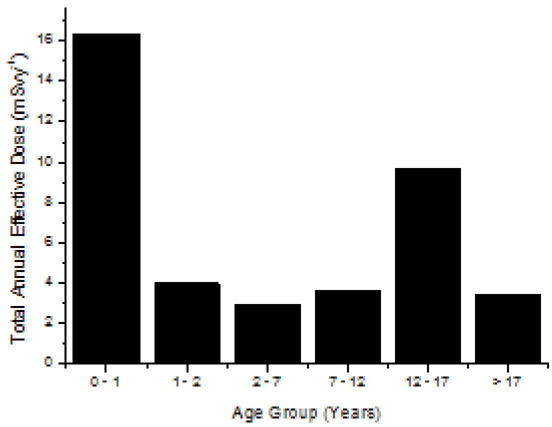

Figure 2: Total Annual Effective Dose for Different Age Groups

The result obtained in this study compared favorably with other result from similar studies all over the world. All though, the value of the activity concentration in the borehole water that was obtained is a bit higher that the value obtained by Ajayi and Achuka in deep well water samples from Ogun State, Nigeria, with a rather narrower margin. The result of ^{226}Ra concentration when compared with other result from different countries, shows an enhanced activity than many other countries except Finland which has a maximum concentration of ^{226}Ra to be 49 BqL^{-1} as shown in Table 6 and figure 3.

Table 6: Activity Concentration Comparison of 226Ra (Bq l-1) inBoreholeWaters from Nigeria with Other Countries

Country	^{226}Ra	
	Min	Max
USA	4×10^{-4}	1.8×10^{-3}
China	2×10^{-4}	0.12
Finland	1×10^{-2} 7	49
France	7×10^{-3}	0.7
Germany	1×10^{-3}	1.8
Italy	2×10^{-4}	1.2
Romania	7×10^{-4}	0.021
Switzerland	0	1.5
Spain	2×10^{-2}	4
UK	0	0.18
Nigeria Deep Well(Ajayi&Achuka, 2009)	2.89	7.79
Nigeria borehole (This Study)	7.84	11.75

Data for other countries was obtained from UNSCEAR 2000 report.

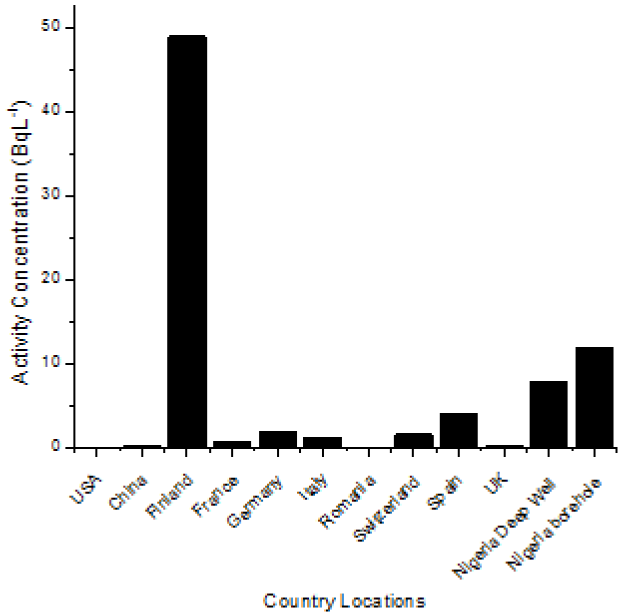

Figure 3: Illustration of Ra-226 Activity concentration in Different Countries

Collective Health Detriment

The estimated collective health detriment as a result of radionuclides present in borehole water is presented in Table 7. It could be observed that a large population of individual is susceptible to a radiation induced diseases. The value ranges from 409 persons in the age group 1 – 2 years to 5,408 persons in the age group >17 years with a total no of 13,621. The indication of this result calls for a serious attention to safe water availability in the area and all over the world.

Table 7: Collective Health Detriment in the Different Age Groups

Age Group (Years)	*Collective Health Detriment in (Person)*
0 – 1	1,057
1 – 2	409
2 – 7	1,506
7 – 12	1,424
12 – 17	3,817
> 17	5,408
Total	13,621

4. Conclusion

Activity concentration determination of natural radionuclides in borehole water samples has been carried out from some boreholes in Akure, South-Western Nigeria. The result shows an enhanced radioactivity in borehole waters.The mean activity concentration of ^{40}K, ^{226}Ra and ^{232}Th were found to be 76.16 ± 18.97 Bq/L, 9.51 ± 3.62 Bq/L, and 7.38 ± 3.11 Bq/L respectively.

The total annual effective dose for different age groups ranges from 2.96 ± 1.12 $mSvy^{-1}$to 16.33 ± 6.50 $mSvy^{-1}$ with a mean of 6.72 ± 2.61 $mSvy^{-1}$.This value is higher than the limits of 1 $mSvy^{-1}$ and 0.1 $mSvy^{-1}$recommended by ICRP & WHO respectively (ICRP 1990, WHO 2006). The research work has shown that the natural radioactivity in borehole water is high. This could be as a result of the remote source of the water which is deep down inside rocks. Akure is characterized by underground rocks which makes well water a little difficult to come by and in many cases rocks has to be blasted before water can be obtained. Considering the Phosphate composition of rocks hence a reason for an enhanced radioactivity of the borehole water in the area. The health risk through the ingestion of borehole water is very high in the area and this is likely to be the situation in any part of the world where there are underground rocks. Effort should be made therefore to provide alternative source of safe drinking water in such environment so as to reduce the level of health risk of radiation induced diseases to human.

References

[1] Ajayi,O. S., Achuka,J. A. (2009). Measurement of Natural Radioactivity in Drilled and Dug Well Waters of Ogun State, Southwestern Nigeria. Radiation Protection Dosimetry, **130**, 1–10

[2] Alam, M. N., Chowdhury, M. I., Kamal, M., Ghose, S., Islam, M. N., and Anwaruddin, M. (1999): Radiological assessment of drinking water of the Chittagong Region of Bangladesh. Radiat. Prot. Dosimetry **82**, 207-214.

[3] Eludoyin O.M., Adelekan I.O., Webster R. and A. O. Eludoyin A.O. (2014) Air temperature, relative humidity, climate regionalization and thermal comfort of NigeriaINTERNATIONAL JOURNAL OF CLIMATOLOGY(DOI: 10.1002/joc.3817)Int. J. Climatol.**34**: 2000 – 2018

[4] Gilmore, G., and Hemingway, J.D. (1995): *Practical Gamma Ray Spectrometry* John Wiley & Son, Chichester. (1995)

[5] International Atomic Energy Agency, Measurement of Radionuclides in food and the Environment Guide book, Technical Report series No **295**, IAEA, Vienna, 1989.

[6] International Atomic Energy Agency (1996)Basic safety Standards for Protection against ionizing Radiation and for the safety of radiation Sources, (Safety Series Number **115**).

[7] International Commission on Radiological Protection (1990), Recommendations of the International Commission on Radiological Protection Publication 60, Vol. **21**,No. 1-3.

[8] ICRP (1991). Recommendations of the International Commission on Radiological Protection. Annals of the ICRP-**60**. Pergamon Press.Oxford. 200pp.

[9] Nigeria Population Commission, NPC, (2006). Population Distribution by Age and Sex. Federal Republic of Nigeria 2006 Population and Housing Census. Priority Table. Volume **IV**.

[10] National Council on Radiation Protection and Measurements, NCRP (1987). 'Exposure of the Population in the United States and Canada from Natural Background Radiation'. NCRP Report No. **94**, Bethseda MD 20814.

[11] National Council on Radiation Protection and Measurements (NCRP). 1993. Limitation of Exposure to Ionizing Radiation. Report No. **116**, NCRP Publications, Bethesda, Maryland. 6.

[12] UNSCEAR, 1982. United Nations Scientific Committee on Effects of Atomic Radiation, 1982. Sources and effects of ionizing radiation. United Nations, New York

[13] United National Scientific Committee on Effects of Atomic Radiation, (UNSCEAR), 2000: Sources and Effects of Ionizing Radiation. Report to General Assembly, with Scientific Annexes, United Nations, New York.

[14] United Nations Scientific Committee on Effects of Atomic Radiation, (2000): Exposures from NaturalRadiation Sources, UNSCEAR.

[15] WHO (2006): World Health Organization, Guidelines for drinking water quality vol**1**, Recommendations; Radiological aspects (197 - 209).

[16] WHO (2003): Guidelines for drinking- water quality – Draft, Vol. **3**, Chapter 9 (Geneva: WHO).

[17] Worldometers (2015). (www.worldometers.info/world-population/nigeria-population/) retrieved 19-06-2015, by 15:36.