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DETERMINATION OF RADON CONCENTRATION IN UNDERGROUND WATER WITH LATITUDE IN SELECTED AREAS IN THE ASHANTI REGION OF GHANA

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ABSTRACT

Radon is one of the carcinogenic radioactive gases. Radon causes radiological risk to the public via ingestion and inhalation. The aim of this study was to determine radon concentration in underground water in selected areas in and around Kumasi Metropolis of the Ashanti Region of Ghana. Water samples were taken from Mowire, Kronum, Aburaso, Medoma, Kenyase, Buokrom, Bomfa, Ayeduase, Kotei and Tikrom. Water samples from boreholes and wells in the selected towns were sampled and the radon concentration level was measured. The Roll's method was used for the radon concentration analysis on all the 100 samples from all the towns used for the study. Radon levels were found to vary from 4.82 ± 1.32 Bq/l to 964.63 Bq/l ± 320.896 Bq/l. At Kronum, the minimum and the maximum radon concentrations ranged from 17.09 to 83.89 in Bq/l with mean of 42.593 ± 20.55 Bq/l. Kenyase and Abira recorded mean radon concentration of 133.23 Bq/l. Buokrom had mean radon concentration of 29.14 Bq/l ± 10.07 Bq/l, Ayeduase and Kotei recorded mean radon concentration of 34.266 Bq/l ± 12.64 Bq/l, Bomfa recorded mean radon concentration of 21.18 ± Bq/l 11.04 Bq/l, Mowire and Tikrom recorded mean radon concentrations of 325.667 Bq/l and 689.053 Bq/l respectively. This study conclude that water samples rom Kronum, Buokrom, Ayeduase, Kotei and Bomfa had mean radon concentrations below the reference level of 100 Bql^{-1} proposed by WHO and EU Commission. Kenyase, Abira Mowire and Tikrom had mean radon concentrations above the reference level of 100 Bql^{-1} proposed by WHO and EU Commission.

KEYWORDS: Radon; radioactive gases; concentrations; latitude; underground water.

INTRODUCTION

The determination of random in drinking water is a prime interest for many researchers all over the globe.[1] Water is absolutely needed for most of all life on this earth. Ground and surface water are the freshwater resources that can be utilized for drinking purposes.[2] Groundwater had been gaining increasing attention as essential and vital water resource. In coastal regions, groundwater is only the dependable freshwater resource than the surface water. Groundwater quality is much higher than surface water and it contains dissolved compounds, minerals, and several naturally occurring radioactive elements in varying concentration.[1] Its demand had been rising rapidly in the last several decades with the overpopulation and enhanced standards of living.[1,2]

Groundwater is one of the sources of freshwater for many communities owing to its relatively low susceptibility to pollution as compared to surface water.[3] Both groundwater and surface water may contain many constituents, including micro-organisms, gases and radioactive particles, inorganic and organic materials. The concentration of these radioisotopes in water depends on the rock types, variety of minerals present in the rock, porosity-permeability and nature of the geological aquifers.[1] Scientists assess water quality by measuring the amounts of the various constituents contained in the water.[4]

^{226}Ra, ^{228}Ra, and ^{222}Rn are commonly occurring radionuclides in the water which causes severe health hazards to human health. They discharge α- particles and their respiration and ingestion may result in high radioactive dose to delicate cells in the respiratory tracts, digestive organs and also other organs of the human bodies.[1,5]

Several environmental problems are seriously threatening Ghana and especially Kumasi.[6] Deterioration of groundwater quality is considered as one of the main problems that exert huge pressure on our economy and there is the need for urgent response because it had not received serious investigation.[6]

Exposure to radioactive materials is one of these water quality problems that has not been investigated widely and will be the subject of focus in this study. High concentrations of these radioactive isotopes in the environment can be a threat to our health.[7] The highest fraction of the natural radiation comes from the radioactive gas radon. [8] Radon is a chemically inert, radioactive gas, which decays by alpha particle emission with a half-life of 3.82 days. Radon originates from the disintegration of radium and both elements are part of the 238U decay series. Radon is ubiquitous in soil and rock in varying concentrations depending on the radon concentration and several factors. Radon is soluble in water, and therefore, is present and able to travel in ground water.[7,8] Radon,^{222} Rn is a naturally occurring, radioactive gas formed within the ^{238}U decay series.[9]

Several environmental problems are threatening Kumasi and the surrounding towns, and one of these problems is the groundwater quality.[6] Most of the previous studies done onthe quality of groundwater were focused on the chemical, physical, and microbiological analysis, but not much on natural radiation analysis has been done.[6] The number of people who depend on groundwater such as boreholes and well water as their main source of water supply is increasing.[6] This is because; the government water supply is not reliable. These sources of water do not undergo quality examination with respect to natural radiation, which is the leading cause of lung and stomach cancer. [6] There is therefore the need to researchon the quality of groundwater water with regards to the natural radiation contamination and compare it to international standards.

The objective of the study was to determine radon concentration in underground water in selected areas in and around Kumasi Metropolis of the Ashanti Region of Ghana.

METHODOLOGY

Description of Experimental Site

The study was conducted in selected areas in and around Kumasi Metropolis of the Ashanti Region of Ghana. The names of the towns are shownon the map (Figure 1) and from each town; a number of water samples were taken. There are two main rock types for all the towns from which the underground water sampleswere taken. Some of the towns are distributed over the rock type known as the besin type granitoid.

Mowire, Kronum, Kenyase, Buokrom, Bomfa, Ayeduase, Kotei, Tikrom, Aburaso and Trabuom were the towns selected for the study. Climatic factors such as barometric pressure and rainfall can affect the concentration of radon in ground water over time. These factors can be difficult to evaluate in a regional study, however, because of the overwhelming effects of other variables on radon concentration. Radon distribution in groundwater underlain by igneous and metamorphic rocks and limestone follows a general geographical pattern related to rock type.

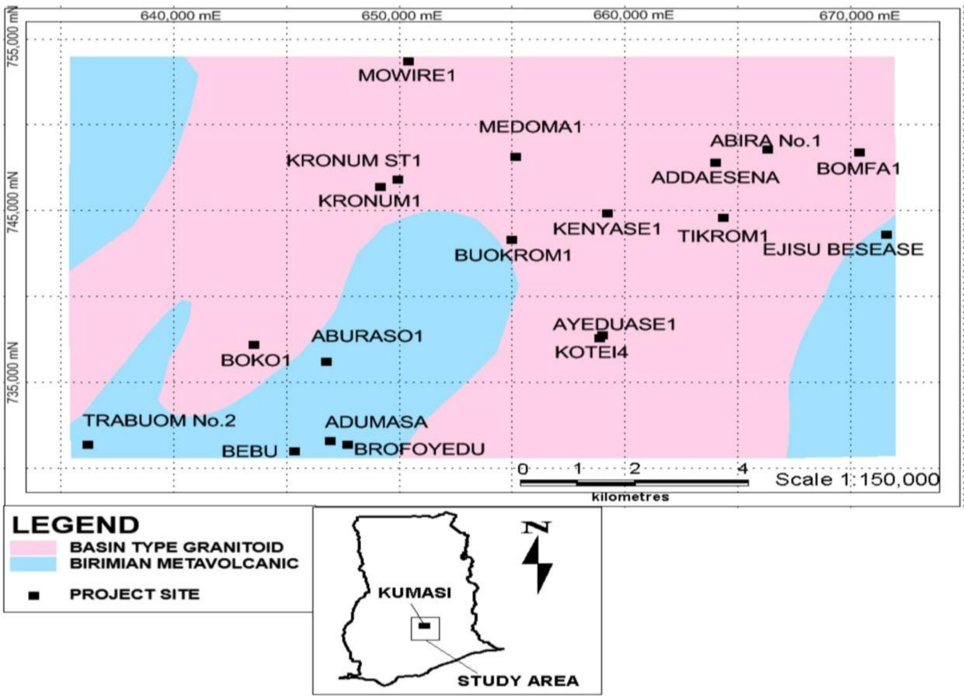

Figure 1: Geological structures of the towns under study

Source: Ghana Districts[10]

Most igneous and metamorphic rocks in the study areas are of predominantly granitic composition.[6] These rocks contain higher concentrations of uranium, on average, than do limestones. Rocks of this type contain much less uranium, on average, than do limestones or granitic rocks. Radon concentrations in ground water underlain by sandstone and shale are much more variable than those underlain by other rock types.[7] The uranium content of sandstones and shales is commonly related to the uranium content of the sediments from which they formed. Radon concentrations in ground water from sandstones and shales can therefore be highly variable if these sediments were derived from different sources.[8]

Determination of background of Scintillation Cell

Twenty of the lucas cells were used for collecting radon gas from water sample from each site. In other to calculate the radon concentration of each water sample, it is required that the background reading of the cell was taken. The background reading of the cell was one of the parameters needed to calculate the radon concentration in the water sample.[6,9]

Compressed nitrogen gas was used to flush the cells using two tube connectors connected firmly to the valves of the cell,[7] One of the tubes connects to the nitrogen gas source and the other tube leads to the outside of the laboratory. The cells were flushed for about 30 minutes each after which all tube connectors weredisconnected.[9] The AB-5 was switched off, the cap was removed and the scintillation cell was mounted to the AB-5. After 30 seconds of mounting the cell to the AB-5, the AB-5 is then turned on. In the Continuous mode, the AB-5 was programmed for an interval length of 30 minutes. The AB-5 was allowed to count for four readings within a time interval of 2 hours. The counting was stopped and the values for the counts were recorded for the set time. The average count was determined and and converted to count per minute and then recorded. This gave the current background level of the system.[6,8]

Sampling Water

In order to study radon in ground water from an open borehole, it is necessary to adequately sample the water. Generally speaking, there are two basic means to collect a sample of water, either draw water out with a pump or send down a bailer to collect a sample.[9] Clearly, these two methods have differing effects on the well. When water is pumped, the water in the well evacuates and/or new ground water is drawn from the surrounding aquifer. In the above studies, when the radon in water was observed over time to show temporal variations, it was performed by pumping water out of the well from some arbitrary depth. However, using a bailer only takes a small volume of water from a desired depth. Collecting a sample with a bailer will mix water in the well but has minimal effect on the aquifer.[8] There are a few basic designs. One type is made from a stainless steel tube with a collection vial housed inside. It has inlet and exhaust ports designed such that the collection vial does not fill until it has remained stationary for a few seconds. Another bailer is made from a flexible polyethylene bag with a floating ball check valve. It can be maneuvered with proper up and down movements to fill the bag [11]

A third type involves applying positive pressure (above the ambient pressure of the water to be sampled) to the sampling vessel while the sampler is lowered and raised.[11] This involves running a tube from the sampler to the surface where an inert gas can be applied with an air pump or gas cylinder. The sampler is outfitted with floating check valves to allow water to flow under the desired pressure differences between the inside and ambient water. It is clear that the application of positive pressure to the sample will keep it from leaking and ensure a water sample from a discrete depth in the well. However, the unit is expensive and the application of a gas at a correct pressure before and after every sample adds to the labor involved.[11]

A fourth type uses a diffusion bag lowered down to a depth in a well. It relies on the diffusion across the membrane. [1] The obvious drawback of this method is the long (several days) waiting period for equilibrium across sampler membrane. Aside from those samplers mentioned, a pump can also be used to take samples from a discrete interval. The pump (if submersible) or the tube from a surface driven (or peristaltic) pump can be lowered to discrete depths. This process can be aided by placing packers above and below the pump point. Typically these packers, like balloons, can be inflated when in position to block off other parts of the well. That interval can then be pumped to purge that portion of the well or simply pumped long enough to collect a sample at the surface.[9,11]

The major drawback of all of these discrete interval samplers for measuring radon is the ability to collect a sample following the protocol for liquid scintillation analysis. [9] The water collected for radon analysis must first be drawn into a syringe where a fixed volume can be obtained.[1,9] It is also ideal for the water entering the syringe to have minimal radon loss due to degassing. In order to use these samplers for radon analysis, modifications would need to be made to allow a syringe to draw water from the collected water. Of the samplers mentioned, the pressurized sampler seems to be the most suited for the task of collecting water for radon analysis. The positive pressure applied during transit ensures no leaking of water into the empty sampler on the way down, as well as keeping the high pressure inside during removal of the sampler from the well. [12] The other designs claim to resist the pressure changes while the sampler is in transit, but it remains to be shown how well they resist loss or out-gassing of radon. The sampling methods discussed above are technical and efficient methods in sampling the water such that, the radon gas lost from the water as a result of the sampling can be minimized. In this work, the source of the groundwater was well water and boreholes.[12]

The total number of underground water samples collected for this project was One Hundred (100). Water samples were collected from eight different towns in and around Kumasi. At each site a number of the water samples were collected depending on the average number of people depending on that water as their main source of drinking, cooking washing, bathing and all other domestic activities. The separation between any two samples collected from the same towns was also considered so that, the samples were uniformly distributed throughout that particular town.

Water Sample Degassing Method

Samples of water (approximately 200 cm^3) were collected from the boreholes and wells. The sampling time, ie, the time at which the water sample was collected (T_s) was recorded. The pump was plug in the pump connector and the cell inserted into the scintillation cell connector. The system was then evacuated to a minimum of 27 inches of mercury (Hg) at sea level barometric pressure.[9] At higher altitudes, the average barometric pressure was taken into account when the minimum evacuation of the cell was determined.[9]

The pump was disconnected. It was ensured that the drierite, ie the drying agent was blue. The drierite turns pink as it absorbs moisture. It should be replaced at this stage to avoid the possible condensation in the cell. Ensuring that the ON/OFF and bypass valves were closed, 190 ml of a sample was quickly transferred into a sample cylinder and sealed tightly by inserting a diffusion stone and rubber stopper rapidly and carefully.[13] The bubbler was promptly connected with the first line going into the bubbler inlet. Then the exhaust dryer connection was plugged in and some bubbling was observed for a few seconds. The ON/OFF valve was then opened and a fine steady bubbling was maintained for a timed period of about 4 to 5 minutes. After the vacuum gauge indicated three inches or less of mercury, the bypass valve was opened slowly for 5 to 10 seconds to wash out radon from the tubing into the cell. The bypass and the ON/OFF valves were closed and the bubbler disconnected from the exhaust dryer connector. The above steps were repeated for each samples collected. [13] In order to count, the scintillation cell was placed in a radiation monitor approximately 3.5 hours after sampling. This was done to ensure that the radon activity had come to secular equilibrium. The cell was counted three times five minutes intervals. The counts and time were then recorded. To use the cell for other water samples, the residual radon must be must be flushed out of the cell. To flush the residual radon out the system, the cell was positioned back on the water degassing system. The bubbling apparatus was installed but without water in the cylinder. The inlet and exhaust lines were connected to their respective connectors and the ON/OFF and BYPASS valves closed. With the help of a hand pump or an electric pump, the cell was evacuated to a minimum of 27 inches of mercury (Hg) at sea level barometric pressure. The BYPASS valve was opened. The process was repeated 2 or 3 times. This method was repeated for each cell, each measurement and each site.

RESULTS AND DISCUSSION

Radon Concentration with Latitude at Kronum

A scatter plot was drawn to show the trend of the variation of the radon concentration in the water samples from Kronum (Figure 2). All the water samples were taken between latitude 746200 and 747400. The Radon concentration values obtained in the underground water samples collected at Kronum were relatively low as compared with that of other towns and the WHO,[14] and EU,[15] recommended levels of 100 Bq/l. The minimum and the maximum values of the radon concentrations recorded were 17.095 and 83.890 in Bq/l. The mean value is 42.593 Bq/l and the standard deviation is 20.547 Bq/l. The values were due to the fact that the depth of the water was low as compared to other areas. Other factors that might contribute to the low values of the radon concentration in the water sample might be attributed to the type of soil and type of rock at that area. [9] The low radon concentration is possibly because of the dissolved radon is disrobed and get released in the way between the water source and water sample collection point.[1]

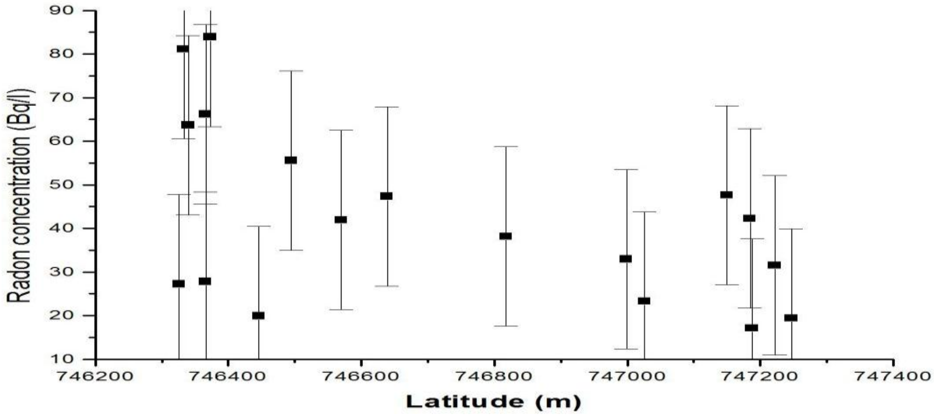

Figure 2: Radon concentration with latitude for water samples from kronum.

Variation of Radon Concentration with Latitude at Kenyase

The water samples at Kenyase were randomly distributed in the town and they are not in any pattern or along any profile. From the GPS data, it can be seen that most of the samples were taken around the same latitude. It can be seen that, most of the samples have concentration with small difference between the samples. This could be as a result of the same rock type at that area. Three samples were also taken from different points which are a little far from the others. These three samples are near each other and it can be seen that, the radon concentration in those samples are almost the same. The Radon concentrations in each water sample in Kenyase at different locations measured in Bq/l are shown in Figure 3. The arithmetic mean of measurements was 133.229 Bq/l, with a range of values between 18.500 and 654.945 in Bq/l with average standard deviation of 192.481 Bq/l. The results indicate that radon concentrations in water samples from Kenyase were very high and were above the WHO [14] and EU [15] recommended levels of 100 Bq/l. This large variation in Radon concentrations may be due to the difference in the soil type, rock type and the depth of these wells.[16]

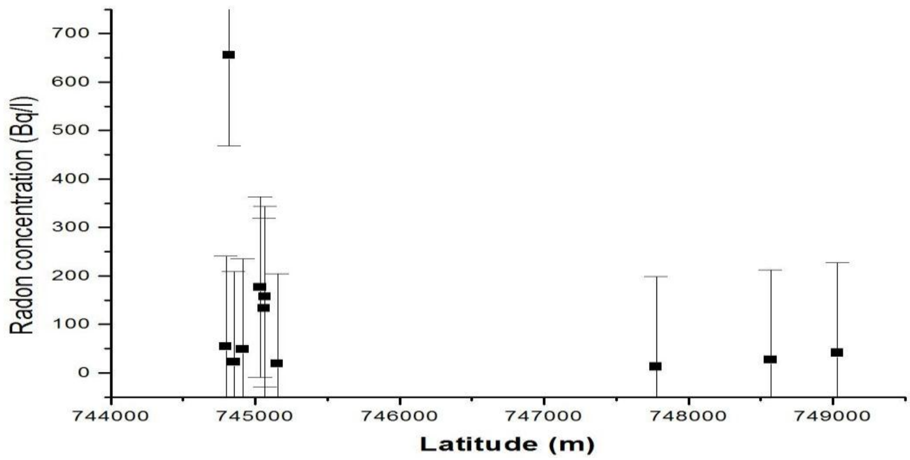

Figure 3: Radon concentration with latitude for water samples from Kenyase.

Variation of Radon Concentration with Latitude at Buokrom

Figure 4 show the radon concentration values against latitude obtained underground water samples collected at Buokrom. The plot shows that the samples were scattered and no trend is easily identified. The values were very low as compared with that of other towns like Mowire and Tikrom and the WHO,[14] and EU,[15] recommended levels of 100 Bq/l. However, the results are not very far from that obtained in Kenyase. The two towns were not far from each other. How close the values were could be due to the proximity and similarities in the soil type and also that of the water samples in the two towns are not very different. The mean value was 29.135.836 Bq/l and the standard deviation is 10.068 Bq/l. The minimum and the maximum values were 4.818 and 13.034 in Bq/l. The low random concentration recorded at Buokrom could be attributed to the type of soil and type of rock at that area.[17]

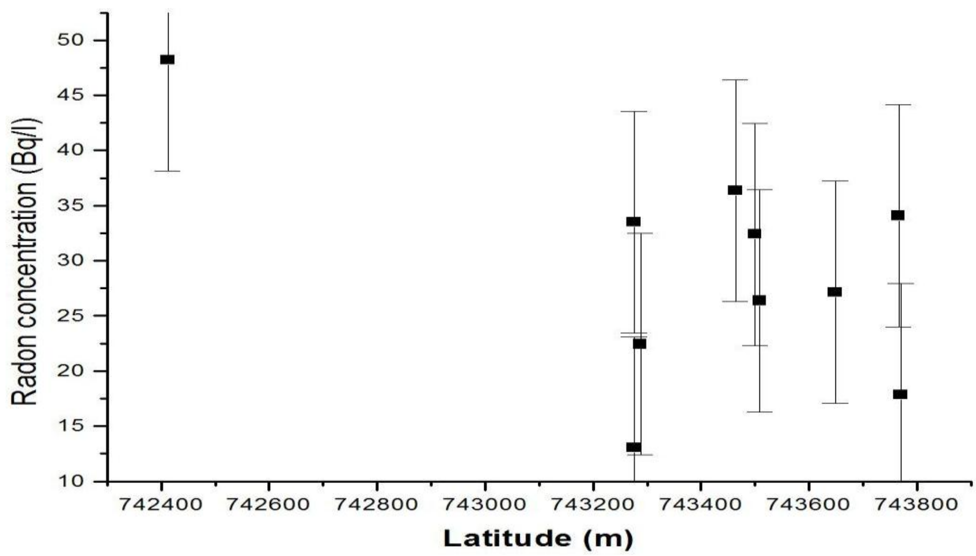

Figure 4: Radon concentration with latitude for water samples from Buokrom.

Variation of Radon Concentration with Latitude at Ayeduase and Kotei

An increasing trend was noticed in the radon concentration in the samples collected from Ayeduase and Kotei with respect to the latitude. The water samples were not collected in any profile line since the source of the samples were collected randomly from different houses and hostels. The arithmetic mean of measurements was 34.266 Bq/l with a range of values between 12.637 and 52.634 Bq/l and with average standard deviation of 12.615 Bq/l (Figure 5). The results indicate that radon concentrations in this area was very low as compare with WHO,[14] and EU,[15] recommended levels of 100 Bq/l.[1] This large variation in Radon concentrations may be due mainly to the difference in the soil type, rock type and the depth of these wells.[7,17]

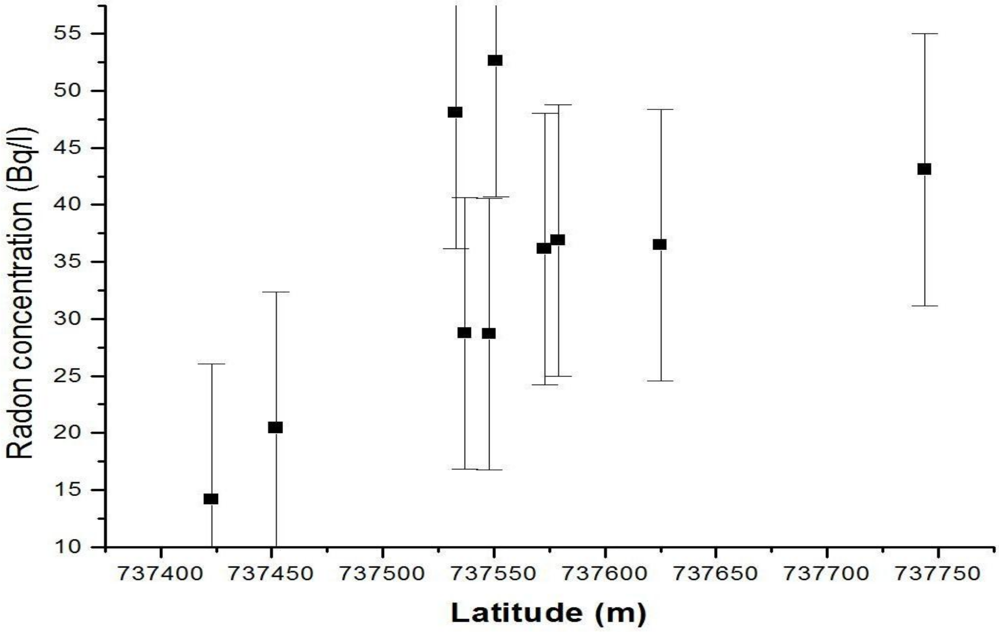

Figure 5: Radon concentration with latitude for water samples from Kotei and Abira.

Variation of Radon Concentration with Latitude at Bomfa

The Radon concentration values obtained in the underground water samples collected at Bomfa were very low as shown in Figure 6, as compared with WHO,[14] and EU,[15] recommended levels of 100 Bq/l.[11] The minimum and the maximum values are 13.017 and 43.570 in Bq/l. The values were low due to the fact that the depth of the water was low as compared to other areas. Other factors that might contribute to the low values of the radon concentration in the water sample might be the type of soil and type of rock at that area. The mean value is 21.184 Bq/l and the standard deviation is 11.044 Bq/l.[18]

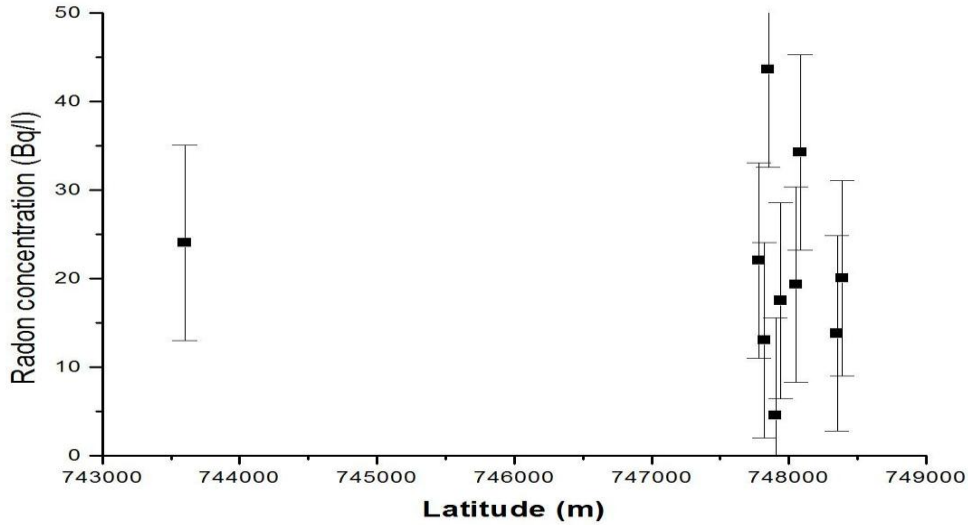

Figure 6: Radon concentration with latitude for water samples from Bomfa.

Variation of Radon Concentration with Latitude at Mowire

Radon concentration in the water samples taken from Mowire at different locations measured in Bq/l as shown in Figure 7. The arithmetic mean of measurements was 325.667 Bq/l with a range of values between 64.555 and 964.629 Bq/l and with average standard deviation of 320.896 Bq/l. The results indicate that random concentrations recorded at Mowire were higher than the WHO,[14] and EU,[15] recommended levels of 100 Bq/l. Again, radon concentration in water samples taken from Mowire was 900.074 Bq/l which was very wide as compared to the other experimental sites. This large variation in Radon concentrations may be due mainly to the difference in the soil type, rock type which might be very rich in radioactive sources and the depth of these samples collected.[8,18]

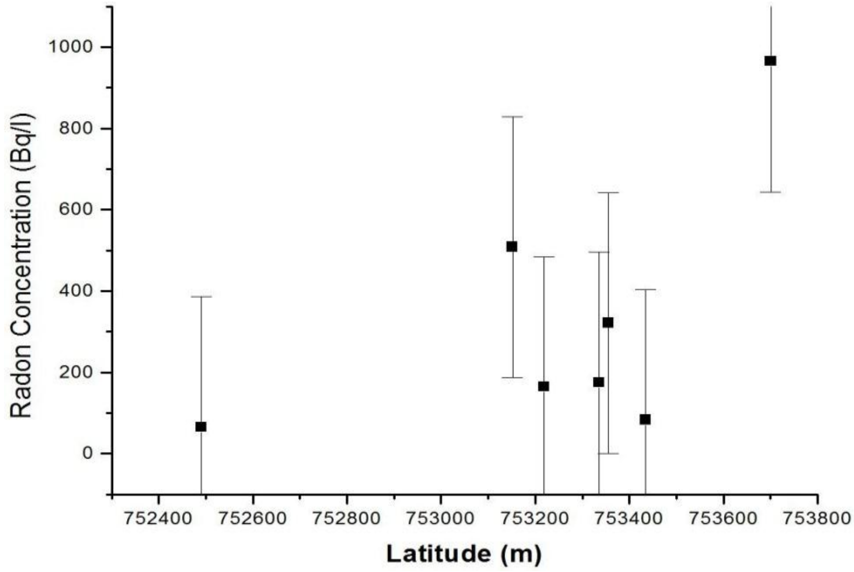

Figure 7: Radon concentration with latitude for water samples from Mowire.

Variation of Radon Concentration with Latitude at Tikrom

Radon concentrations in the water samples taken from Tikrom at different locations measured in Bq/l as shown in Figure 8. The arithmetic mean concentrations ranged from 94.450 -783.553 Bq/l with an average standard deviation of 41.205 Bq/l. The results indicate that random concentrations recorded at Tikrom were higher than the WHO.[14] and EU [15] recommended levels of 100 Bq/l. This large variation in Radon concentrations may be due to the difference in the soil type, rock type and the depth of the samples collected. [16, 19] The higher concentration of ^{226}Ra in the water samples could be attributed to the mineral compositions of the parent bedrock present in the study area.[20]

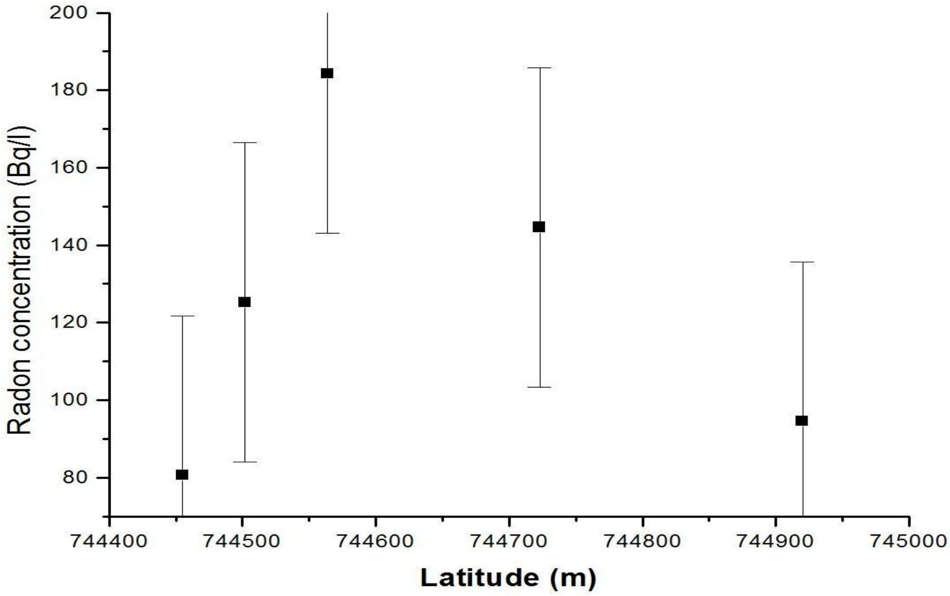

Figure 8: Radon concentration with latitude for water samples from Mowire.

CONCLUSIONS

This study conclude that water samples rom Kronum, Buokrom, Ayeduase, Kotei and Bomfa had mean radon concentrations below the reference level of 100 Bql^{-1} proposed by WHO and EU Commission. Kenyase, Abira Mowire and Tikrom had mean radon concentrations above the reference level of 100 Bql^{-1} proposed by WHO and EU Commission. This study also concludes that the variation in radon concentration levels observed across the towns selected or the study was mainly due to the difference in rock type, soil type, depth of the well and the geology of the area.

Disclosure of conflict of interest

Authors have declared that, no conflict of interests exist.

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