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STUDIES ON RADON CONCENTRATION IN UNDERGROUND WATER OF IDAH, NIGERIA

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Abstract

Studies on ground water samples from selected boreholes and wells in Idah were carried out to determine the concentration of radon (^{222}Rn) using the Liquid Scintillation Counter (LSC). The average concentration of radon obtained was 14.09±1.10 BqL^{-1} for boreholes and 13.45±1.00 BqL^{-1} for well waters. The overall average concentration of 13.77±1.05 BqL^{-1} was recorded. The results obtained in this work were compared with the maximum contamination level (MCL) of 11.1 BqL^{-1} set by USEPA and the world average value of 10.0 BqL^{-1} for drinking water and it was observed that 80% of the samples exceeded these values. The average annual effective dose by ingestion of 0.051$mSvy^{-1}$ was recorded for boreholes and 0.049$mSvy^{-1}$ for well water samples. All values of effective dose were below the ICRP recommended intervention level of 3-10$mSvy^{-1}$.

Keywords: Radon; Ground Water; ^{222}Rn Concentration; Idah; Stomach Cancer; Maximum Contamination Level.

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1. Introduction

Water is the most abundant substance on earth and the principal constituent of all living things. It existed long before man came into existence. Man uses water for many purposes in areas such as agriculture, power generation and above all for domestic purposes. Water for human consumption should be free from chemical, microbiological and radiological contamination. But unfortunately in developing countries like Nigeria most people are not opportune to have access to such safe drinking water. Due to chronic scarcity of portable water in Idah, Kogi state and in many other states across the nation, people normally collect water from surfaces and ground sources comprising hand dug wells and boreholes. The pipe borne are mostly not operational where provided; therefore most of the populace rely heavily on untreated ground water and

surface water sources as their sources of drinking water and the authorities concerned have not taken serious measures to address the issue of providing adequate and safe drinking water for the area. Therefore it is important to investigate the radiological content of water from such sources.
Radon (^{222}Rn), a neutral byproduct of the radioactive decay of uranium, radium and thorium, is an alpha-emitting noble gas with a half-life of 3.825 days. Radon gas is soluble in water and consequently the gas maybe incorporated into groundwater flows (Lawal, 2008). Radon is extracted from the volcanic deposits in which the aquifer resides, its transport taking place basically through the fissure network in the fractured system or from mantle degassing. The quantity of radon dissolved in groundwater depends on different factors such as the characteristics of the aquifer, water – rock interaction, water residence time within aquifer, material content of radium etc. (Gates and Gundersen, 1992; Choubey *et al.*, 1997).

The increased awareness of radon (^{222}Rn) as a significant potential threat to public health has made it necessary to further investigate and expand our understanding of radon in natural water. The main source of indoor exposure to long-lived radionuclides in the uranium decay-series in general, is potable water, whereas ^{222}Rn may enter the indoor environment by direct water transport, by groundwater transport and diffusion to the dwelling by advection transport and diffusion from the ground to the dwelling, or by emanation from building materials. The water transport pathway has been regarded as a less significant contributor to the radon levels found in dwellings (Sadid and Jabbar, 2013). However, recently more attention has been paid to this pathway, especially when considering exposure of infants and children by ingestion of radon in drinking water, and if combined with high levels of U, Ra and Po in drinking water it may constitute a significant public health risk. It is a gas which is formed by series radioactive decay of uranium-238 (^{238}U) (Garba *et al.*, 2013). Radium -226 (^{226}Ra) is the parent radionuclide of ^{222}Rn in the decay series and ^{226}Ra is found in a wide variety of rocks and soils. Volcanic rocks in the Rocky Mountain region possess a high ^{222}Rn generating potential. Therefore colluviums and alluvium originated from uranium bearing rocks present moderate to high ^{222}Rn generating potential and they are abundant in Idaho (NCIFS, 2009).

Radon is the number one cause of lung cancer among non-smokers; overall, radon is the second leading cause of lung cancer and is responsible for about 21,000 lung cancer deaths every year (Paulus, 1995). ^{222}Rn gas generated from the colluviums and alluvium can enter groundwater by dissolution. Numerous factors such as geology, geochemical properties of parent radionuclide's hydrological conditions, abundance of parent radio nuclides, and radionuclides sorbent by the rocks or soils are potential parameters that can affect the concentration of ^{222}Rn in groundwater (USEPA, 2008). The United States Environmental Protection Agency (USEPA) is in campaign to promote Radon testing and mitigation and radon resistance construction practices. The month of January is recognized as National Radon Action Month by the USEPA (USEPA, 1999).The USEPA recommended zero concentration of ^{222}Rn in drinking water and this has been proposed as maximum contaminate level goal (MCLG) since 1999; however, this limit is anon – enforceable limit (IAC, 2008).

In the Safe Drinking Water Act Amendments of 1996 the USEPA has recommended the Maximum contaminant level (MCL) for ^{222}Rn in drinking water as 11.1Bq/ L (300pCi/L).This limit should be followed if there is no indoor air multimedia mitigation (MMM) program Implemented for public water treatment and supply system. If a MMM program is implemented, then the limit for ^{222}Rn becomes 148 Bq/L (4000pCi/L) (USEPA 2008, USEPA 1999). Presumably, the MMM program would reduce the fugitive ^{222}Rn gas escaped from the drinking water to an acceptable risk level. Although this rule should only be followed by public water suppliers, private wells and water providers should also follow the recommended MCL due to health concerns. The standard organization of Nigeria (SON) neither regulates ^{222}Rn in drinking water, nor does it have any MMM programs for Idah and Nigeria at large. Nevertheless if human health is a priority, ^{222}Rn concentration in the drinking water should be below 11.1Bq/L when it is consumed domestically without a MMM program. Radon from the groundwater can enter our living environment by various routes: such as radon gas released from water in showering, dishwashing, and laundry (Fitzgerald *et al*,. 1997). Direct inhalation is probably the most likely mechanism that radon ^{222}Rn, enters into our body, although other route such as dermal sorption is possible. High concentrations of ^{222}Rn in water may pose a serious health threat to human as ^{222}Rn is a known carcinogen (USEPA, 1999).

Hopke *et al*, (2000) have listed inhalation and ingestion risk for ^{222}Rn in water: the authors estimated a lifetime risk of lung cancer for a mixed population that included smokers and nonsmokers in men and women as a result of air exposure to ^{222}Rn generating from ^{222}Rn water with concentration of 0.0009 Bq/L as 1.3 x 10^{-8}. For the same ^{222}Rn water concentration the lifetime risk of stomach cancer was reported as 0.2 x 10^{-8} the lung cancer risk was more than six times of the stomach cancer risk. Although these risk factors are relatively low, the aforementioned concentration in water, from the report was also orders of magnitude (10,000 times) lower than the 11.1 Bq/L limit. Species in groundwater and the proposed MCL of 11.1 Bq/L (300 pCi/L) as the reference concentration for our discussions commonly called radon, is a naturally occurring colorless, odorless, and invisible radioactive gas resulting from the decay of ^{226}Ra in the uranium-series decay chain. It is commonly transported freely via faults and fragmented rocks and soils to the open atmosphere, surface dwellings, underground water and cavities (Aleksender *et al*, 2010).As explained above radon (^{222}Rn) is emitted by the decay of ^{222}Ra, an element of the ^{238}U decay series. Radon-222 decays into a series of other radioactive elements, of which^{213}Poand^{218}Po are the most significant, as they contribute the majority of radiation dose when inhaled. Following a number of decay series, ^{218}Po transforms into^{210}Po and it decays into stable ^{206}Pb.

The^{222}Rn and its decay products are reported as major causes of lung cancer (UNSCEAR,2000; ICRP, 1991), especially when they are inhaled attached to dust particles in the air.The^{222}Rn exists in soil and water, and propagates into the atmosphere from these natural sources. Meteorological parameters such as temperature, pressure differences, and humidity also affect indoor^{222}Rn concentrations. Levels of^{222}Rn can also be modified by the ventilation conditions, heating cooling systems and the life style of inhabitants (Bochicchio *et a*l., 2009, Khattak *et al.*, 2011).It is believed that average concentration of uranium in earth's crust is about 4 mg/kg. This radioactive element decays into numerous other radioactive isotopes including ^{222}Rn (Natasa *et al.*, 2012).

Measurement of radon contents in groundwater have been performed in connection with geological, hydro geological and hydrological surveys and health hazard studies. On the one hand, the half-life of radon and its solubility have allowed the use of radon gas as a natural groundwater traces to identify and quantity groundwater discharge to surface waters (Hector *et* *al*., 2015) or to attempt to elucidate the type of rocks through which ground waters flow. On the other hand, the presence of high levels of radon in drinking water constitutes a major health hazard. The commission of European communities (CEC) recommends the monitoring of radon levels in domestic drinking water supplies originating from different types of ground water sources and wells in different geological areas, in order to determine consumer population exposure. The limit is fixed at below 100Bq/L (Lawal, 2008). The routes of radon to human are through inhalation of radon when its escapes from water into the air or through ingestion when water containing radon is consumed, therefore the quality of water is now essential, since water is indispensable in our daily activities (Oni *et al.*, 2016).

Keeping the above facts in view, it is then imperative to determine the quantity of radon concentration in underground water of Idah and also to estimate the annual effective dose from the drinking water.

1.1. Description of the Study Area

Idah is a local government in Kogi state Nigeria. In the study area Idah, and its environs there is total dependence and reliance on ground water source for drinking, agricultural purposes and domestic usage. Idah is bounded by latitudes 7^o 49 N - 7^o 62 N and longitudes 6^o 44 E - 6^o 75 E. It has a total landmass of 36km^2 (14Sq.mile) and a population of 76, 815 persons at the 2006 census (National Population Commission 2006). The study area falls within the forest region of Nigeria (McCurry, 1976), the area is underlain by Gneisses, magnetite and metamorphic rocks of Precambrian age which have been intruded by series of granite rocks which are sources of uranium, the parent of radon-222. However, some portion of the study area fall within region underlain by sand stones (sedimentary rock) which could provide a source of water through the tapping of the aquifers while the remaining portion is underlain by igneous rocks (Adams, 2010).

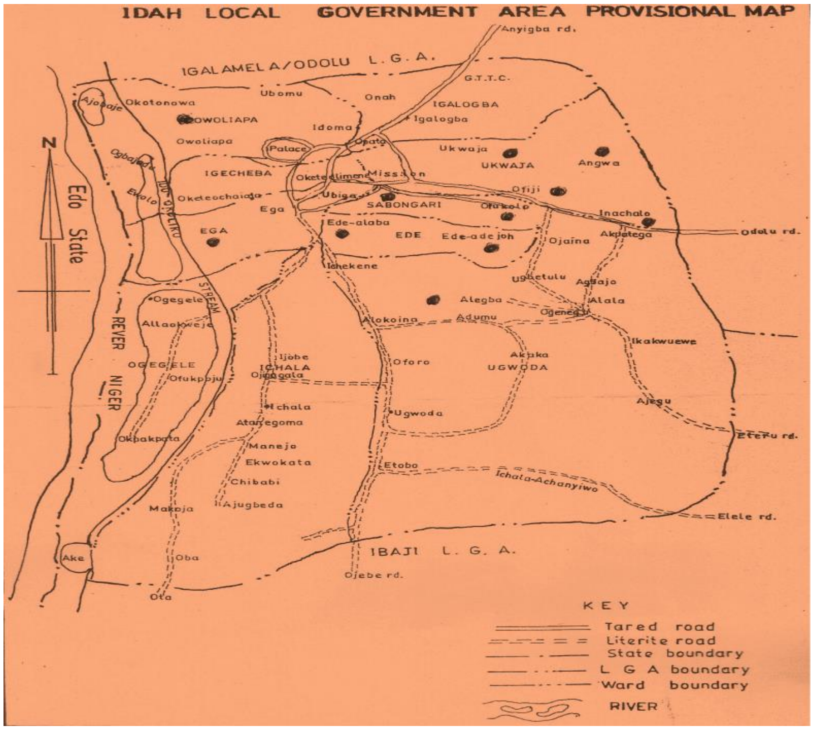

Figure 1: Map of the study area showing sample locations.

2. Materials and Methods

2.1. Materials

The following materials were used in this research as listed by Paul and Stephen (1991) in a publication titled "Determination of Radon in Drinking Water by Liquid Scintillation Counting Method 913.0;

i. Plastic sample collection bottles (200ml) was used for sample collection
ii. Scintillation cocktail dispenser – adjustable to deliver 10ml.
iii. Liquid scintillation counter (Packard Tri-Carb LSA 1000TR)
iv. Disposable hypodermic syringe (20ml, 10ml and 2ml) capacity with 38mm hypodermic needle.
v. Distilled water
vi. Scintillation vial – 20ml glass with cap.
vii. Surgical globe
viii. Indelible ink and masking tape
ix. Mineral oil (insta-gel)

2.2. Methodology

Sample Collection and Pretreatment

A total of 20 samples of groundwater (deep wells and boreholes) were collected from 11 different locations in Idah in plastic bottles. The plastic bottles were first wash cleaned and rinsed with distilled water to avoid radon present in the samples from being contaminated or absorbed.

The water samples from boreholes where collected after the boreholes were operated for at least four minutes. The samples from dug wells were collected with the aid of a bailer, but the stagnant water in the wells was first purged by drawing it out and allowing the well to refill, this was done severally to ensure fresh samples were obtained.

The samples were taken to the laboratory immediately after collection without allowing them to stay long (three days maximum) for analysis. This is done so as to achieve maximum accuracy and not to allow the composition of the sample to change.

Sample Preparation

10ml each of the water samples were transferred into a 20ml glass scintillation vial to which 10ml of insta-gel scintillation cocktail is added. Having been sealed tightly, the vials were shaken for more than two minutes to extract radon – 222 in water phase into the organic scintillate, and the samples collected were then counted for 60minutes in a liquid scintillation counter using energy discrimination for alpha particles.

Sample Analysis

The prepared samples were analyzed by using Liquid Scintillation Counter (Tri-Carb LSA 1000TR) model located at the centre for Energy Research and Training (CERT), Ahmadu Bello

University, Zaria – Nigeria, after they were allowed to stay for three hours for equilibrium to be attained between radon-222 and its daughter progeny.

The ^{222}Rn concentration in a sample of water is determined using the formula.

$$(BqL^{-1}) = \frac{1000mL\ (CS-CB)}{10mL\ X\ 1.0L\ (CF\ X\ D)} \tag{1}$$

Where
Rn = Radon level in BqL^{-1}
CS = Sample Count/Second
CB = Background Count/Second
CF = Conversion factor
D = Decay Constant

To calculate the annual effective dose of ^{222}Rn through drinking water, an equation as proposed by the United Nation Scientific Committee on the Effects of Atomic Radiation (Isam, 2003) was used.

$$E = K \times G \times C \times T \times 1000 \tag{2}$$

E = Annual effective dose (mSvy^{-1})
K = Conversion coefficient concentration of ^{222}Rn (SvBq^{-1})
G = Daily Consumed Water (L/d)
C = Concentration of ^{222}Rn (BqL^{-1})
T = time span of water consumption (365 days)
1000 = conversion coefficient of Sv to mSv

3. Results and Discussions

Table 1: ^{222}Rn Concentrations and annual effective doses in samples of water from Idah metropolis

S/N	Sample ID	Latitude (°) N	Longitude (°) E	Radon conc. (Bq/L)	Annual effective dose by ingestion (mSvy^{-1})
1	IB1	7.12	6.72	17.94±1.10	0.065
2	IB2	7.17	6.70	18.24±1.10	0.067
3	IB3	7.11	6.74	12.90±1.10	0.047
4	IB4	7.12	6.73	12.82±1.10	0.047
5	IB5	7.11	6.72	9.15±1.10	0.033
6	IB6	7.11	6.73	7.94±1.10	0.029
7	IB7	7.21	6.41	15.46±1.10	0.056
8	IB8	7.24	6.43	14.89±1.10	0.054
9	IB9	7.25	6.43	21.21±1.10	0.077
10	IB10	7.22	6.42	13.80±1.10	0.050
11	IB11	7.23	6.33	14.10±1.10	0.051
12	IB12	7.26	6.39	10.60±1.10	0.039
13	IW1	7.11	6.69	10.16±1.00	0.037

14	IW2	7.12	6.74	13.71±1.00	0.050
15	IW3	7.11	6.73	14.87±1.00	0.054
16	IW4	7.11	6.67	13.42±1.00	0.049
17	IW5	7.10	6.72	14.03±1.00	0.051
18	IW6	7.16	6.74	14.09±1.00	0.051
19	IW7	7.18	6.75	13.21±1.00	0.048
20	IW8	7.16	6.72	14.12±1.00	0.052
			Average	**13.77±1.05**	**0.055**

Table 2: Comparison of radon concentration of groundwater samples used for drinking in Idah with other Parts of the world and Nigeria.

Location	**Radon concentration (BqL^{-1})**
India	2.63
Turkey	9.28
Romania	15.40
Jordan (many locations)	2.80 – 116.00
Lebanon	11.30
Tassili, South – east Algeria	0.67 – 21 .25
Eastern Doon Valley, Outer Himalayas	20.00 – 95. 00
Northern Venezuela	0.10 – 5.76
Finland	630.00
United States of America	5.20
Ado-Ekiti, Nigeria	13.59
Zaria, Nigeria	12.43 – 16.36
Idah, Nigeria (Present work)	13.77

The results for radon concentrations in drinking water samples collected in Idah Local Government of Kogi State Nigeria were reported in Table 1. The radon concentration values in samples from Idah were in the range of 7.94±1.10 BqL^{-1} to 21.21±1.10 BqL^{-1} with an average value of 14.09 ±1.10 BqL^{-1} for borehole water samples and 10.16±1.00 BqL^{-1} to 14.87±1.00 BqL^{-1} with an average value of 13.45±1.00 BqL^{-1} for well water samples. The overall average radon concentration of 13.77±1.05 BqL^{-1} was recorded.

The recorded value of radon concentrations are within the recommended safe limit of 4.0 – 40.0 BqL^{-1} suggested by United Nation Scientific Committee on the Effect of Atomic Radiation. All the radon concentration values were found to be below the recommended action level of 100BqL^{-1} set by the European Commission for drinking purpose. The US Environment Protection Agency has proposed that the allowed maximum contamination level (MCL) for radon concentration in water is 11.1 BqL^{-1} in which about 80% of samples assayed were above the maximum contamination level. The higher values of radon concentration can be ascribed to the nature of the basement rock and other human activities in the study locations.

Comparing the result of this study with the other part of the world in Table 2, it can be noticed that the radon concentration of water taken from Idah is lower than the radon concentrations from places like Romania, parts of Jordan, outer Himalayas and Finland, but higher compared to radon concentrations from India, Turkey, Lebanon, some parts of Jordan, Algeria, Northern Venuzuela and USA.

The annual effective dose by ingestion from the corresponding measured radon concentrations were estimated for different locations of study. It was found out that the annual effective dose by ingestion varies from 0.029mSvy^{-1}to 0.077mSvy^{-1} with an average value of 0.051mSvy^{-1} for borehole water samples and 0.037mSvy^{-1} to 0.054mSvy^{-1} with an average value of 0.049mSvy^{-1} for well water samples. The overall average annual effective dose of 0.050mSvy^{-1}was recorded. All values for annual effective dose by ingestion were below the recommended ICRP intervention level of 3-10 mSvy^{-1} (1984) and the WHO recommended reference level of 0.1mSvy^{-1} for intake of radionuclides in water which was adopted by SON (2003).

4. Conclusion

The present study showed that the radon concentration in the ground water samples from Idah has been observed to have radon concentration above the maximum limit of 11.1BqL^{-1} set by USEPA which call for immediate action for radon reduction in the area. Also, comparing the results with value of 0.1 BqL^{-1} set by Standard Organization of Nigeria (SON), it was observed that all the water samples assayed for radon concentration are not safe for domestic purposes and consumption. Hence, the data in the study could be used for the study location, since this work pioneer the determination of radon in ground water in the study area.

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