Original Research

Volume 3, Issue 1, pp 194-202, June 2021

ACHIEVERS JOURNAL OF SCIENTIFIC RESEARCH

Opecn Access Publications of Achievers University, Owo

Available Online at www.achieversssciencejournal.org

Investigation of Radon Activity Concentration in Groundwater Samples from Ondo State, Southwestern Nigeria and Estimation of Corresponding Effective Dose

Oniya, E.O.[1], Amanesi, A.[1]*, Olubi. O.E.[1,2]

[1]Physics and Electronics Department, Adekunle Ajasin University, Akungba-Akoko, 342111, Ondo State, Nigeria.

[2]Achievers university, P.M.B 1030, Owo, Ondo State, Nigeria.

***E-mail Address:** amanesiabdulfatai@gmail.com

Submitted: March 25, 2021, Revised: April 28, 2021, Accepted: June 3, 2021 Published: June 28, 2021

ABSTRACT

This research work investigates radon concentration levels in ground water samples from the Akoko region of Ondo state, Nigeria and the estimation of annual effective dose due to ingestion of water from these sources. A total of seventeen groundwater (borehole and hand dug wells) samples collected from different locations within the study area were collected using standard methods. The radon concentrations in all the samples were analyzed using Liquid Scintillation Counter (LSC). The activity concentration of radon in the water samples ranged `from 12.61 Bq/L to 57.50 Bq/L and 10.30 Bq/L to 41.89 Bq/L with mean values of 28.01Bq/L and 25.34Bq/L respectively for Boreholes and wells. The annual effective dose due to ingestion of raon from the borehole samples were found to have mean values of 0.20, 0.40 and 1.40 mSv/y for adults, children and infants respectively. For well water samples, mean values of 0.19, 0.37 and 1.29 mSv/y were found. The results of radon activity concentration were compared with the maximum contaminant level of 11.1 Bq/L set by United States Environment Protection Agency and it was observed that 94% of the samples exceeded the value. Also, all of the annual effectice doses estimated were above 0.1 mSv/y set by the World Health Organisation for intake of radionuclides in water. The geology of the study area may be a factor responsible for the observed trend. It is recommended that water sources in the region should be treated before consumption.

KEYWORDS: Effective Dose; Liquid Scintillation; Radon-222; Water

1. Introduction

Water is one of the most abundant substances on earth and is a principal constituent of all living things. It is important for water meant for ingestion to be free from all kinds of contamination. Water quality is one of the most important parameters of environmental studies (Garba *et al.* 2013). In rural and sub-urban communities, the number of people who depend on groundwater such as boreholes and well water as their main source of water supply is increasing. This is because pipe borne water is not readily available (Muller and Michael, 2017). Private wells which are not regulated by the government have become common among inhabitants of these areas. It is therefore important for groundwater to be free from radiological contamination. The measurement of radioactivity in drinking water permits one to determine the exposure of the population to radiation from the habitual consumption of water.Radon is one of the sources of radiological contamination in water and the largest contributor of the total radiation received by the general public from natural radioactive sources (Alghamdi *et al.,* 2019). Naturally occurring radioactive materials enter the human body either by inhalation of radioactive gas like radon or ingestion of primordial radionuclides as well as their radioactive progenies (Oniya, 2014; Faweya, *et al.* 2018; Yussuf *et al.,* 2012). The radionuclides such as radon-222, radium-226 and radium-228 most commonly occurring in natural waters present a risk to human health (Akar *et al.,* 2012).A product of uranium decay,radon is a natural radioactive gas without odour, colour or taste. It cannot be detected without special equipment. It is an alpha-emitting noble gas that is found in various concentrations in soil, air and in water as a result of migration from rocks and soil in contact with the water (Kitto *et al.,* 1996).

Radon is an unstable radionuclide that disintegrates through short lived decay products before reaching the end product of stable lead. The short lived decay products of radon are responsible for most of the hazard by inhalation (UNSCEAR, 2000). (Messier and Serre 2017)(Raquel *et al.*, 2017) (Joseph *et al.* 2018). (Faweya, *et al.*, 2018; Garba *et al.*, 2013; Njinga, *et al.*, 2015; Oni *et al.*, 2016; Ademola and Oyeleke, 2017; Kalip *et al.*, 2018).

2. Materials and Methods

Study Area

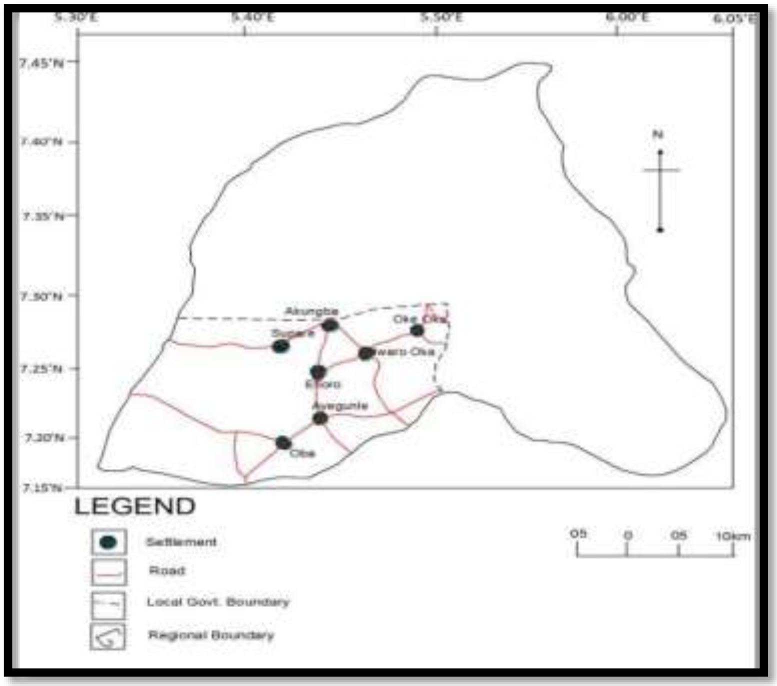
The Akoko region is in thenorthern district of Ondo, southwestern Nigeria. It lies between latitude7°20' N’ and 7°30'N and longitude 5°30'E and 5°30' E. The Southwest area of the Akoko region where samples have been collected has a land size of about 226 km^2, with a population of about 229,486 as at 2006 national census. It is basically underlain by the Precambrian rock of southern Nigeria. The most predominant rock type in the area is migmatite and granite/granite gneiss (Falowo *et al.* 2017). The basement rock exposures are however as lowland outcrop in few places within the area particularly where basement is shallow and erosional activities are active (Mohammed *et al.* 2012). The study area is of significant interest as it plays host to a university and houses a large number of students and staffers of the university. Farming is a major occupation of the locals and the major source of water in the community is ground water. Individually owned and public boreholes are seen to be present while hand dug wells are the most common in the communities that make up the study area.

Sample collection

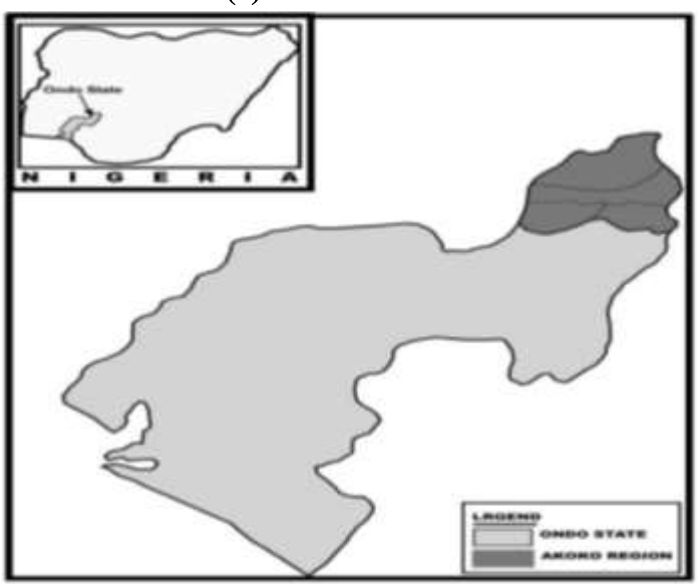
A total of seventeen (17) samples were collected for analysis from the selected groundwater (Boreholes and open wells) sources at different locations in Akoko South West Local Government Area Ondo State. Samples were collected using plastic vials. Boreholes were pumped and allowed to flow for at least two minutes before samples were collected in order to ensure that fresh samples were obtained. Water samples from wells were first collected with bailers and then transferred into vials. Each collected sample was properly labeled and the time of sample collection was recorded.

Sample preparation

l of each sample was added into a vial containing 10 ml of insta-gel based cocktail (scintillator) using a hypodermic syringe. The vials were tightly capped and shaken vigorously for three (3) minutes to extract radon in water phase into the organic scintillator (Forte *et al.,* 2006).



(a)



(b) Fig. 1(a) Map showing the sample collection areas (b) Map showing the location of the sampling area within Ondo State.

The prepared samples were kept for at least three (3) hours each in order for radon and its alpha decay products attain equilibrium before counting. In a similar manner a blank sample for the background was prepared using distilled water that has been kept in a glass bottle for at least 21 days.Afterwards the prepared samples and the blank were each analyzed using the Liquid Scintillation Counter (Tri-Card LSA 1000) at the Center for Energy Research and Training (CERT), Ahmadu Bello University Zaria, Nigeria.

The activity concentration of radon was calculated from the samples and background results obtained using the formula below:

$$C_{Rn}(BqL^{-1}) = \frac{100\times(SC-BC)exp\lambda t}{60\times CF\times D} \qquad (1)$$

Where: $C_{Rn}(BqL^{-1})$= Concentration of Radon-222 in Becquerel per litre. SC= Sample Count (Count min^{-1}), BC = Background Count ($Countmin^{-1}$). t =Time elapsed between sampling to counting (minutes), $\boldsymbol{\lambda}$ = Decay constant (1.26 ×10−4 min^{-1}). 100 = Conversion factor from per 10ml to per liter, CF = Calibration factor D = Fraction of 222Rn in the cocktail in a 22 ml total capacity vial for 10ml of sample, 10 ml of cocktail and 2 ml of air.

The corresponding annual effective doses (mSv/y) due to ingestion of Radon-222 in water samples were also calculated using equation 3.2 by taking into account the dose coefficient (Sv/Bq), the annual water consumption (L/y) and the activity concentration of Radon-222 obtained from equation 3.1. (Ryan *et al.*, 2003).

$$E(mSv/y) = C_{Rn} \times D \times L \qquad (2)$$

Where: C_{Rn}= Concentration of Radon-222(BqL^{-1}), L= Annual water consumption of 2 litres, 1.5 litres and 0.7 litres per day that is 730L/y, 547.5 L/y and 255.5 L/y for adults, children and infants respectively (Malakootian and Nejhad, 2017). D = Dose coefficient($10^{-8}Sv/Bq$, 2×$10^{-8}Sv/Bq$, 7×$10^{-8}Sv/Bq$) for adults, children and infants respectively. (UNSCEAR, 2000). According to United Nation Scientific Committee on the Effect of Atomic Radiation (UNSCEAR, 2000) doses due to ingestion of radon in water for similar consumption rates could be factor of 2 and 7 higher for children and infants respectively.

4. Results and Discussions

Radon concentrations for groundwater samples

The mean values of Radon-222 concentrations were found to be 28.01 and 25.34 Bq/L for boreholes and wells respectively with an overall mean of 26.91 Bq/m^{3}as shown in tables 1-3. The higher mean radon levels observed in the borehole samples is in agreement with previous studies in the literature that have also shown that the level of radon is higher in boreholes than in dug wells. A positive correlation has been seen to exist between radon concentration in ground water and depth (Korany et al., 2013). This is principally because dug wellwater is low in radon concentration due to atoms escaping from their surface which are closer to the earth's surface unlike boreholes that are dug deep into the ground allowing more water to interact with the aquifer (Choubey et al., 2001).The results of this work show that 94% investigated samples have of radon-222 concentration level above the United State Environmental Protection Agency(EPA, 2018) Maximum Contamination Level(MCL) of 11.1 Bq/L.

Annual Effective Doses (AED)

The corresponding Annual Effective Doses due to intake of Radon-222 from borehole water samples collected were estimated for the samples and found to range from 0.09 to 0.42mSv/y, 0.14 to 0.63mSv/y and 0.23 to 1.03mSv/y as shown in table 1 with corresponding mean values of 0.21, 0.31 and 0.50mSv/y for adults, children and infants respectively.

The estimated annual effective doses due to ingestion of Radon-222 from well water samples were found to range from 0.08 to 0.31mSv/y, 0.11 to 0.46mSv/y and 0.18 to 0.75mSv/y with corresponding mean values of 0.19, 0.28, and 0.45 mSv/y for adults, children and infants respectively. 88.2% for adults, 100% for children and 100% for infants of the estimated Annual Effective doses were found to be above the recommended reference level of 0.1 mSv/y for intake of radionuclide in water set by World Health Organization (WHO, 2004) as presented in figure 2. These higher values of annual effective doses showed that most of the water sample from the study area should be tested for radon contamination.

Table 1. Radon concentration and calculated effective doses for adults, children and infants.

S/N	Sample Code	Radon concentration (Bq/L)	Annual Effective Dose ADULT (mSv/y)	Annual Effective Dose CHILD (mSv/y)	Annual Effective Dose INFANT (mSv/y)
1	Aku 1 (BH)	20.44	0.15	0.22	0.37
2	Aku 2 (BH)	14.52	0.11	0.16	0.26
3	Aku 3 (BH)	12.61	0.09	0.14	0.23
4	Aku 4 (DW)	10.30	0.08	0.11	0.18
5	Aye 1 (BH)	27.42	0.20	0.30	0.49
6	Eti 1 (BH)	14.95	0.11	0.16	0.27
7	Iwa 1 (DW)	15.30	0.11	0.17	0.27
8	Iwa 2 (DW)	15.59	0.11	0.17	0.28
9	Oba 1 (DW)	21.80	0.16	0.24	0.39
10	Oba 2 (BH)	21.50	0.16	0.24	0.38
11	Oba 3 (DW)	38.78	0.28	0.42	0.69
12	Oka 1 (DW)	33.71	0.25	0.37	0.60
13	Oka 2 (DW)	41.89	0.31	0.46	0.75
14	Oka 3 (BH)	31.95	0.23	0.35	0.57
15	Sup 1 (BH)	27.98	0.20	0.31	0.50
16	Sup 2 (BH)	57.50	0.42	0.63	1.03
17	Sup 3 (BH)	51.25	0.37	0.56	0.92
	Mean values	26.91	0.20	0.29	0.48

***BH- Borehole, DW-Dug well**

Table 2. Radon-222 concentration in borehole samples

Samples	Location	Radon Concentration (Bq/L)
Borehole 1	Aku 1	20.44
Borehole 2	Aku 2	14.52
Borehole 3	Aku 3	12.61
Borehole 4	Aye 1	27.42
Borehole 5	Eti 1	14.95
Borehole 6	Oba 2	21.50
Borehole 7	Oka 3	31.95
Borehole 8	Sup 1	27.98
Borehole 9	Sup 2	57.50
Borehole 10	Sup 3	51.25
	Mean value	28.01

Table 3. Radon-222 concentration in dug well samples

Samples	Location	Radon Concentration (Bq/L)
Well 1	Aku 4	10.30
Well 2	Iwa 1	15.30
Well 3	Iwa 2	15.59
Well 4	Oba 1	21.80
Well 5	Oba 3	38.79
Well 6	Oka 1	33.71
Well 7	Oka 2	41.89
	Mean value	25.34

Remediation processes like aeration of water from theses sources may be a viable way to reduce the concentration of radon in them. Although aeration systems are quite expensive, research should be encouraged into devising local means of aeration.

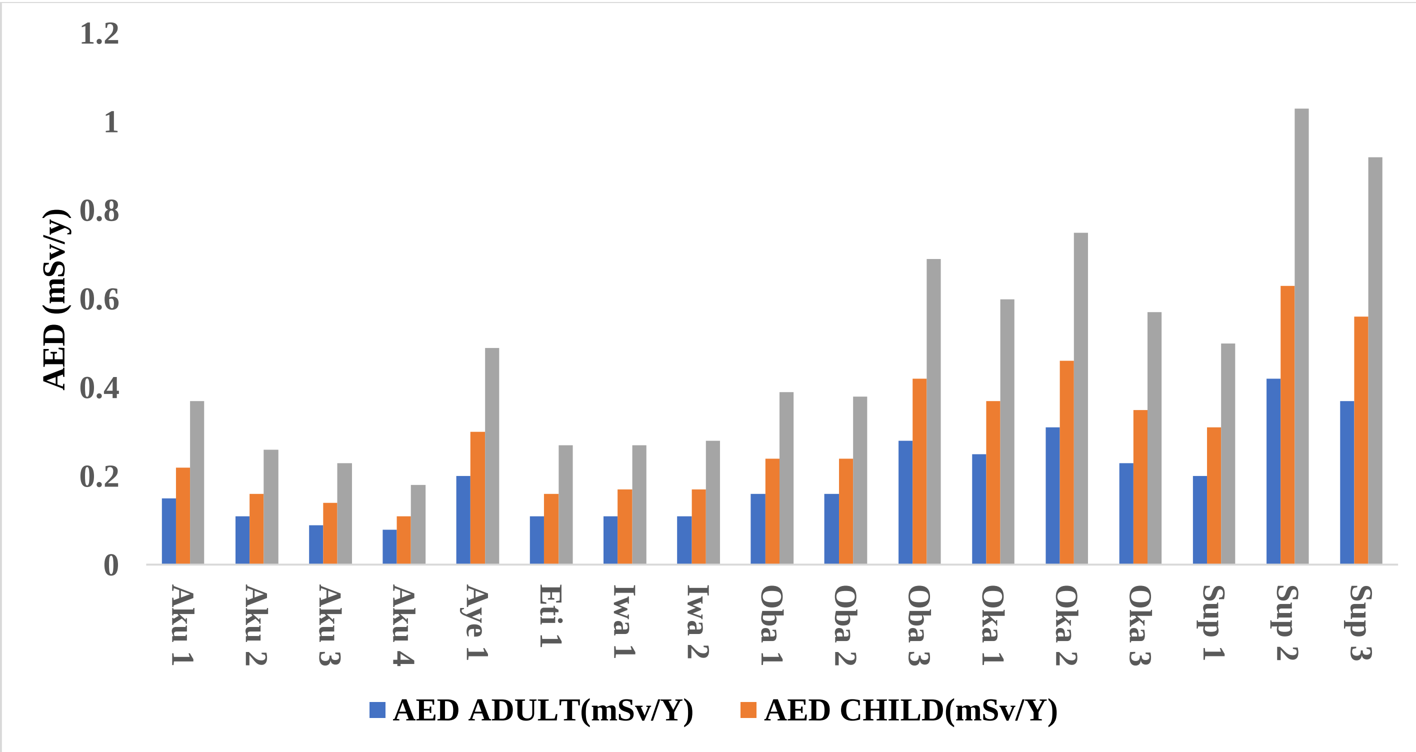


Figure 2: Estimated Annual Effective Doses (AED) from consumption of groundwater samples by adults, children and infants.

5. Conclusion

Results obtained from the measurement of the activity concentrations of radon in water samples collected at different locations in the region revealed that most of the samples contained radon concentration that were above the MCL set by Environmental Protection Agency.These significantly high values of radon concentration can be ascribed to the nature of the basement rock and soil type in the study area.These high levels may contribute significantly to buildup of radon in indoor air when water from these sources are in domestic use.These water sources pose a threat to the health of the inhabitants if continually ingested without proper treatment. The likelihood of this threat to health (which could be stomach or lung cancer) is more on infants and children than adults as evident from the estimated Annual Effective doses of the corresponding radon concentrations in water in which most of the estimated annual effective doses were found to be above the reference level set by World Health Organization (WHO, 2004) for intake of radionuclide in water.

References

Ademola, J.A. and Oyeleke O.A. (2017). Radon-222 in groundwater and effective dose due to ingestion and inhalation in the city of Ibadan, J. Radiol. Prot. 37(1), 189-200. doi:10.1088/1361-6498/37/1/189

Akar, U., Gurler, O, Kahram, A., Yalcin, S., Kaynak, G. and Gundogdu, O. (2012). Measurement of radium levels in bottled natural spring water of Marmara Region Turkey. Rom. J. Phy. 57(7-8), 1204-1210.

Alghamdi, A.S., Aleissa, K.A. and Al-hamarneh I.F. (2019). Gamma Radiation and indoor radon concentrations in western and southwestern regions of Saudi Arabia. Heliyon. 5(1), 1-18. doi:10.1016/j.heliyon.2019.e01133

Asere A.M. and Ajayi I.R. (2017). Estimation of Indoor Radon and Its Progeny in Dwellings of Akoko Region, Ondo State, Southwestern Nigeria, J. Sci. Res. Report. 14(3), 1-7. 10.9734/JSRR/2017/32246.

Choubey, V.M., Bartarya, S.K., Saini, N.K and Ramola, R.C. (2001). Impact of geohydrology and neotectonics activity on radon concentration in groundwater of intermontane Doon Valley, Outer Himalaya, India. Environ. Geol. 40(3), 257-266. DOI:10.1007/s002540000177

EPA. (2018). 2018 edition of the drinking water standards and health advisories, EPA822-F18-001, Office of Water, U.S. Environmental Protection Agency, Washington D.C.

Falowo, O.O., Ojo, O.O. and Akindureni Y. (2017). Groundwater potential and vulnerability Assessment from Integrated Geophysical Methods, Borehole Logging and Hydrogeological Measurement. Int. J. Advan. Sci. Res. Engin. 3(8), 41-57. 10.7324/IJASRE.2017.32496.

Faweya, E.B., Olowomofe, O.G., Akande, H.T., Adewumi T.A. (2018). Radon emanation and heavy-metals assessment of historical warm and cold springs in Nigeria using different matrices. Environ. Syst. Res. 7, 1-22 https://doi.org/10.1186/s40068-018-0125-x

Garba, N.N., Rabiu, N., Dewu, B.B.M., Sadiq, U. and Yamusa, Y.A. (2013). Radon assessment in groundwater sources from Zaria. Int. J. Phy. Sci. 8(42), 1983-1987. 10.5897/IJPS2013.4035.

Joseph, E., Atsue, T. and Adams S. (2018). Assessment of Radon-222 in Selected Water Sources at Dutsin-Ma Town, Dutsin-Ma Local Government Area, Katsina State. J. Sci. Eng. Res. 5(5), 49-59.

Kitto, M.E, Kuhland, M.K. and Dansereau R.E. (1996). Direct comparison of three methods for the determination of radon in well water. Health. Phy. 70(3), 358-362. doi: 10.1097/00004032-199603000-00005

Korany, K.A, Shata, A.E., Hassan, S.F. and Nagdy M.S.E. (2013). Depth and seasonal variations for the soil radon gas concentration levels at Wadi Naseib Area, southwestern Sinai, Egypt. J. Phy. Chem. Biophy. 3(4), 1-6.

Malakoontian, M. and Nejhad Y.S. (2017). Determination of radon concentration in drinking water of bam villages and evaluation of the annual effective dose. Int. J. Rad. Res. 15(1), 81-89. doi:10.18869/acadpub.ijrr.15.1.81.

Messier, K.P. and Serre, M.L. (2017). Lung and Stomach cancer associations with groundwater radon in North Carolina, USA. Int. J. Epidem. 46, 676-85.

Mohammed, M.Z., Ogunribido T.H.T. and Funmilayo, A.T. (2012). Electrical Resistivity Evaluation of Groundwater Potential of AraromiAkungba-akoko Ondo State. J. Environ. Earth. Sci. 2(7), 29-40.

Muller, M. and Michael, A. (2017). Understanding Cape Town water crisis. Civil engineering. http://ssrn.com/abstract=2995937.

Njinga, R., Elele, U. and Muhammad, I. (2015). Radiological Health Hazards Analysis in Groundwater by Gross Alpha and Gross Beta Measurements, J. Dis. Global. Health. 2(3), 99-108.

Oni, E.A., Oni, O.M., Oladapo, O.O., Olatunde, I.D. and Adediwura, F.E. (2016). Measurement of Radon concentration in Drinking Water of Ado-Ekiti, Nigeria. J. Acad. Ind. Res. 4(8), 1-10.

Oniya, E.O. (2014). Assessment of radiological hazard levels in drinkable water: a case study of sachet water consumed in Adekunle Ajasin University community and its environ. Sci. Res. Annal. 6(1), 33 – 41.

Raquel, B.L., Juan, M.B.D. and Alberto R.R. (2017). Radon and Stomach cancer. Int. J. Epid. 46 (2), 767-768, https://doi.org/10.1093/ije/dyx011.

Ryan, T.P., Sequeira, S., Mckittrick, L. and Colgan, P.A. (2003). Radon in Drinking water in Co. Wicklow- A Pilot Study. *Radio protect instit.* Ireland.

UNSCEAR. (2000). Sources and effects of ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation, Report to the General Assembly, with scientific annexes, New York.

WHO. (2004). Guideline for third edition Recommendation drinking water quality, Geneva.

Yussuf, N.M., Hossain, I. and Wagiran H. (2012). Natural radioactivity in drinking and mineral water in Johor Bahru (Malaysia). Sci. Res. Essay. 7(9), 1070-1075.