Journal of Natural Sciences Research www.iiste.org
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.5, No.24, 2015

Measurement of Radon Concentration in Water Sources around Ririwai Artisanal Tin Mine Kano State, Nigeria

Zakari, Y. I.[1] Nasiru, R.[1] Ahmed, Y. A.[2] Abdullahi, M. A.[3]
1.Department of Physics, Ahmadu Bello University, Zaria Nigeria
2.Centre for Energy Research and Training, Ahmadu Bello University, Zaria Nigeria
3.Department of Applied Science, College of Science and Technology,Kaduna Polytechnic, Kaduna- Nigeria

Abstract
In this work liquid scintillation analysis was used to measure the concentration of ^{222}Rn in three sources of water around Ririwai Artisanal Tin mine. The annual effective dose due to ^{222}Rn concentration in surface water source and Domestic water were also determined. The result shows that the tailing bearing water has the highest ^{222}Rn concentration of 3.04±0.14 Bq/L followed by surface water source with ^{222}Rn concentration of 2.51±0.13 Bq/L while the Domestic water has the lowest ^{222}Rn concentration of 2.23±0.11 Bq/L. The results also indicated that the annual effective dose due to the ^{222}Rn concentration is higher in surface water with 13.05±0.55 μSv/year than in Domestic water with 11.11 ± 0.44μSv/year. The mean ^{222}Rn concentration obtained in this work is lower than 10.00Bq/L recommended by WHO and UNSCEAR. Also in this study the annual effective dose obtained is lower than the maximum permissible of 0.1mSv/year recommended by UNSCEAR.
Keywords: Radionuclide, activity concentration and annual effective dose

1.0 INTRODUCTION

Mining is a global industry undertaken for its economic benefits of wealth creation and employment. In Africa, commercial scale mining provides important benefits in terms of exports/foreign exchange earnings and tax receipt to nineteen African countries (Hayumbu, and Mulenga, 2004).

Beside the socio-economic benefits of the mining industry in the developing countries such as Nigeria, the industry may be faced with three potential negative effects. The first one is the socio-economic dislocation all ill-prepared mining communities go through at mine closure, which arise from exploitation of a non-regenerative resources (Hayumbu and Mulenga, 2004). The second and third undesirable aspects arise when non-optimal management of mining operations results in environmental degradation and /or negative health impacts on miners and mining communities. Principal health problems among miners and mining communities from various countries that have been cited in the literature include respiratory disease, neoplasm/cancer, chronic hypertension, mental health and genetic impact (WHO, 1999).

Human beings are continually being exposed to ionizing radiation from natural sources. There are two main contributors to natural radiation exposures: high-energy cosmic ray particle incident on the earth's atmosphere and radioactive nuclides that originated from the earth crust and are present everywhere in the environment, including the human body (UNSCEAR, 2000).

The radionuclides in the decay series are more or less in radiological equilibrium however, this equilibrium becomes disturbed through human activities such as mining and mineral processing, resulting in either an enrichment or depletion of some of the radionuclides concentrations compared to the original matrix. This disequilibrium is as a result of differences in the properties of the radionuclides in the series, due to geochemical migration processes and differences in their half-lives [Cember, 1996; UNSCEAR, 2000; Sato and Endo, 2001].

Radon is a gas with three natural isotopes of the radioactive element: Actinon, (^{219}Rn) from the ^{235}U decay series; Thoron (^{220}Rn) from the ^{232}Th decay series; and Radon (^{222}Rn) from the ^{238}U decay series [UNSCEAR, 1993].

Due to the low activity concentration of ^{235}U and the short half-life of ^{219}Rn of 3.96 s, the radiation exposure from ^{219}Rn is not significant for human exposure. Radon-220 (220Rn), with a half-life of 55.6 s is of concern only when the concentration of ^{232}Th is high.

The isotope of concern in terms of human radiation exposure is ^{222}Rn which has a relatively longer half-life of 3.82 days. It is a noble gas with a slight ability to form compounds under laboratory conditions. It has a density of 9.73 g/L at 0 oC. The solubility of ^{222}Rn in water at 0oC is 510 cm3/L decreasing to 220 cm3/L at 25 oC and 130 cm3/L at 50 oC.

The production of ^{220}Rn and ^{222}Rn in terrestrial materials depends on the activity concentrations of ^{228}Ra and ^{226}Ra present, respectively which are predominantly alpha emitters. Radon is the most significant element of human irradiation by natural sources. The most significant mode of exposure is the inhalation of the short-lived products, ^{210}Pb and ^{210}Po of the parent isotope ^{222}Rn [UNSCEAR, 1993; 1996 and 2000].

The concentrations of ^{222}Rn in surface air are quite variable with time-average concentrations in the

range of 2-30 Bq/m3 [UNSCEAR, 1993]. In the soil and also in the root zone, radon concentrations may be higher by a factor of about 1000 than in the open air [UNSCEAR, 1996]. The average concentration varies widely depending on the composition of the soil and the bedrock. For soil with an average ^{226}Ra concentration of 40 Bq/kg, the average ^{222}Rn concentration in the soil water would be about 60 Bq/m3. Much higher values of 8000 Bq/m3 and 50, 000 Bq/m3 have been measured in deep ground waters in areas such as Maine in the United States of America and in Finland respectively [UNSCEAR, 1996]. The action level of radon recommended by the ICRP for which intervention is necessary is 1000 Bq/m3. This value is based on an assumed occupancy of 2000 hours per year and this is equivalent to an effective dose of 6 mSv per year. This value is also the midpoint of a range of 500-1500 Bq/m3 [ICRP, 1993]. Radon can present hazards in a wide range of work places including the mining industry and other work places other than the mines. Specific measures need to be put in place to reduce radon concentrations in air and water to prevent concentrations reaching very high levels even in places where the concentrations of uranium and radium in raw materials may be very low [UNSCEAR, 2000]. The mechanisms by which radon enters buildings is pressure driven flow of gas from soil through cracks in the floor. In addition, most building materials produce some radon due to the presence of elevated levels of ^{226}Ra and high porosity of the materials allow for the escape of the gas [Van der Steen and Van Weers, 1996].

It is also known that, inhalation of short-lived decay products ^{210}Pb and ^{210}Po of ^{222}Rn and to a lesser extend ^{220}Rn and their subsequent deposition along the walls of the various airways of the bronchial tree provide the main pathway for radiation exposure of the lungs [UNSCEAR, 2000]. The exposure is mostly due to the alpha particles emitted by these radionuclides as well as the beta particles and the gamma radiation emitted during the decay process. According to UNSCEAR 2000 report, there is a general agreement among scientists that it is the alpha particle irradiation of the secretory and basal cells of the upper airways that is responsible for the lung cancer risk in miners. There are some uncertainties as to which cells are the most important for the induction of lung cancer. In this work concentrations of ^{222}Rn was determined in the water sources within the Ririwai artisanal tin mine and the surrounding communities using liquid scintillation analysis.

2.0 MATERIALS AND METHOD

The study area is Ririwai town headquarter of Doguwa Local Government Area in the extreme south of Kano State, Nigeria. It has an area of 1,473 km² and a population of 151,181 at the 2006 census. Figures 1 shows the Map of Kano State showing the study area respectively. Table 1 shows the locations where samples were collected.

Table 1: Sampling locations

S/No	North	East	Elevation
1	10^0 44′ 35.3″	008^0 45′ 16.3″	856m
2	10^0 44′ 35.3″	008^0 45′ 16.4″	856m
3	10^0 44′ 35.2″	008^0 45′ 16.4″	857m
4	10^0 44′ 36.7″	008^0 45′ 15.8″	856m
5	10^0 44′ 33.8″	008^0 45′ 17.8″	856m
6	10^0 44′ 32.3″	008^0 45′ 21.0″	858m
7	10^0 44′ 30.3″	008^0 45′ 27.0″	862m
8	10^0 44′ 23.8″	008^0 45′ 27.3″	864m
9	10^0 44′ 25.9″	008^0 45′ 27.7″	865m
10	10^0 44′ 28.2″	008^0 45′ 26.9″	869m
11	10^0 43′ 48.2″	008^0 44′ 57.1″	896m
12	10^0 43′ 49.1″	008^0 44′ 53.4″	894m
13	10^0 43′ 48.5″	008^0 44′ 53.0″	895m
14	10^0 43′ 50.2″	008^0 44′ 58.7″	892m
15	10^0 43′ 49.5″	008^0 44′ 59.2″	894m
16	10^0 43′ 50.4″	008^0 44′ 41.8″	894m
17	10^0 43′ 58.2″	008^0 44′ 38.7″	893m
18	10^0 44′ 21.1″	008^0 45′ 26.4″	894m

Water samples were collected from 3 sources surface water, domestic water (taps and hand dug wells), and tailing bearing water within the mines. The samples were collected into labelled two and half litres (2.5 L) plastic bottles. The bottles were acid washed with Concentrated HNO_3 before the bottles were filled with water to ensure radionuclides remain in solution rather than adhering to the walls of the container. The bottles were also filled to the brim without any head space to prevent CO_2 being trapped and dissolving in water which might affect the chemistry e.g. pH. 10 ml each of the sample were added into a scintillation vial containing 10 ml of the instagel scintillation cocktail having been sealed tightly, the vials were then shaken for more than two minutes to extract ^{222}Rn in water phase into the organic scintillator and the sample so prepared were then taken to the laboratory for measurement. Annual effective dose were also calculated from the activity concentration of ^{222}Rn in surface and domestic water sources using

$$E_{Rn} = DF_{Rn}\ x\ I_{in}\ x\ A_{Rn} \quad \text{..... 1}$$

Where E_{Rn} is the annual effective dose in µSv/year.
DF_{Rn} = effective dose per unit intake for Adult = $10^8 Sv/Bq$
I_{in} = Water consumption rate = 2 lit per day
A_{Rn} = radon concentration

3.0 RESULTS AND DISCUSSION

The results of the liquid scintillation analysis (L.S.A) as indicated in Tables 2-4 shows that the ^{222}Rn concentration in tailing bearing water has a mean concentration of 3.08±0.14 Bq/L and ranges between 2.88±0.05 Bq/L to 3.53±0.33 Bq/L. The surface water source has a mean ^{222}Rn concentration of 2.51±13.3 Bq/L with minimum and maximum concentrations of 2.50 ± 0.08Bq/L and 2.78±0.12 Bq/L respectively while the mean concentrations of ^{222}Rn domestic water is 2.23 ± 0.11 Bq/L and ranges between 1.66 ± 0.16 and 2.61±0.2 Bq/L.

Table 2: ^{222}Rn concentrations in tailing bearing water

S/No	Sample code	Concentration in Bq/L
1	RWT_1	2.90 ± 0.19
2	RWT_2	3.18 ± 0.24
3	RWT_3	2.89 ± 0.26
4	RWT_4	2.96 ± 0.09
5	RWT_5	3.53 ± 0.33
6	RWT_6	2.88 ± 0.05
7	RWT_7	3.36 ± 0.06
8	RWT_8	2.92 ± 0.20
	Mean	**3.08 ± 0.14**

Table 3: ^{222}Rn concentrations in surface water source

S/No	Sample code	Concentration in Bq/L
1	RWS_1	2.59 ± 021
2	RWS_2	2.78 ± 0.12
3	RWS_3	2.55 ± 0.18
4	RWS_4	2.53 ± 0.10
5	RWS_5	2.65 ± 0.09
6	RWS_6	2.75 ± 0.20
7	RWS_7	2.55 ± 0.10
8	RWS_8	2.50 ± 0.08
9	RWS_9	2.66 ± 0.13
10	RWS_{10}	2.53 ± 0.09
	Mean	**2.51 ± 0.13**

Table 4: ^{222}Rn concentrations in domestic water

S/No	Sample code	Concentration in Bq/L
1	RWW_1	2.41 ± 0.05
2	RWW_2	2.48 ± 0.13
3	RWW_3	2.61 ± 0.21
4	RWW_4	2.45 ± 0.06
5	RWW_5	2.34 ± 0.09
6	RWW_6	2.38 ± 0.10
7	RWW_7	2.43 ± 0.16
8	RWW_8	2.46 ± 0.11
9	RWP_1	2.33 ± 0.21
10	RWP_2	2.19 ± 0.08
11	RWP_3	2.24 ± 0.10
12	RWP_4	2.23 ± 0.06
13	RWP_5	2.33 ± 0.14
14	RWP_6	2.34 ± 0.10
15	RWP_7	1.96 ± 0.03
16	RWP_8	2.04 ± 0.06
17	RWP_9	2.12 ± 0.12
18	RWP_{10}	1.86 ± 0.20
19	RWP_{11}	1.66 ± 0.16
20	RWP_{12}	2.38 ± 0.07
21	RWP_{13}	2.08 ± 0.09
22	RWP_{14}	1.88 ± 0.01
	Mean	**2.23** ± 0.11

The result shows that the level of ^{222}Rn concentrations in (tailing bearing water, domestic water and surface water) differs significantly from each other, hence domestic water has the least mean ^{222}Rn concentration, while tailing bearing water has the highest ^{222}Rn concentration, as shown in fig. 2 below

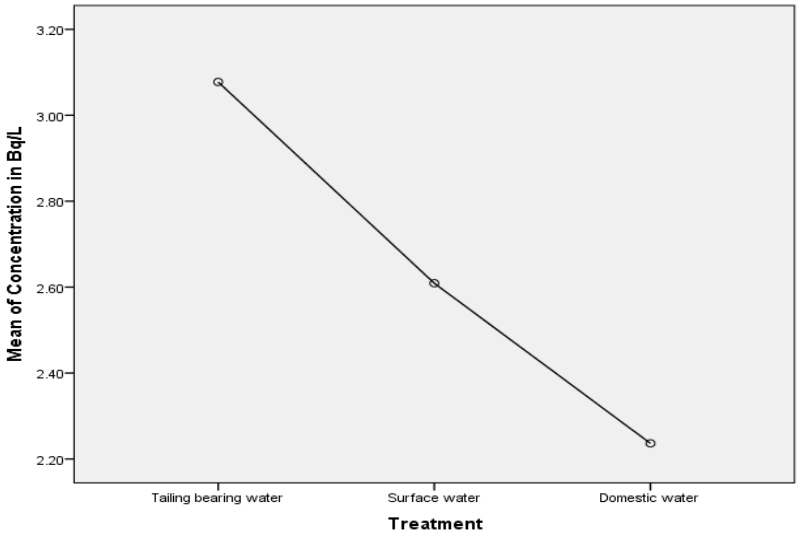

Fig. 2: Plot of mean ^{222}Rn concentration and water sources.

The annual effective dose for surface water sources and domestic water were calculated using equation 1 and are tabulated in table 5 and 6.

Table 5: ^{222}Rn concentrations and annual effective dose for surface water source

S/No	Sample code	Concentration in Bq/L	Annual effective dose in μSv/year
1	RWS_1	2.59 ± 021	12.95 ± 1.05
2	RWS_2	2.78 ± 0.12	13.90 ± 0.60
3	RWS_3	2.55 ± 0.18	12.75 ± 0.90
4	RWS_4	2.53 ± 0.10	12.65 ± 0.50
5	RWS_5	2.65 ± 0.09	13.25 ± 0.45
6	RWS_6	2.75 ± 0.20	13.25 ± 1.00
7	RWS_7	2.55 ± 0.10	12.75 ± 0.50
8	RWS_8	2.50 ± 0.08	12.50 ± 0.40
9	RWS_9	2.66 ± 0.13	13.30 ± 0.65
10	RWS_{10}	2.53 ± 0.09	12.65 ± 0.45
	Mean	**2.51 ± 0.13**	**13.05 ± 0.55**

Table 6: ^{222}Rn concentrations and annual effective dose for domestic water

S/No	Sample code	Concentration in Bq/L	Annual effective dose in µSv/year
1	RWW_1	2.41 ± 0.05	12.05 ± 0.25
2	RWW_2	2.48 ± 0.13	12.40 ± 0.65
3	RWW_3	2.61 ± 0.21	13.05 ± 1.05
4	RWW_4	2.45 ± 0.06	12.35 ± 0.30
5	RWW_5	2.34 ± 0.09	11.70 ± 0.45
6	RWW_6	2.38 ± 0.10	11.90 ± 0.50
7	RWW_7	2.43 ± 0.16	12.15 ± 0.80
8	RWW_8	2.46 ± 0.11	12.30 ± 0.55
9	RWP_1	2.33 ± 0.21	11.65 ± 1.00
10	RWP_2	2.19 ± 0.08	10.95 ± 0.40
11	RWP_3	2.24 ± 0.10	11.20 ± 0.50
12	RWP_4	2.23 ± 0.06	11.15 ± 0.30
13	RWP_5	2.33 ± 0.14	11.65 ± 0.70
14	RWP_6	2.34 ± 0.10	11.70 ± 0.50
15	RWP_7	1.96 ± 0.03	9.80 ± 0.15
16	RWP_8	2.04 ± 0.06	10.20 ± 0.30
17	RWP_9	2.12 ± 0.12	10.60 ± 0.60
18	RWP_{10}	1.86 ± 0.20	9.30 ± 1.00
19	RWP_{11}	1.66 ± 0.16	8.30 ± 0.80
20	RWP_{12}	2.38 ± 0.07	11.90 ± 0.35
21	RWP_{13}	2.08 ± 0.09	10.40 ± 0.45
22	RWP_{14}	1.88 ± 0.01	9.40 ± 0.05
	Mean	**2.23** ± 0.11	**11.11 ± 0.44**

The result indicated that the surface water source has a mean annual effective dose of 13.05±0.55µSv/year and ranges between 12.50±0.40µSv/year and 13.90±0.60µSv/year while domestic water has a mean annual effective dose of 11.11±0.44 µSv/year with minimum and maximum values of 8.30 ± 0.80 µSv/year and 13.05 ± 1.05 µSv/year respectively.

The result of the independent t-test, indicated that there is significant differences in the mean annual effective dose between surface water and domestic water source, since the p-value (0.00) is less than 0.05 level of significance with surface water having the highest mean annual effective dose (13.90±0.60µSv/year) while domestic water source have the least mean annual effective dose (11.11±0.44µSv/year) (0.25561mSv/year), as shown on fig. 3 below.

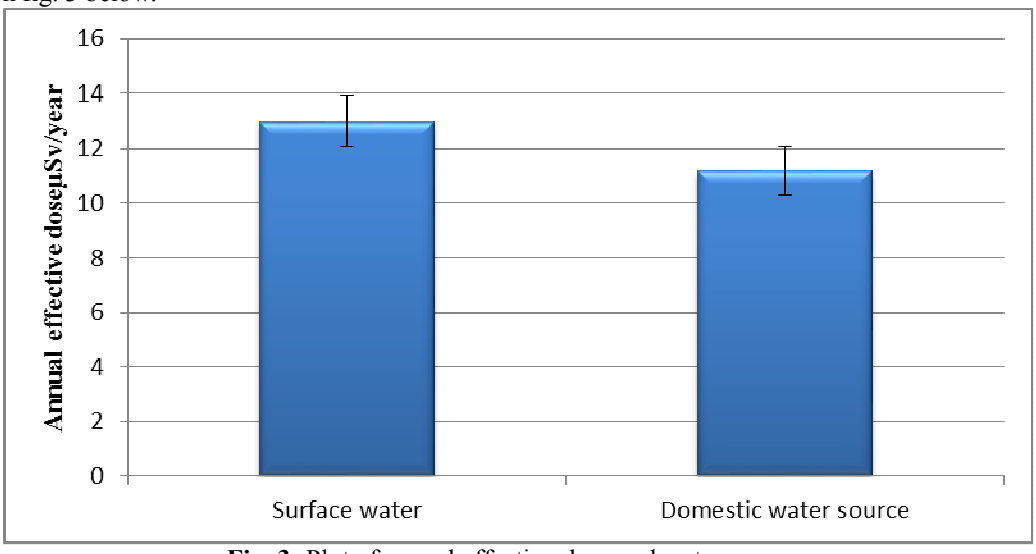

Fig. 3: Plot of annual effective dose and water sources

4.0 Conclusion

The ^{222}Rn concentration in water sources (Tailing bearing surface and Domestic) from Ririwai artisanal tin mine and surrounding communities were determined using liquid scintillation analysis (L.S.A). The result obtained from the studies shows that the tailing bearing water has the highest mean ^{222}Rn concentration of 3.08±0.14Bq/L.

The surface water source has a mean ^{222}Rn concentration of 2.51±0.13 Bq/L while domestic water (taps and hand dug wells) has the lowest mean ^{222}Rn concentration of 2.23±0.11Bq/L. The mean concentration of ^{222}Rn in domestic water source has the least value and is below the mean ^{222}Rn concentration of 10Bq/L recommended by WHO (1993) UNSCEAR 1993 and the maximum permissible value of 11.1Bq/L by USEPA (1991) and adopted by the Standard Organization of Nigeria (S.O.N).

Similarly the annual effective dose for surface and domestic water were also determined using the adult rate of water consumption of 2 liter per day. The result indicated that the mean annual effective dose for surface water is 13.05±0.55 μSv/year of Domestic water. The annual effective dose obtained in this work is less than the 0.1mSv/year recommended by UNSCEAR (2000).

REFERENCE

Cemeber, H. (1996). Introduction to Health Physics, 3rd Edition, McGraw- Hill, New York.

Hayumbu, P. and S. Mulenga, (2004). Status of radon dosemetry in Zambia underground mine. Processings of the IAEA International Conference (NORM iv) S2OZyrk, Poland.

ICRP (1993). Protection against Radon -222 at home and work, ICRP Publication 65, Pergamon Press, Oxford.

Sato, J., and Endo, M. (2001). Activity ratios of uranium isotopes in Volcanic Rocks from Izu-mariana Island-Arc Volcanoes, *Journal of Nuclear and Radiochemical Sciences*, *Vol. 2, Japan*.

United State Environmental Protection Agency (USEPA 1991). National primary drinking water regulations for radionuclides. US Government printing office. Washington D.C, EPA/570/9-91/700.

UNSCEAR, (1993) Exposures from Natural Source of Radiation, 1993 Report to General Assembly, Annex A, New York.

UNSCEAR, (1996) Source and Effects of Ionising Radiation, 1996 Report to the General Assembly, with Scientific Annex, United Nations, New York.

UNSCEAR, (2000) Exposures from Natural Source, 2000 Report to General Assembly, Annex B, New York.

Van der Steen J and Van Weers A.W. (1996). Radiation Protection in NORM industries, NRG, Radiation and Envrionment, Netherlands.

WHO, (1999). Hazard prevention and control in the work environment. Air borne dust WHO/SDE/OEHJI 99.14, Geneva.

World Health Organization (WHO 1993). Guidelines for drinking water quality vol. 1 (2nd ed.).