Journal of Informatics and Mathematical Sciences
Vol. 9, No. 2, pp. 241–249, 2017
ISSN 0975-5748 (online); 0974-875X (print)
Published by RGN Publications

http://www.rgnpublications.com

Proceedings of
International Conference on Science and Sustainable Development (ICSSD)
"The Role of Science in Novel Research and Advances in Technology"
Center for Research, Innovation and Discovery, Covenant University, Nigeria
June 20-22, 2017

Research Article

Radioisotopes Burden in Ground Water of Ogun State, South-West, Nigeria

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Abstract. Access to safe drinking water is a means of poverty alleviation and socio-economic development of a nation. Interventions to improve the quality of drinking water will provide significant benefits to health. The activity concentration of ^{60}Co, ^{134}Cs, ^{137}Cs, and ^{241}Am measured in twenty (20) ground water sources from three industrial zones of Ogun State using gamma spectroscopy techniques. The mean activity concentrations were found to be ^{60}Co (0.15±0.03Bq/l); ^{134}Cs (0.15±0.04Bq/l);^{137}Cs (0.17±0.05Bq/l) and ^{241}Am (0.69±0.20Bq/l). Three samples (AB1, JB2 and ID1) recorded high activity of ^{241}Am above the guidance level of 1 Bq/l recommended by the World Health Organization (WHO). The estimated mean total annual effective dose for three age groups, infant; children and adult are: 0.08 mSv y^{-1}; 0.06 mSvy^{-1}; and 0.11 mSv y^{-1} respectively. The recommended WHO standard of 0.1 mSv y^{-1} was exceeded for adult.This implies that other than nuclear accidents manmade radionuclides can be found in drinking water at a rate higher than the recommended permissible limit. Also, the tendency for higher dose to be recorded in the nearest future will be inevitable if the source of contamination is not controlled. Therefore, anthropogenic activities influencing the concentrations of radioisotopes in the study environment should be checkmate and remediation action implemented. This will promote tangible health benefits to the populace.

Keywords. Radioisotopes; Water; Activity; Concentration; Dose

MSC. 92B05

Received: May 31, 2017 **Revised:** June 30, 2017 **Accepted:** July 15, 2017

1. Introduction

Water is an amazing natural resource that the earth cannot survive without it. Yet, the influences of man on its environment have rendered water a latent poison. Worldwide, access to safe water is becoming more demanding as water pollution is witnessed all over. Much have been said about the occurrences of natural radioactivity in drinking water, which to a large extent is attributed to primordial radionuclides, geological formation and anthropogenic activities such as mining among others. Contrarily, few literatures exist on the impact of manmade radionuclides in drinking water. The reason might be traceable to negligible concentration of these radioisotopes in water. Notably, our environment is highly polluted to what it used to be decades ago. It is therefore essential to access the concentration of radioisotopes in our drinking water to enhance safety. The presence of manmade radionuclides in drinking water is mainly anthropogenic in origin. Urbanization is a great threat to water quality. Though, it comes with several opportunities but the challenges associated with it are enormous. One of such challenges among others is the increase in radioactivity contamination, thereby subjecting man to be more prone to the dangers of radiation exposure. Research had shown that radioactive isotopes found in waste sometimes accumulate to hundreds of thousands of tonnes (Michalik, 2008). These wastes find their way into the water body thereby polluting them and exposing individual to the risk of radiation through ingestion.

Radioisotopes of ^{134}Cs are easily dispersed in the environment (Grambow and Poinssot, 2012). During Fukushima accident, huge amount of ^{134}Cs were released into the Pacific Ocean and the atmosphere, and the radioactive contamination were felt inother nations (Koo et al., 2014). Similarly, zone with massive radioactive pollution was witnessed in other countries from Chernobyl accident (Kortov and Ustyantsev, 2013). ^{137}Cs is known to persist in the environment from fallout from Chernobyl, weapon tests, nuclear power and processing facility discharge; it is transported over long distances by water and contributes towards radioactive contamination of marine environment (Tsabaris, 2008). According to World Health Organization (WHO), isotopes of cesium induce cancer after long exposure (WHO, 2012; Altikulac *et al*., 2015). They concentrate in soft tissues exposing living tissues to beta and gamma radiation (Altikulac *et al*., 2015; Shore and Rattner, 2001). The study of Altikulac *et al.,* (2015) reported activity concentration of 2.58 Bq/l for ^{137}Cs in a single sample out of fifty two water samples while the activity of^{137}Cs in all other water samples were below detection limit. Similar study conducted in Spain noted that the activity concentration of ^{137}Cs were below detection limit in all the water samples (Duenas *et al*., 2011; Pujol and Sanchez-Cabeza, 2000).

^{241}Am have both domestic and industrial applications and as such it is a significant components of radioactive waste (Plaska *et al*., 2016). The populace can be exposed to elevated levels of ^{241}Am by residing in areas at close proximity to hazardous waste sites where this radionuclide is present (ATSDR, 2004). Ingested ^{241}Am isotope is known to concentrate in bone, liver and muscle. They tarry long in the body and as such irradiate neighbouring tissues thereby increasing the risk of developing cancer (USEPA, 2002; Kathren, 2001). All isotopes of cobalt are

known to behave the same chemically and have the same chemical effects on the body (ATSDR, 2004). ^{60}Co has several industrial benefits but its radioactive nature renders it a potent health risk. Animal studies have shown that ^{60}Co can cause both temporary and permanent sterility, lung disease, genetic cell damage, cancer and even death (ATSDR, 2004).

The significance of this study is that the activity concentration of artificial radionuclides has not been reported in the study area. This study will serve as a guide for future studies regarding measurement of activity concentration of artificial radionuclides in the study environment. Alpha and beta emitting radionuclides are classified as carcinogens irrespective of the source (IARC, 2001). Determination of the activity concentration of radionuclides in drinking water is a means by which the health risks of radiation exposure from radionuclides can be measured. Therefore, this study was embarked upon in order to estimate the radiation risks that are accrue to the populace living in the study area from the ingestion of artificial radionuclides in their water in order to enhance radiation safety.

2. Materials and Methods

2.1 Study Area

The study area is made of 29 % of the population of Ogun State with approximately 3.8 million people according to the estimate a decade ago (NBS, 2012). Presently, the State has emerged as one of the fastest growing business destinations in Nigeria, with over 7 million populations (The Nation, 2014; Champion, 2016). It is notable for having a high concentration of industrial estates and a major manufacturing hub in Nigeria. It harbors various local and international businesses and factories because its serves as gateway to several other States from Lagos being the nearest. Also, it has the highest number of universities in Nigeria and several other higher institutions of learning. The State lies between coordinates 7.00 ^{0}N and 3.35 ^{0}E and covers an area of about 16981 km^2. The mean annual rainfall, temperature and evaporation are 1270 mm; 28 ^{0}C and 1100 mm respectively.

2.2 Activity Measurement

A total of 20 ground water samples were collected randomly from three industrial zones of Ogun State namely: Abeokuta zone (7), Ijebu zone (7) and Ota zone (6) at depths range 15.6 to 54.0 m. The locations of the wells are widely spread out to ensure that every region of the study area was covered. This is to ensure a wide coverage for the measurement of the level of radioisotopes contaminations of well water in the study area, as the level of industrial evolution at the different locations varies.

Sample preparation was carried out as documented by the International Atomic Energy Agency (IAEA, 1989). Chemical analysis of all the samples was conducted using standard techniques according to APHA, 1995. Gamma spectrometry measurements were carried out as documented by Achuka et al., (2017).

3. Results and Discussion

The pH values and other chemical parameters analyzed in the water samples from the three industrial zones of Ogun State are presented in Figure 1. The results showed slight variation in the chemical properties of these water samples from one industrial zone to the other except for chloride. High concentration of chloride in water samples from Ijebu zones may be due to the presence of rich chloride content in the rock bearing aquifer. Chloride is found in nearly all waters and comes from mineral deposits; agricultural and irrigation discharges; industrial and sewage effluents. Generally, the concentrations of these natural chemicals in the study area are within tolerance limit according to World Health Organization (WHO) standards (WHO, 2011).

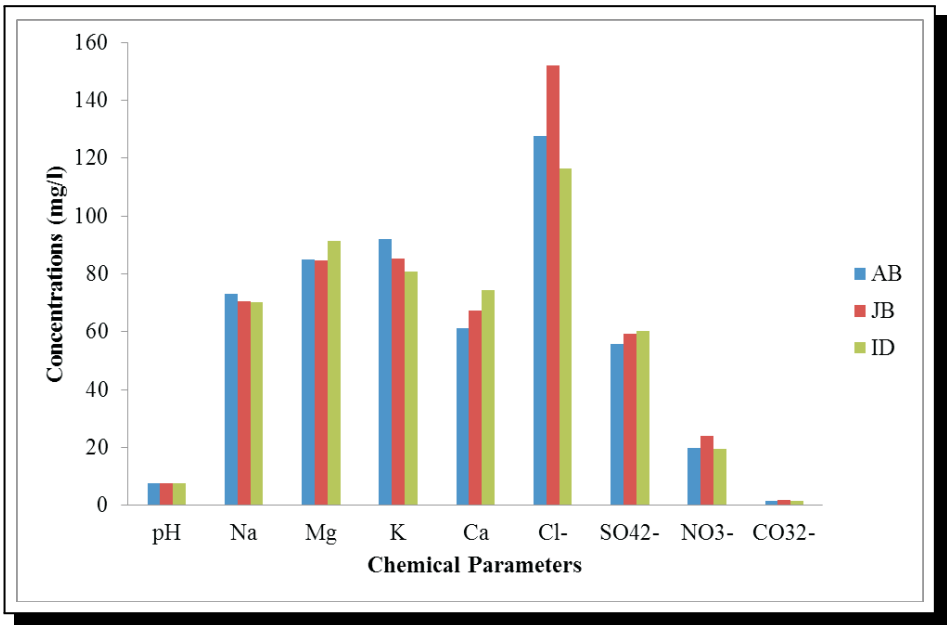

Figure 1. Chemical parameters of water samples from the three industrial zones

The activity concentrations of ^{60}Co, ^{134}Cs, ^{137}Cs and ^{241}Am in the study area is presented in Table 1. The concentration of ^{60}Co ranged from 0.09±0.00 to 0.27±0.09 with a mean of 0.15±0.03. A range of 0.09±0.01 to 0.27±0.04; 0.10±0.01 to 0.30±0.04; and BDL to 1.14±0.31 were recorded for ^{134}Cs, ^{137}Cs and ^{241}Am respectively and the mean activities were 0.15±0.04; 0.17±0.05; and 0.69±0.20 for ^{134}Cs, ^{137}Cs and ^{241}Am respectively. The activities of ^{60}Co, ^{134}Cs, and ^{137}Cs falls below the recommended guidance level established by World Health Organization (WHO) and Health Canada in all samples. While ^{241}Am exceeded the guidance level of 1.0 Bq/l recommended by World Health Organization (WHO) in sample AB1, JB2 and ID1 and exceeded the guidance level of 0.7 Bq/l recommended by Health Canada in sample AB1, AB7, JB2, JB3, JB5, JB6, ID1, ID5 and ID6. Though the activity concentration of ^{60}Co, ^{134}Cs, and ^{137}Cs in this study is below the recommended guidance level, it is far greater than that reported in other regions of the world. The activity of ^{137}Cs in open waters of Canada varies from 0.0007Bq/l to 0.006 Bq/l (Health Canada, 2009). Other researchers reported that the activity of ^{137}Cs were

below detection limit in the analyzed water samples (Altikulac *et al*., 2015; Duenas *et al*., 2011; Pujol and Sanchez-Cabeza, 2000).

The mean values of ^{60}Co in the three industrial zones were approximately the same as shown in Figure 2. ^{60}Co are known to be widely dispersed in the environment in a low concentration (ATSDR, 2004). The mean values of ^{134}Cs and ^{137}Cs are a bit higher in AB and ID zones than in JB zone. This might be attributable to the concentrations of cesium in the waste generated in those locations. Higher level of ^{241}Am in the three zones is traceable to its elevated concentration in radioactive waste as it is used for several industrial purposes and in homes (Gladysz-Plaska *et al*., 2016). Also, due to its long half-life it will persist longer in the environment. The significance of this study is that the aforementioned artificial radionuclides are detected in all the water samples of the study area. This raises a concern especially in the developing countries where waste management is a major challenge.

Table 1. Activity concentrations of ^{60}Co, ^{134}Cs, ^{137}Cs and ^{241}Am in the water samples (Bq/l)

Locations	**^{60}Co**	**^{134}Cs**	**^{137}Cs**	**^{241}Am**
AB1	0.27±0.09	0.27±0.04	0.30±0.04	1.11±0.25
AB2	0.09±0.02	0.10±0.03	0.12±0.01	0.46±0.10
AB3	0.11±0.00	0.12±0.01	0.15±0.07	0.52±0.13
AB4	0.19±0.00	0.19±0.05	0.22±0.07	BDL
AB5	0.13±0.00	0.15±0.03	0.17±0.41	0.57±0.29
AB6	0.09±0.00	0.10±0.03	0.10±0.01	0.42±0.05
AB7	0.19±0.00	0.16±0.05	0.17±0.00	0.89±0.31
JB1	0.18±0.02	0.17±0.02	0.20±0.04	0.67±0.14
JB2	0.17±0.05	0.22±0.02	0.23±0.03	1.14±0.31
JB3	0.17±0.02	0.15±0.08	0.17±0.05	0.90±0.23
JB4	0.18±0.14	0.16±0.14	0.18±0.03	0.50±0.21
JB5	0.13±0.01	0.14±0.04	0.17±0.03	0.79±0.17
JB6	0.13±0.01	0.13±0.04	0.15±0.05	0.93±0.04
JB7	0.09±0.01	0.09±0.01	0.11±0.01	0.40±0.13
ID1	0.17±0.08	0.21±0.03	0.23±0.05	1.06±0.76
ID2	0.13±0.02	0.14±0.07	0.16±0.03	0.67±0.57
ID3	0.15±0.04	0.15±0.01	0.17±0.01	0.60±0.06
ID4	0.11±0.01	0.11±0.05	0.12±0.00	0.47±0.14
ID5	0.12±0.05	0.12±0.01	0.15±0.03	0.80±0.04
ID6	0.20±0.03	0.21±0.03	0.22±0.03	0.88±0.14
Minimum	0.09±0.00	0.09±0.01	0.10±0.01	BDL
Maximum	0.27±0.09	0.27±0.04	0.30±0.04	1.14±0.31
Mean	**0.15±0.03**	**0.15±0.04**	**0.17±0.05**	**0.69±0.20**
GL: (WHO 2011)	**100.0**	**10.0**	**10.0**	**1.0**
GL: Health Canada (2009)	**40.0**	**7.0**	**10.0**	**0.7**

AB: Abeokuta; JB: Ijebu Ode; ID: Idiroko; GL: Guidance Level

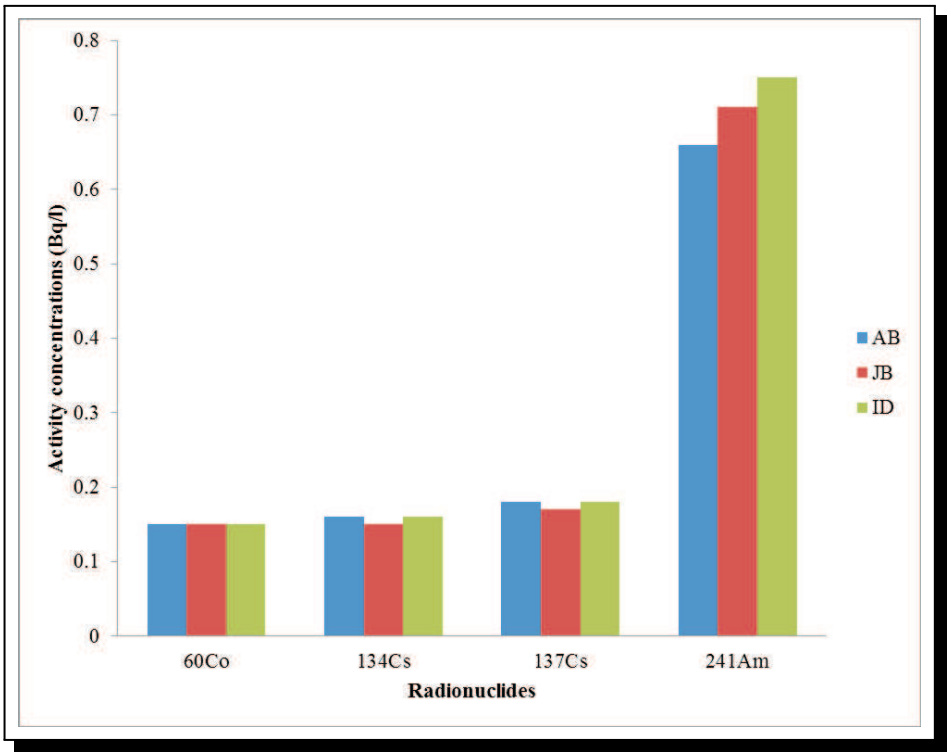

Figure 2. Mean activity concentrations of ^{60}Co, ^{134}Cs, ^{137}Cs and ^{241}Am in the three industrial zones (Bq/l)

3.1 Calculation of Total Annual Effective Dose

The total annual effective dose E_T (Svy^{-1}) to an individual is estimated by summing annual effective dose contributions from ^{60}Co, ^{134}Cs, ^{137}Cs and ^{241}Am present in the water samples using equation (1).

$$E_T = \sum A_C I_A C_F \tag{1}$$

Where E_T is the total annual effective dose to an individual due to the ingestion of radionuclides (Sv y^{-1}); A_c is the activity concentration of radionuclides in the ingested drinking water (Bq l^{-1}); I_A is the annual intake of drinking water (l y^{-1}); and C_F is the ingested dose conversion factor for radionuclides (Sv Bq^{-1}). For this study, C_F values are adopted from ICRP (2012) and I_A for infant, children and adult were taken as 260, 350 and 730 l respectively.

The total annual effective dose due to the ingestion of ^{60}Co, ^{134}Cs, ^{137}Cs and ^{241}Am through drinking the water from the study area is presented in Table 2. The mean values for the three age groups are: 0.08; 0.06 and 0.11 mSvy^{-1} for infant, children and adult respectively. The mean values for infant and children were below 0.1 mSvy^{-1} guidance level as recommended by the World Health Organization. However, the guidance level was slightly exceeded for adult. The higher value recorded for adult might be due to the amount of water consumed and due to high dose contribution from ^{241}Am. According to literature, many radionuclides in low level waste reduced to harmless levels in the environment within relatively short time but not for long lived radionuclides (IAEA, 2006; ATSDR, 2001). Also, alpha particles emitted by radionuclides

are associated with chromosomal aberrations, gene mutations, cell transformation, damage to biological molecules, cancers and other radiation related diseases (IARC, 2001). Considering the health implications of ingesting ionizing radiation, improvement on the safety of drinking water is a necessity for healthy living and consequently for poverty alleviation.

Table 2. Total annual effective dose for the different age group

	Total dose ($mSvy^{-1}$)		
Locations	**Infant**	**Children**	**Adult**
AB1	0.11	0.09	0.17
AB2	0.05	0.04	0.07
AB3	0.05	0.04	0.08
AB4	0	0	0
AB5	0.06	0.05	0.09
AB6	0.04	0.03	0.06
AB7	0.09	0.07	0.13
JB1	0.07	0.05	0.1
JB2	0.11	0.09	0.17
JB3	0.09	0.07	0.14
JB4	0.05	0.04	0.08
JB5	0.08	0.06	0.19
JB6	0.09	0.07	0.14
JB7	0.04	0.03	0.06
ID1	0.1	0.08	0.16
ID2	0.07	0.05	0.1
ID3	0.06	0.05	0.09
ID4	0.05	0.04	0.07
ID5	0.08	0.06	0.12
ID6	0.09	0.07	0.13
Mean	**0.08**	**0.06**	**0.11**

4. Conclusion

The activity concentrations of ^{60}Co, ^{134}Cs, ^{137}Cs and ^{241}Am were analyzed using gamma spectroscopy techniques. All the activity concentrations reported were found to fall below the World Health Organization (WHO) recommended guidance level in all samples but for samples AB1, JB2 and ID1. Also, the mean total annual effective dose exceeded 0.1 $mSvy^{-1}$ guidance levels for adult group but the mean total annual effective dose for infant and children age groups is below the recommended guidance by the World Health Organization.This implies that other than nuclear accidents, manmade radionuclides can be found in drinking water in elevated amount compared to the recommended permissible limit. Also, the tendency for higher dose to be recorded in the nearest future will be inevitable if the source of contamination is not controlled. Therefore, anthropogenic activities influencing the concentrations of radioisotopes

in the study environment should be checkmate and remediation action implemented. This will promote tangible health benefits to the populace.

Acknowledgment

The authors appreciate Covenant University for sponsoring this research.

Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

All the authors contributed significantly in writing this article. The authors read and approved the final manuscript.

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