alpha activity in Obajana, $1.56 \times 10^{-2}$ Bq/l, is below the contaminant limit of 0.1Bq/l and the mean beta activity 10.9Bq/l is above the contaminant limit of 1Bq/l recommended by ICRP (1997). The result obtained is lower in comparison than some result reported from other countries.

### 3.1. 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 $^{238}$U and $^{232}$Th series of the natural occurring radionuclides as shown in equation (4).

$$E_{avg}(\alpha/\beta)(\mathrm{mSv/yr}) = \sum_{i}^{R(\alpha/\beta)} A_{i(\alpha/\beta)}\,(Bq/l)\; X\; DCF_{i(\alpha/\beta)}(mSV/Bq)\; X\; 730\,(l/yr) \text{ ----------(4)}$$

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 gross alpha or beta concentration activity of individual radionuclide present in water sample and $DCF_{i(\alpha/\beta)}$ is dose conversion factor for ingestion of the individual natural radionuclides taken for an adult from UNSCEAR (2000) report. A daily water intake of 2 l/day is assumed by (EPA, 2000-05) thus resulting in annual consumption rate of 730 l/year.

The major contributors of gross β activities in drinkable water are $^{210}$Pb and $^{228}$Ra (Gorur *et. al*., 2011). Also, it was considered that $^{226}$Ra contribute more than 50% of annual dose from intake of water (Damla, 2006). DCF of $2.80 \times 10^{-4}$ mSvBq$^{-1}$ and $6.90 \times 10^{-4}$ mSvBq$^{-1}$ for both $^{210}$Pb and $^{228}$Ra was used for the effective dose calculation (WHO, 2004). The radionuclides in the gross alpha and beta activities in the sample water could not be determined due to limited functions of the equipment used.

**Table 5:** Total Effective equivalent dose due to both alpha and beta-emitting radionuclides in drinkable water

| S/No. | Sample ID | E due to alpha radionuclides (mSv/yr). | E due to Beta radionuclides (mSv/yr) | Total (mSv/yr) |
|---|---|---|---|---|
| 1 | WW1 | 4.54E-03 | 1.79E+00 | 1.80E+00 |
| 2 | WW2 | 3.65E-03 | 1.62E+01 | 1.62E+01 |
| 3 | WW3 | 1.61E-03 | 3.45E+00 | 3.45E+00 |
| 4 | WW4 | 1.51E-03 | 4.12E-01 | 4.14E-01 |
| 5 | WW5 | 1.61E-03 | 3.06E+00 | 3.06E+00 |
| 6 | WW6 | 2.00E-03 | 2.55E+00 | 2.55E+00 |
| 7 | WW7 | 1.09E-02 | 2.01E+01 | 2.01E+01 |
| 8 | BH | 4.34E-03 | 6.21E+00 | 6.21E+00 |
| 9 | STRM 1 | 5.87E-04 | 1.48E-01 | 1.49E-01 |
| 10 | STRM 2 | 1.10E-03 | 9.87E-01 | 9.88E-01 |

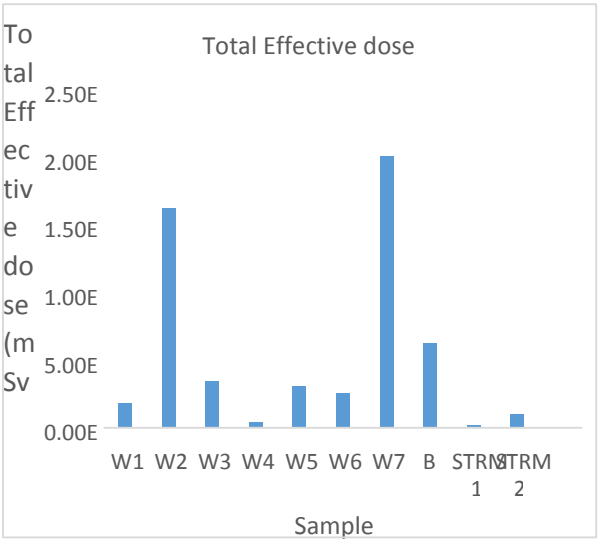


**Fig 6:** Total Effective equivalent dose due to both alpha and beta-emitting radionuclides in drinkable water

The total effective equivalent dose was greatest at WW7 (2.01E+01 mSv) and least at STRM1(1.49E-01 mSv). It was observed that all the sampling area exceed the Recommended reference dose level (RDL) of 0.1 mSv from 1 year consumption of drinking water, which might be due to high presence of beta activity concentration in the sampled water.

### 4.0. Conclusion

The mean alpha and beta activity in the water samples were measured and effective dose computed. The alpha activity might be due to presence of natural alpha-emitting radionuclides (e.g $^{226}$Ra and $^{210}$Po) and high beta activity might be due to presence of natural beta-emitting radionuclide (e.g $^{210}$Pb and $^{228}$Ra) in the analyzed water sample. The radionuclide could not be determined due to limited function of the detector. Therefore, water from the sampled location might pose high risk due to cement production and presence of natural radionuclides, if adequate measures are not taken.

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